Master Thesis

Multi-stakeholders' participation in decision making: Identifying suitable areas for Pneumatic Waste Collection System installation

Colophon

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Preface

This master thesis is written as completion of the master program of Construction Management and Engineering at Eindhoven University of Technology.

For the last half year of master program, it was dominated by in-depth research regarding pneumatic waste collection system, analytic hierarchy process, geographic information system, municipal waste management in Netherlands, and interviewing the experts in the field of waste management or pneumatic waste collection system. This research is conducted under the guidance of CentralNed BV and Eindhoven University of Technology.

During the investigation of this research, I met many setbacks and challenges, from identifying a suitable research direction and corresponding methodology, to search key input data and respondents for questionnaire survey. It is not possible to carry out research and write this paper without many people's help. Firstly, I would like to thank my supervisor from Eindhoven University of Technology: Mr. Brano Glumac, who helped me with my research directions, methodology and arrangement of thesis. Secondly, I want to show my gratitude to Mr. Paul zaal from CentralNed BV and Ms. Tong wang from Eindhoven University of Technology. Mr. Paul zaal gave me the opportunity to deep understanding the benefits and operation mode of PWC system, to reach the respondents to carry out interview and questionnaire survey. Ms. Tong wang gave me advice on research model structure and access to search the key input data. Thirdly, I want to thank Mr. Bauke de Vries and Mr. Peter van der Waerden for finding the questionnaire respondents and helping with map data processing.

Last but not least, I would like to thank my family, girlfriend and other friends for their help and support !

I hope you will enjoy reading this thesis,

Zhuo wang
Eindhoven
July, 2015

Summary

As the component of urban waste management, waste collection ways become to attract more and more government attentions. It will lead to a throng of questions if the waste collection way is not appropriate. Municipality solid waste could accounts for more than 5% expenditures of public authorities, it has close relationship with urban traffic, environment and government image.

In recent years, attention is increasing on sustainability in relation with municipal waste management. Therefore, both European Union and Netherlands has issued some directives and plans in the context of waste management. Considering both strengths and weaknesses of two waste collection system (Pneumatic waste collection vs Underground container), there is great potential for PWC system taking the place of container system in Netherlands. Hence, the focus of this research consist in planning the location of PWC system regarding to the system characteristics and stakeholders requirement.

Considering various interests of multi-stakeholders, it is difficult for collaborating stakeholders to identify location or estimate performance of PWC system. Hence, a most promising development of PWC system on the basis of stakeholders requirement needs to be carried out.

The framework of this research is constructed to answer the main research question: “Is there exist feasible area for Pneumatic waste collection system installation based on the decision makers of municipality and service provide company within a city ?”.

There are three kinds of stakeholders involved in planning process of PWC system, ‘municipalities’, ‘investors’ and ‘service provider’. Among these three party, investors can be treated as indirectly involved in the planning process, due to their roles could be replaced by municipalities. Therefore, municipalities and service provide company are regarded as the key decision makers in this research. The considerations of these stakeholders can be summarized as three aspects: environmental, economical and social aspects.

According to the literature review, it is found that AHP with GIS would be the best methodology for this research. Meanwhile, criteria that constraint area become alternatives, influential criteria and evaluating criteria that compose the structure of AHP, also be recognized in this phase. The influential criteria can be seen as the expression of stakeholders requirement. The evaluating criteria reflecting various features of alternative lands. For intensifying the connections between evaluating criteria and alternative locations, each evaluating criteria are further link to several classified scales. In order to obtain each criteria impacts and scales preference, decision makers are asked to prioritize the criteria and scales by using pair-wise comparisons in a form of online questionnaire survey.

After synthesizing the results of both stakeholders group, the scales preference of each evaluating criteria can be obtained. Based on the pre-set rules, the evaluating criteria

data could categories into different scales. Therefore, each evaluating criteria map could be expressed as a scaled map layer.

The results of questionnaire survey shows that both municipalities and service provide company stakeholders group consider 'population density' as the most important criterion during the process of their decision making, followed by 'road level in community' and 'pickup trucks travel distance'. 'land price in community area' is considered as the last preferred criterion. Among the three classified scales under population density, 'scale 3 (population density above 90 people per hectare)' is most preferred by both groups. These experts also believe that the lower degree of road level within the community have the higher need to install the new waste collection system, hence, ' scale 1 (road condition is primary level)' is most preferred. Considering the 'pickup trucks travel distance', both groups prefer the area that waste pickup distance 'above 153.06km' to 'below 153.06km'.

Inserting the scales preference rates into each scaled map layer, through overlaying these generated layers, one city's suitability map for installing pneumatic waste collection system could be created. From created suitability map, the neighborhood with name of 'Kerstroosplein' is distinguished from neighborhood map of Eindhoven city, owing to its high population density and appropriate geographic environment.

Finally, it is concluded that the Pneumatic waste collection system could assist Netherlands government to accomplish its established goals with less resource input. It is not only government will gain profit from this system, but residents will obtain benefits as well due to improved environment. Moreover, it is proved that one most optimal area can be identified for PWC system installation within a city by using combined AHP with GIS approach.

Abstract

Municipal waste management is a complicated process, and started to arouse the widespread concern in recent decades. There are two types of waste collection facilities co-exist in Netherlands, standalone underground container and pneumatic waste collection system. Along with Netherlands and European Union put more and more focus on waste and environment problems, PWC system begins to be paid attention owing to its excellent system performance and environment consideration.

Decision makers that involved in PWC system project look for a decision making framework to assist them to identify the suitable are for PWC system installation. In order to resolve this decision making problems, multi-stakeholders, such as municipalities and service provide company need to be involved.

Combining AHP with GIS is the most popular framework to solve the problem of identifying location of municipal waste management facilities. AHP method help multi-stakeholders to evaluate the impacts of conflicting criteria, prioritizing classified criteria scales. GIS could creating the close link between stakeholders preference with specific city map, and then ranking the alternative areas.

Results of this thesis show that pneumatic waste collection system have a great potential to be widely installed in Netherlands. The combination of AHP with GIS is most suitable methodology in consideration of multi-stakeholders participants in study of searching PWC system location.

1. Introduction

In the chapter, the topic of this research will be explained, followed by the problem statement and research questions. Next, the research design and expected results of project is elaborated. At the end of chapter, a reading guide for whole thesis is introduced.

1.1 Sustainable waste management

Municipalities usually are responsible for the collection of household waste in their own territory, and obliged to collect organic household waste separately(Leonidas, 2013). As an indispensable task of city authorities, municipality solid waste management can comprise 5-25% expenditures of public authorities(McLeod & Cherrett, 2011). For many years, the importance of collection-transfer-transportation has been underestimated within the waste management systems (Kogler, 2007).

European Commission published legislation in 2008, called Waste Framework Directive(2008/98/EC), which reflects the EU sustainable development strategy. This legislation not only promulgates the preference order of waste management, but also enforces mandatory recycling levels for difference waste fractions(Francesco & Caterina, 2014). For the purpose of turning European Union into a recycling society, waste framework directive set goals for EU member states to recycle 50% of municipal waste and 70% of construction waste in the year of 2020(European Commission, 2010).

In Netherlands, Ministry for housing, Spatial Planning an Environment should draft out waste management plan every six years under the stipulation of Environment Management Act (ETC/SCP, 2009). Under the second National Waste Management Plan, the recycling rate of household waste needs to increased to 60% in 2015(Leonidas, 2013).

According to the statement of Intergovernmental Panel on Climate Change (IPCC), the western countries need to reduce 80-95% of its greenhouse gas emission in 2050 compared to 1990 level (DHV Management Consultants, 2009). As a member of European Union, Netherlands advocates to achieve the target of reducing 40% of greenhouse emission as soon as possible.

With the policy requirement improving, more resources and manpower have to be input for the purpose of keeping the process of waste collecting, reusing and recycling more efficient. Waste collection is an important aspect of waste management in urban environment. Waste collection facilities, as an temporary waste carrier, has strong ties to the waste sorting and transportation. Traditional waste collection is utilizing a door-to-door or container-to-container way, and lacking of additional fractions to separate organic household waste. As a result, a more effective and efficient waste collection system is needed, called Pneumatic Waste Collection system.

On the basis of specific characteristics of Pneumatic Waste Collection system, only specific area can be implement this system, for the purpose of achieving best performance.

Considering PWC system have a range of capture area, municipalities have various land use plan and development strategies for different neighborhoods. Moreover, installing a new waste collection facilities, several stakeholders should be involved, each of them have their own considerations. Therefore, how to organize the requirements of each stakeholders, and searching an optimal location to install PWC system in order to reach the highest system performance is the first issue to be considered.

1.2 Research question

The research will present out a main research question and will be supported with a couple of sub-questions to answer the main question. The main question in this research is: "Is there exist feasible area for Pneumatic waste collection system installation based on the decision makers of municipality and service provide company within a city ?".

Five sub-questions are defined below:

1. What are the capable and feasible of PWC system to be implemented in Netherlands ?
2. What kinds of stakeholders are involved in the decision making process ?
3. Which criteria could be used to evaluate the area regarding the new system installation ?
4. How to map the alternative locations for PWC system ?
5. What is the importance of selected criteria, and how to identify the potentials of location for deploying new waste collection system ?

1.3 Research design

In this section, the research framework is presented. As can be seen from Figure 1, three parts are list out, in order to resolve the main research question.

In literature review part, the waste management legislation and its decision making are revealed as a way of background. Besides, it carry out the comparisons between underground container system and PWC system to choose a promising system to accomplish national waste management plan. The relevant stakeholders and their characteristics are revealed and discussed. Moreover, literature review also identified the criteria that relate with stakeholders requirement and influence new systems performance. These findings will be used to formulate the components of research methodology in next stage, and to answer the first three questions.

Decision making in identifying location of PWC system is a complicated process, owing to multi-stakeholders participate in. In this research, two important stakeholder groups are separated, municipalities and service provide company (PWC company). In the methodology stage, AHP model will be constructed by using the criteria which obtained from literature review part, with the purpose of meeting stakeholders requirements and goals.

After building the framework of AHP, an questionnaire survey is proceeded to investigate the impacts of each criteria. Experts from both stakeholder groups will be reached, and asked to fill in the questionnaire, which designed by using pair-wise comparison of criteria. After receiving the survey results, it needs to be carried out the consistency check. Only the results that meet the requirements of consistency check could be considered as usable data for synthesis analysis.

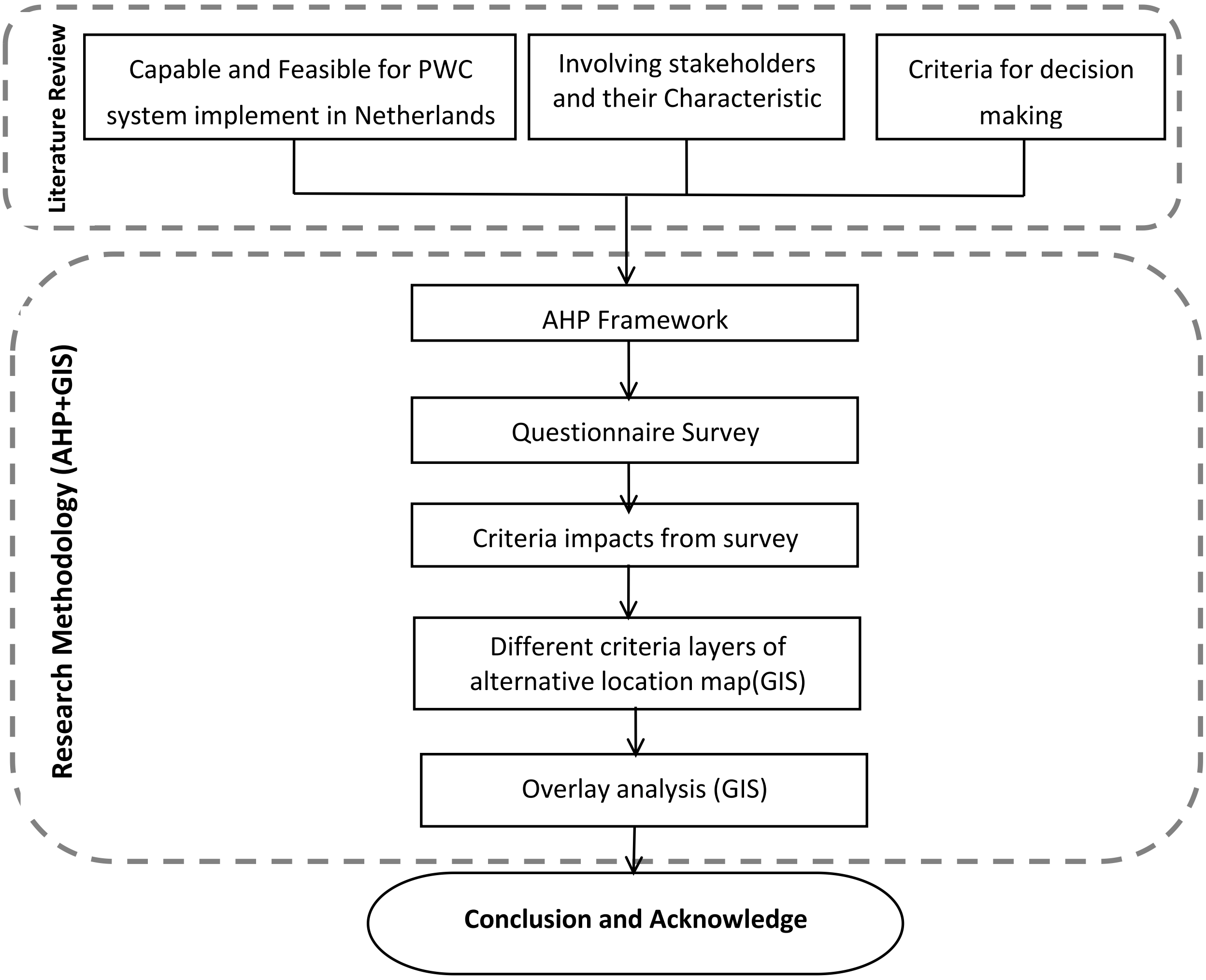


Figure 1. Research Framework

In order to search the optimal location for PWC system, a city map and relevant data needs to be acquired. These data are pre-defined in literature review part, it has close relations with city's area, each of them could influence the performance of system. By eliminating the impossible location, an alternative location map could be formulated. The acquired data will be imported into alternative location map afterwards. The sub-question four will be answered by this step.

In order to create the suitability map of installing PWC system, these data layers will be overlay together by using the weights from AHP model. From land suitability map, most optimal area of the city could be recognized, and answer the fifth sub-question.

In the conclusion and acknowledge part, the analysis results from literature review and research methodology will be used to resolve the main research questions.

1.4 Expected results

In this research, it is expected to find that the Pneumatic waste collection system is more economical feasible and environmental friendly for Netherlands to accomplish the national waste management plan, by comparing with underground waste container system. I believe that the analysis will show the PWC system could meet the requirements of national policy, guaranteeing a healthy environment for citizens.

The results is also expected to reveal the stakeholders that involved in decision making of new system installation, to present important criteria to reflect stakeholders requirement and connections among them. I hope these criteria can be found, and used as the components to formulate the framework of AHP model.

Another important results I expect to see from research is a connection between AHP and GIS map. By creating a suitability map of a city, I hope that the stakeholders who wants to search a location for PWC system can get inspirations.

2. Glossary

Waste

"Waste is unwanted or undesired material left over after the completion of a process. 'Waste' is a human concept: in natural processes there is no waste, only inert end products. Waste can exist in any phase of matter (solid, liquid, or gas). When released in the latter two states, gas especially, the wastes are referred to as emissions. It is usually strongly linked with pollution."(Kogler, 2007).

Waste management

"Waste management is the collection, transport, processing or disposal of waste materials, usually those produced by human activity, in an effort to reduce their effect on human health or local amenity. A sub focus in recent decades has been to reduce waste materials' effect on the environment and to recover resources from them."3 "Waste management encompasses the sum of all measures of waste avoidance, non- harmful treatment, recovery, reuse and final disposal of wastes of all types while giving due consideration to ecological and economic aspects."(Kogler, 2007).

Municipal solid waste management

Municipal solid waste (MSW) management can be separated into three main activities: collection, treatment and disposal. Waste management configuration means how these activities are performed and combined for managing a single tonne of MSW. Efficient source segregation (SS) collection can contribute significantly to maximizing waste material recycling, but can represent up to 70% of the entire cost of MSW management(Francesco & Caterina, 2014)。

Waste collection system

A collection system is "defined as a combination of technology and human labour, specially: Collection method, Container system, Vehicles and Personnel"(Kogler, 2007).

Residual waste

Residual waste is mostly solid waste from private households not including bio-waste, potential recyclable and household hazardous waste (HHW)(Kogler, 2007).

Organic waste

Organic waste is the "biodegradable component of municipal waste (e.g. food and garden waste)."(Kogler, 2007).

Waste transportation

The term transportation refers to the physical act of transporting the collected waste to waste treatment facilities. These may be: recycling centres, incineration plants, chemical or physical treatment facilities or both, landfill or other facilities such as transfer stations(Kogler, 2007).

Underground space

Underground space refers to a space that is situated below ground level(Dimitrios & Andreas, 2013).

Underground container system

Underground container system also called stand-alone collection, follows a more traditional approach, where waste containers are replaced by underground collection points. These points have their greater portion placed underground, having only their inlets above ground surface(Dimitrios & Andreas, 2013).

Pneumatic waste collection system

waste is deposited by generators to fraction-specific waste points, transported in underground pipelines through the use of vacuum to a central waste collection terminal, where each fraction is diverted to its own container. Full containers are then transported by trucks to final processing and disposal sites. This system has obvious advantages, as it is quiet, clean and hygienic(Schiettecatte et al, 2014).

Multi-criteria decision analysis

Multi-criteria Decision Analysis (MCDA) is the most popular framework employed on municipal solid waste management. MCDA methods help multiple stakeholders evaluate the often conflicting criteria, communicate their different preferences, and rank or prioritize municipal solid waste management strategies to finally agree on some elements of these strategies and make an applicable decision (Atousa et al., 2014).

Analytic Hierarchy Process

AHP helps decision-makers by providing them with a structure to effectively compare the competing alternatives. AHP compares alternatives based on their performance in each criterion as well as decision-maker(s)' preferences over those criteria. Decision-maker(s) often express their preferences by assigning weights to criteria(Atousa et al., 2014).

Geographic Information System

GIS is described as an efficient tool to monitor long term land-cover changes in and around urban areas, moreover, providing a framework for spatial analysis and modeling based on geographic principles (Rajesh & Yuji, 2008).

3. Alternative waste collection

3.1 EU & Netherlands plan towards sustainable waste collection

During the last few decades efforts have been dedicated to investigating the sustainable municipality solid waste management, due to the increase costs and complexity of service, and city growth (Germa & Melania , 2009; Bernardino, Maria , & Jose, 2011). In 2011, McLeod and Cherrett demonstrated that as an indispensable task of city authorities, Municipality solid waste can comprise 5-25% expenditures of public authorities.

3.1.1 European Union Plan

In European Union, it is estimated that waste generation at more than 1.3 billion tonnes per year, increasing rates does not have much difference with economic growth (Thomas, 2007). Over the last 30 years, EU environment policy has been put more concentration on waste through a series of environmental action plans and a framework of legislation, the purpose of EU environment legislation is trying to improve the way of dispose and recycle specific waste streams, and to create an energy and resource efficient economy (Thomas, 2007; European Commission, 2010).

In European Union, there are also exist some Directives strongly influence the waste collection and transportation, such as the Packaging Directive, aiming to prevent any impact of packaging and packaging waste on the environment of all Member States as well as of third countries, or to minimize such impact(European Commission, 2010).

In 2001, the First EU sustainable Development Strategy (SDS) was carried out by the European Council, aiming to enable the EU to reach continuous improvement of life quality for both current and future generations by means of support and promote actions (Ana, Graca, & Ni-Bin, 2011). European Commission published legislation in 2008, called Waste Framework Directive (2008/98/EC), which reflects EUSDS and brings new challenges to Solid Waste Management System (Francesco & Caterina, 2014). This legislation not only promulgates the preference order of waste management, but also enforces mandatory recycling levels for different waste fractions.

Waste prevention and management were stipulated as one of top priorities by the EU's sixth Environment Action Programme (2002-2012), for the sake of ensuring economic growth does not meet with waste generation increase. In 2005, the Thematic Strategy on waste prevention and recycling was promulgated, caused the revision of the Waste Framework Directive, and becoming the cornerstone of EU waste policy. This revision makes people regard waste as a valued resource instead of an unwanted burden. To achieve the object of turning EU into a recycling society, the Directive set goals for EU member states to recycle 50% of municipal waste and 70% of construction waste in the year of 2020 (European Commission, 2010; Leonidas, 2013; Thomas, 2007).

3.1.2 Netherlands Plan

In Netherlands, the basic hierarchy principle aims at preventing the waste as much as possible, recycling and utilization of valuable raw materials from waste, and in an environmentally sound way to landfill the left over waste (Sloot., 1996; Leonidas, 2013).

The European Union (EU) gives rise to its member states liable to control and reduce the effect on the environment due to industrial emissions. In Netherlands, this Directive is transformed into three Dutch legislation, Environmental Activities Decree, Environmental Law Decree and General Provisions Environmental Law (Diana, 2014). Overall Dutch environmental policies are responsible by a government agency called Ministry of Infrastructure and the Environment. The ministry carries out the national policy and strategies regarding the environmental issues in a national context, ensuring the implementation of EU's Directive (Diana, 2014)

On the provincial level, governments are in charge of interpreting the national policy into the regional framework, awarding environmental permits, examining waste treatment facilities (e.g. Incineration and landfill) and formulating the limits of noise and emissions. Moreover, the municipal governments are responsible for accomplishing the national policy and strategy regarding to environmental management, performing environmental regulations e.g. separation, collection, treatment, recycling and waste disposal from households, commercial and industrial activities in their own territory (Diana, 2014; Leonidas, 2013).

In Netherlands, The first National Waste Management Plan(NWMP) came into effect starting in 2003 and was amended in 2009, it institutes the framework of future Dutch waste management, meanwhile, presenting national level control of waste policies. It is restricted to disposal unsorted municipal waste to landfills directly and required to increase of waste utilization 5% during the period from 2000 to 2012 through recycling and applying non-recyclable waste material for useful object (Leonidas, 2013; Diana, 2014).

In 2011, the recycled and composted of municipal solid waste occupied 61% of national treated waste. The remaining amount of waste was sent to incineration and landfill, accounting for 38% and 1% respectively. Guiding with a well-defined national waste management policy, and combining with quantitative targets and waste processing facilities, has let the Netherlands ahead of the overall Europe on the aspect of recycling and thermal waste treatment (Diana, 2014).

In Netherlands, there is a huge difference (20%) in organic recycling between Drenthe and South Holland, the former is the best performer in the country, however, South Holland has worst performance and produces the largest amount of MSW (Leonidas, 2013). Meanwhile, Marielle et al (2013) points out that the digested households wet organic waste and biomass only account for 7% of separately collected waste. Another research carried out by Jobien et al (2010) demonstrate that the separated collected paper from household occupied 62% in 2008, for high-quality recycling, it is crucial that the collected paper should be separated from food and other organic waste in case of contamination.

Considering both EU's Directives and existing issues, the goals of second National Waste Management Plan are to limit the growth of waste volume, to encourage waste recovery and optimize the use of energy content of non-reusable waste, and to minimize the environmental impacts(e.g. reduce the GHG emissions) (Ministry for Housing, Spatial Planning and Environment, 2003). The quantitative targets of this plan aim to increase the household waste recycling to 60% by 2015, to limit the total waste amount below 68Mt in 2015 and 73Mt in 2021, to keep the recovery of construction and demolition waste at 95% (Leonidas, 2013; Marielle, Ernst, Magda, & Armande, 2013).

Therefore, for the municipal decision makers, the waste recycling targets should be put into more waste fractions, such as organic waste, hazardous waste and etc, collecting and transporting the waste in a more efficient and environmental way in the future.

In next section, the developments and trends of waste collection shall be analyzed, in order to accomplish the national waste management plan.

3.2. Developments of waste collection by using underground space

Because of rapid advances process of urbanization throughout the world, environmental friendly and sustainable developments of urban areas turn into an important thing of global. As an important component of urban area resources, subsurface space can greatly improve the efficiency of land use, and reduce the traffic density of central urban areas (Dimitrios & Andreas, 2013; Xia et al., 2013; Nikolai, 2009).

In recent decades, underground space has been increasingly developed in many cities, more and more administrators, planners, and researchers become to recognize it importance (Xia, Feng, Xianjin, Min, & Zehua, 2013; Nikolai, 2009). In Netherlands, there was a national strategic study regarding the utilization of underground space implemented by the Centre for underground Construction (Centrum Ondergronds Bouwen, COB), for the purpose of surveying the underground space (Edelenbos et al., 1998; Admiraal, 2006).

Nikolai provides in depth analysis of underground space structure utilization in 2009, it is discovered that the underground space for transportation use occupied more than 32% in urban area, such as rail and motor tunnels. The utilities for pipelines, cable collectors and sewage account for more than 8%. The rest utilization of underground space is greatly depending on the city's characteristics and data classified.

Based on the research that proceed by Ronka et al. (1998), the underground structure can be classified into five functions: general public facilities(e.g. connectors between subways), traffic space and transportation systems (e.g. Roadways and packing facilities), technical maintenance facilities (e.g. waste, sewerage treatment, utility pipelines), industrial/production facilities and special use facilities (e.g. defense facilities).

Edelenbos et al., (1998) lists five primary functions of underground space utilization. These are: Residential, Work (e.g. business, service, industrial manufacturing and retailing), Leisure (e.g. sports and bars), Transport (e.g. Goods and passenger transport, waste and electricity transport by piping and tubing), Storage (e.g. goods, waste, oil and gas).

Therefore, it is easier to conclude that the underground spaces are generally divided into four purposes, Public, Transport, Commercial and Special use. Table 1 list the relevant functions and facilities for underground space.

Table 1. Primary functions of underground space

Primary functions	Example of use
Public	-indoor sports and recreation -residential -culture
Transport	-passenger transport -goods transport -cabling, piping and tubing transport(e.g. waste, electric and water)
Commercial	-industrial manufacturing and retailing -business and service -entertainment facilities(e.g. bars)
Special	-defense facilities and sanctuary -telecommunication facilities

3.2.1 Analysizing the benefits of utilizing underground space

In 1995, Godard and Sterling published a paper in which they divided the advantage of underground development into categories, one is the typical structures placed in underground called direct advantage, the other is the service that provided by structures themselves named indirect advantage. In another major study, Ronka et al (1998) summarized the benefits of underground infrastructure more detail, including economic, technical, functional, social, and environmental aspects. Edelenbos and his co-workers (1998) list three basic motives why the underground space has become the center of attention, these are: enhancing the quality of the living environment, improving the efficiency of space use, and reinforcing the functional spatial structure. In her analysis, Durmisevic (1999) identifies that advantage of subsurface can be summed up in the following aspects: enhancing the cost effective use of the structure, decreasing traffic congestion, reducing environment influence (e.g. Noise levels, odor issues, risk threats and etc.), improving the quality of life. According to Godard (2004), the advantage of underground usage was analyzed with respect to land use and location problems, isolation, topography and environmental preservation.

From the above, it can be concluded that the consideration of underground usage can be concluded into three aspects: Environment, Society and Economy.

3.2.1.1 Environment aspect

Concerning environmental issues in urban development, the new concepts and approaches have been brought to solve and thinking more purposefully (Sanja, 1999). Even though the construction of the underground structure could cause some negative effects on the environment, there are also lots of potentials to achieve sustainable urban development by using the underground structure. For instance, reducing atmospheric emissions through reducing the reply on use transport systems and shortening communing distance, reducing the traffic on the road (Bobylev, 2006a) . At the same time, the structures built below the ground level could be regarded as a barrier of above-ground to minimum the risk and obstacles (e.g. visual impact, noise pollution, odours, etc) (Dimitrios & Andreas, 2013; Durmisevic, 1999; Monnikhof et al., 1999).

3.2.1.2 Society aspect

Comparing with private use, the majority of underground space are occupied by a public purpose. This is mainly because of the consideration of cities to have better public infrastructure and social equity. It can cover a variety of usages, including public transport, shopping centers, car garages, etc (Nikolai, 2009). Through constructing certain underground facilities, a large amount of buildings could be fulfilled on the same ground area, releasing the surface space for green field and residential areas. Moreover, the identified nature areas and historical centres could be preserved from underground structures construction (Monnikhof et al., 1999; Dimitrios & Andreas, 2013).

3.2.1.3 Economy aspect

There are generally two economic characteristics with respect to the underground structure, high initial investment during the construction period and the relative low cost of maintenance, when compare with a similar structure located above the ground. High initial investment of underground structure is mainly owing to the geotechnical risk during the process of construction. However, in view of the underground stable space temperature and isolate from external influence, only minimum expense demanded to be used for maintenance (Nikolai, 2009; Dimitrios & Andreas, 2013).

3.2.2 Combining waste collection and underground space

As a non-renewable and valuable resource, the uncontrolled development activities of the underground could generate irreversible consequences. Therefore, careful and professional actions should be proceeding during the process of underground space development (Xia et al., 2013).

The urban cities have become a ‘user-unfriendly’ environment as a result of traffic congestion, increased noise and air pollution, scarce green and recreation areas. Nowadays, numerous of city planners try to solve this problem through extending the borders of the city and linking the countryside, however, such actions do not solve the problem fundamentally but only postpones them. Therefore, the remaining issues such as these problems improve living condition and guarantee a healthy environment is still needed to solve by the city planner and decision makers (Durmisevic, 1999).

In Netherlands, there has been a dramatic increase interest in utilization of underground space in the past few decades, in spite of the adverse ground condition in

Holland. To some extent, this is due to the increasing complexity, number of structures and problems of spatial planning. Moreover, together with the growing awareness of environment, nature and livability (Edelenbos et al., 1998), It has been demonstrated by many studies that the utilization of underground space can obtain an environmental friendly and sustainable development in urban areas (Dimitrios & Andreas, 2013). Dimitrios and Andreas (2013) also describes that the requirement of a waste management system has been increased due to the rising waste amount, increased environmental considerations. The utilization of underground space can facilitate the development of city infrastructure, and capable to settle the limitations of existing waste management schemes in a more efficient way.

There are numerous challenges of waste collection in high density areas, e.g. high costs. For future waste collection in urban area, the development trend should include lower the congestion and related noise and pollutant emissions, higher hygienic standards (Kogler, 2007; Schiettecatte et al, 2014).

Based on the comment made by Bilitewski et al., (1997), the collection and transportation of waste occupied 60% up to 80% of total waste handing, hence, it would lead to a considerable savings if improve the process of organize and implement.

Hence, it is considered as an important evolution that involving the waste management into the development of the underground structure, which would definitely consider into the urgent need of modern society, such as efficient, sustainability and cost effective (Dimitrios & Andreas, 2013).

In next section, two comparable underground waste collection system shall be listed out and analyzed.

3.3 Comparison of alternative underground waste collection system

Over the past few decades, the underground and semi-underground space has been introduced into the systems of waste collection in urban areas.

The main difference between the surface and underground collection system is that the locations of underground waste containers are set in advance. By forming a network of permanent infrastructure, they are used for providing service to waste collection activities (Dimitrios & Andreas, 2013). In traditional form of waste collection (e.g. door to door), it is always a challenge for the system when meeting the vary topography and climate condition, limited space for waste container and transportation vehicles (Poulsen et al., 1995).

In Netherlands, there are two types of underground waste collection systems currently, called: Standalone collection points (underground container) and pneumatic waste collection system.

3.3.1 Attributes for comparison

Solid waste management is an indispensable task for cities authorities with regard to its characteristics of multi-dimensional. Municipalities in general are responsible for solving the diversity of problems and challenges that they meet. Therefore, it is extremely crucial to assess the city's waste management system, when there is a demand to improve a waste management system, or to monitor the performance of municipal service (Arnold & Justine, 2001; Lilliana, Ger, & William, 2013; Teerioja et al., 2012)

As mentioned previously(chapter 3.1), there is a great need for improving the waste management in Netherlands, regarding to increase recycle rate of organic waste, and decrease of GHG emissions.

Comparing with extensive application of underground waste collection system, the pneumatic waste collection technology is relatively new in Holland. Whereas, there are a large volume of areas has been covered by this systems in many cities of Europe, such as Stockholm, Paris, Barcelona, etc.

In order to evaluate the future prospect of development of the waste collection system in Netherlands, an assessment should be performed between these two systems in five main aspects. These five main aspects respectively are:

3.3.1.1 Technical performance

Detailed evaluation of technical performance of waste management system by Arnold and Justine (2001) showed that the components of the system within the municipal waste management should be identified initially. Then, it should be followed by analyzing the fitness level between the waste management systems and local physical conditions and topography, investigating if the waste management compatible or against any other urban systems or not, measuring the collection efficiency and coverage, and vehicle productivity (volume of waste collected per route and per time unit), calculating number of litter bins in commercial areas, measuring performance of waste process plants and etc.).

3.3.1.1.1 System elements

Regarding system elements, the waste container systems include inlets that above the ground, underground containers and special vehicles with a hydraulic crane. Whereas, the pneumatic waste collection system contains waste inlets, air inlet valves, underground pipe, waste collection terminal, hook and life trucks (Dimitrios & Andreas, 2013; Kogler, 2007; Schiettecatte et al., 2014; Rasmus et al., 2009).

3.3.1.1.2 System compatibility and vehicle productive

Concerning the compatibility of systems and vehicle productivity, both systems need to use special vehicles to transport the waste, which will definitely lead to some traffic and environmental problems. Vehicles that equipped by container system should collect the waste from bins to bins due to its limited capacity (0.6-5M^3). However, pneumatic waste collection system only needs to lead the trucks to the terminal building when the collecting containers are full. In the project of Almere city, there are five waste containers ($28M^3$) in the terminal building, one for the paper, two for organic waste and two for the remaining waste. Thereby, it can be concluded that the vehicles productivity of pneumatic waste collection system is superior than waste containers. Meanwhile, there is less influence of PWC system vehicles on the road traffic and environment due to the limited travel of heavy trucks within the community (Vijselaar, 2007; Dimitrios & Andreas, 2013; Kogler, 2007; Rasmus et al., 2009).

3.3.1.1.3 Collection efficiency

For collection efficiency, the PWC system is available to offer collection service 24 hours a day and every day of the year. But, there is a great rely of container system on vehicles transportation due to limited container capacity, the collection service could be suspended during the holiday (Kogler, 2007; Christer, 2009).

With regard to technical performance of two systems, it can be concluded that the performance of PWC system is better than the container system in aspects of system compatibility, vehicle productivity and collection efficiency.

3.3.1.2 Environmental performance

The environmental performance of waste collection system has been widely investigated (Arnold & Justine, 2001; SWECO VIAK AB, 2004; Kogler, 2007; Larsen *et al*. 2009; Rasmus et al., 2009).

3.3.1.2.1 Noise

Reducing the noise level is the prior condition that the collection system should meet in advance. The noise of the system should be as low as possible, and keep the residents from disturbance. A container system noise mostly derived from container handling during the process of waste collection and transportation, even though compaction and reversing also generates considerable noise (Eriksen, 2005; SWECO VIAK AB, 2004; Kogler, 2007; Envac Group, 2012). A deeply investigation of noise level between two systems was carried out by Kogler (2007), the results revealed that the total noise level of container system in a certain area per week is 75-88dBA. The total noise impact that generated by PWC system per week in the same area is 55-72dBA.

3.3.1.2.1 Odour

In order to reach a comfortable living environment and improved the air quality of urban area, minimizing the unpleasant odour as much as possible is great importance that needs to be concerned by urban waste collection systems(Kogler, 2007). In hot climate (e.g. summer), the organic and decomposed materials can lead to considerable malodour, especially that the household waste in containers could not be collected every day. However, based on the characteristics of PWC systems, the waste will be collected everyday within the area where covered by this system, and to be transported into several different fully sealed containers where placed in the terminal building (Kogler, 2007; Christer, 2009)

3.3.1.2.3 GHG emission

Another issue needs to be considered by any collection system is lower the GHG emissions. Larsen *et al*. (2009) investigated the emission volume of CO_2 by measuring diesel consumption for trucks collecting waste (e.g. paper, and glass) from drop off containers in a Denmark city. The research results showed that 11.5-15.7 KG CO_2 would be released for each collected tonnes of waste. In 2007, Mogensen and Holbech published a paper in which they described that the estimated emission amount of CO_2 is 17.5-77.1KG for each tonnes of collected waste by using the PWC system. Besides, Teerioja et al. (2012) demonstrated that the costs caused by CO_2 emissions for PWC were as much as 2.5 times for conventional collection system. However, Win's comparative study (2011) found that approximately 400 tons of emissions per year by utilizing PWC system, because of 75% of waste collection movement are eliminated. Another living example is that 3.6% emissions of greenhouse gases (CO_2) of Madrid City have been reduced through installing the PWC system (Christer, 2009). A serious weakness with Teerioja's argument, however, is that the daily capacity of the PWC system just 5.3 tonnes in her base case. It is only accounts 23% of design capacity of Wembley city).

3.3.1.3 Economic performance

Cost is another important criteria for evaluating the performance of the system. In addition to this, costs also play an essential part in the process of political decision making (Kogler, 2007).

A recent study by Schiettecatte and co-workers (2014) reports that initial investment of PWC system is higher than a conventional waste collection system. Even though conventional waste collection system shares a low investment, it combines with a high operation cost, mainly because of high occupy rate of manpower resource. An important disadvantage, nevertheless, is that it brings along noise and air pollution, enhancing problems of traffic and safety.

Several recent researches compare PWC and conventional collection in cost aspect. According to Teerioja et al (2012), a vacuum system is as much as six times none economical beneficial than conventional waste collection system. Moreover, in their analysis of Pneumatic vs conventional collection, Kamga et al (2013) acknowledges the high investment costs of PWC systems relative to truck-based collection.

However, these researches does not take into account other economic beneficial aspects of pneumatic system, such as saved space on the ground floor and environmental cost of the CO_2, SO_2 and NOX emission.

A serious weakness of both studies, Punkkinen et al (2012) and Schiettecatte et al (2014), it is concluded that the basic environmental cost of gas emission remained below 1% of the total cost, and being overlooked due to it's insignificant.

Another investigation made by Kamga et al (2013), mentioned that Teeerioja designed the pneumatic waste handling capacity is below the commonly amount which assumed to be economically practical in her base case. And put forward that the overall cost differential will be decreased when the pneumatic waste handling volume is increased, this is due to the fixed costs of the PWC system do not increase with additional tonnage.

Moreover, SWECO VIAK AB,(2004) points out that the PWC system is far more cost effective, if the rental income from saved space on the surface is taken into consideration.

Concluding, it can be stated that the increase of waste volume can lead the PWC system more cost beneficial than the conventional waste collection.

3.3.1.4 Social performance

Waste collection activities can significantly conduce to the traffic load in urban areas. More transport activities are needed by separate collection of recyclables, due to different fractions are collected separately. It is well known that the collection activities could bring about a high traffic load and air pollution of gas emissions in a high population density area (Kogler, 2007).

For the purpose of comparing the possibility of decreasing the traffic load between waste container and PWC system, the operational mode of each system should be revealed in the beginning.

Considering the operational mode of the two systems (Figure 2), the traffic generated in the collection area and regions can be distinguished and contrasted. The amount of collection runs of PWC is nearly zero within the collection area. Delivery times from collection center (Terminal) to final waste treatment facility are almost same with the region between these two systems. Even though the collection vehicles could not be totally eliminated by using PWC system, the amount of collection runs within the collection area could be reduced at a considerable rate (Kogler, 2007).

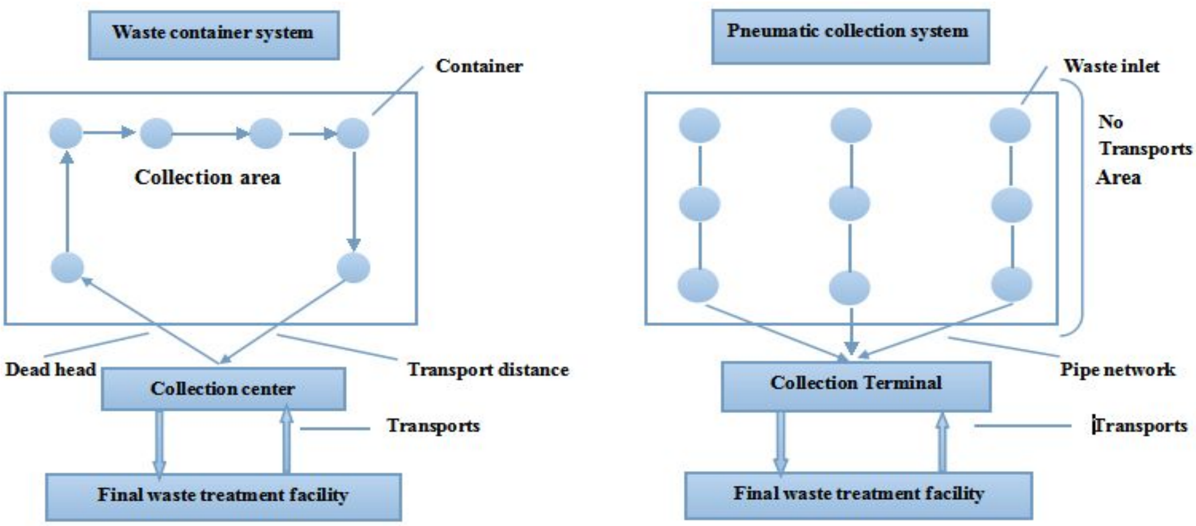


Figure 2: Traffic load comparison between container and PWC system(Source: Kogler, 2007)

3.3.1.5 Policy and legal performance

In Netherlands, Ministry for Housing, Spatial Planning and Environment must to draft out waste management plans every six years under the stipulation of the Environment Management Act. The second National Waste Management Plan is for the period 2009 to 2015, and it's introduced an objective to increase recycling of household waste to 60% by 2015 (Leonidas, 2013).

Organic waste (e.g. kitchen and garden wastes) normally accounts for 30-60% of Municipality solid waste, the figures could be volatile depend on the region, the season, the climate, the population density, etc. (Bilitewski et al., 1997).

A recent study by Leonidas (2013), reports that the organic recycling rate has not been changed from 2001 to 2010 in Netherlands. Moreover, the European Union's (EU) waste framework directive (2008/98/EC) plan to add the organic waste into the waste collection system in 2020(Francesco & Caterina, 2014). In general, there are national and EU level of policy and legislative requirements on increasing the recycling rate of household waste, especially organic waste.

It is to be noted that the organic waste can bring about considerable malodorous in hot climate, especially that the household waste in containers could not be collected every day (Bilitewski et al., 1997). Such adverse impact could influence the enthusiasm of the residents sorting the organic waste. Beyond that, missing the classification of waste in the inlet point maybe is another issue that influences the growth of organic waste recycling rate in Netherlands.

The PWC system could put more fractions of waste in the inlet point when installing the facilities, e.g. organic waste, paper waste, incinerate waste and etc. (Envac Group, 2012)

3.3.2 Development trends for waste collection system

According to the multiplicity of operating conditions, the possibility of MSW collection systems to be improved can be diverse (Teerioja et al., 2012).

In 2012, Teerija et al. published a paper in which they described two ways to improve the MSW systems in developed countries, either promoting the cost-efficiency or enhancing the performance of vehicle operated collection systems, or implementing a new way to collect and transfer the MSW.

Detailed investigation of sustainable waste management in Netherlands by Marielle and co-workers (2013) showed that the current waste management could be improved to a large extent. Particularly, in a scenario of demanding to increase the waste reuse and recycling rate, to lower GHG emission and energy consumption.

Based on the previous comparison of two systems (pneumatic vs. container), and description of future Dutch waste management plan, there is great potential for PWC taking the place of container system in Netherlands. Especially in a scenario where the focus of Holland and EU policy is on increasing recycling rate (e.g. organic waste), reducing energy consumption and GHG emission, and enhancing the protection of environment and human health.

In next section, the decision making of Pneumatic waste collection system shall be introduced.

3.4 Decision making in PWC system implementation

Pneumatic waste collection is a type of technology which could suction out the refuse bags from the central terminal building, and it transporting refuse bags through main underground pipe network (Gary et al., 2008; Nakou et al., 2014). The PWC system (Figure 3) can be separated into three parts: central terminal building, underground pipeline network, and waste discharging valves (drop-off points) (Kogler, 2007; Rosa M., 2010).

Figure 3. Components and operation mode of PWC system (Source: Nakou et al., 2014)

In 2008, Gary et al published a report in which they described the PWC system is best placed in a dense urban area with a view to achieving cost efficiency, because of handling large volume of waste in the area.

In Netherlands, the municipalities are hardly responsible for the collection of commercial waste. Commercial waste producers are free to choose the collection parties, mostly is private collector (Roijen, 2009). For the purpose of performing the best performance of PWC system, it is suggested that local municipalities should formulate more plans to promote more commercial parties involved in the system.

As a mainly vacuum waste system supplier in Netherlands, CentralNed BV has provided several technology requirements of the system, in view of system characteristic. For instance, there is a limited distance for the system to transport waste from inlet points to central terminal, if it is only served by one central terminal building.

It is well known that the Municipal Solid Waste (MSW) management is a complicated process, because it includes waste collection route, transfer station locations, energy recovery and transfer station location (Dewi et al., 2010).

For the purpose of design and perform a suitable MSW management, decision makers should combine the national and regional goals with some of its process (e.g. collection route or plant location) (Atousa et al., 2014).

Nowadays, there are many cities are utilizing PWC system to collect and transport refuse all over the world, e.g. Wembley, Barcelona, Romainville and etc. (Dimitrios & Andreas, 2013; Rodica et al., 2014; Kogler, 2007). However, Plenty of studies have focused on the analysis and compare the ecological and financial aspects with conventional waste collection (Rasmus et al 2009; Schiettecatte et al; Teerioja et al., 2012). And other studies only concentrate on modeling the energy consumption of the PWC system (Cesar et al., 2014; Bejar et al., 2012).

There is almost no research on finding the optimal location for the PWC system. This is mainly due to fact that the system provider company normally in charge of design and maintenance of the system (e.g. Almere city project). Therefore, due to the limited involvement of municipalities and other parties, the environmental and social performance of the system sometimes could not reach the best level.

Searching optimal location for the waste collection system is a mixed process that involves various environmental and socio-economic criteria. It is to be noted that defining alternatives, relevant criteria and their weights, and finding a suitable solution is always searched by decision makers. And it is often required that multiple stakeholders such as government, municipalities, industries, experts, and/or general public to get involved (Atousa et al., 2014).

3.4.1 Stakeholders in decision making

Determining features of a solid waste management scheme should be analyzed and integrated precisely, in order to evaluate it strong points and shortcomings. Meanwhile, it is to be noted that any waste management systems involve a complex interaction of actors accompany with different stakes, such as decision making power and influence (Marco et al., 2014).

Regarding the problem in question and solution, the categories of stakeholder groups could vary a lot (Contreras et al., 2008), if without clearly prior defining (Fassin, 2008).Accordingly, it is greatly important to investigate which kind of stakeholders are involved in the project, and how can they perform their roles to enhance the success of it.

3.4.1.1 Stakeholder identification

Several successful cases of PWC system have been outlined properly in table 2. Involved stakeholders can be classified as Government/Authorities, Developers/Investors, and service providers. Based on the research, stakeholder roles can be diverse: decision makers have the authority to make official decisions of project. Financiers are taking part in project investment and cost control. Technical experts are involved in the project operation and maintenance.

Therefore, according to the case analysis in table 2, the following stakeholders with regard to project implementation and operation can be considered: governmental, financial and technical based

3.4.1.1.1 Governmental stakeholders

Involvement of governmental stakeholders could be either directly or indirectly, based on different scenario and cases.

European Union formulates goals and plans to influence the environment and infrastructure construction of its member state, such as the Netherlands. It can be considered as the indirect involvement of the governmental stakeholders. However, European union also generates the investment plan for the purpose of reviving investment in strategic projects of its member state. For instance, PWC system projects which utilized in historical business district of Leon (Spain) are funded by the European Unions(Stephen B., 2004).

National government and regions are usually involved in projects indirectly in Netherlands. The national government develops policy on a national level and issues it to provinces and municipalities.

Municipalities in Netherlands are responsible for implementing waste management in their own territory, moreover, the right of way in the public area also should be granted by municipalities. Thus, municipalities are involved directly.

3.4.1.1.2 Financial stakeholders

The group of financial stakeholders could be segmented into private property investor, Joint Venture Company, independent investor, and local municipalities.

Private property investor covers the costs of installing the PWC system inside the buildings, for example, the connections and receptacles. This situation can be found on the cases in table 2, such as Barcelona, Almere and Sickla Udde.

Joint Venture Company and independent investors are generally interested in earning the profit from the investment, to avoid losses from economic fluctuation. In different scenarios, they own the PWC system in whole or partly. It can be reflected through the case of Roosevelt Island, Barcelona, Wembley, and Hammarby Sjostad.

Collection and transportation occupy a considerable rate of waste management expenditures in municipalities of the Netherlands. They have obligations to improve the environment and living conditions in their own region. In some cases, municipalities are the leaders of the project. Hence, terminal building construction and pipeline network installation in public area are all borne by municipalities. This situation has been stated in the case of Almere and Barcelona.

3.4.1.1.3 Technical stakeholders

Equipment Company, as a service provider, providing initial design and advice to the municipalities or project initiator, in the field of PWC system on topics like system installation, operation and maintenance. Examples of Equipment Company offer service on mentioned aspects are, Almere, Barcelona and Malmö Cities project.

3.4.1.2 Relationship between stakeholders

According to the analysis in the previous section and table 2, it can be concluded that municipalities play a role of primary initiator and sponsor in PWC system project. They can develop relevant policy and legislation to influence on other stakeholders (e.g. developer and service provider), have a decisive power on system implementation. Service provider would have a service contract with the project owner, regarding system operation and maintenance. The project investor can appear as an independent role, or could be replaced by the municipalities or other authorities. Therefore, their relationship can be represented by Figure 4.

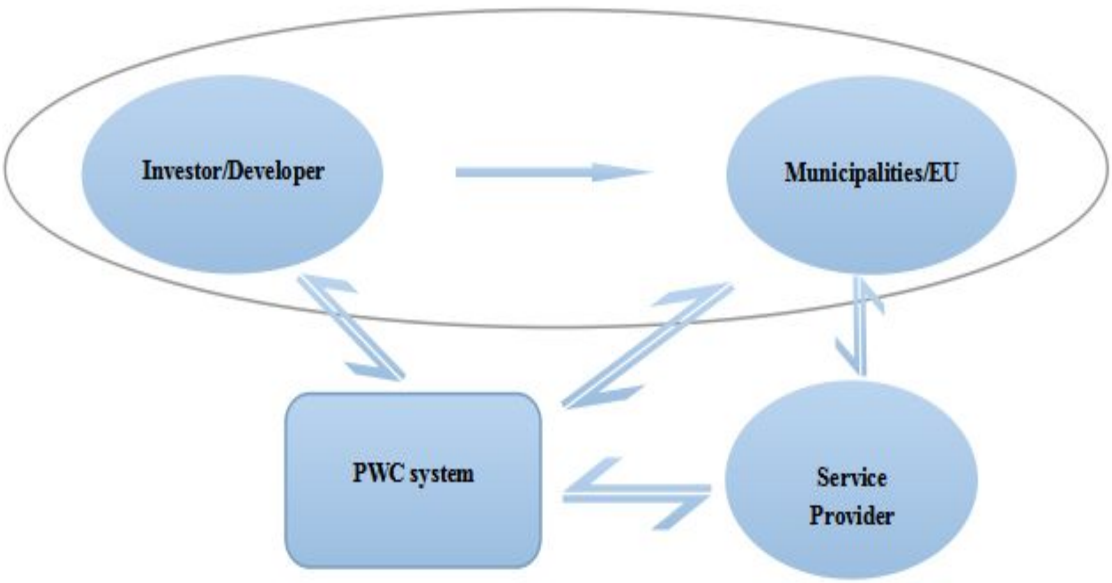


Figure 4. Relationship between stakeholders

Table 2. Summary table of stakeholders in PWC system

Involving party	Project location	Project organization and operation mode	Reference
Almere municipality, private property owner, equipment manufacturer	Almere (Netherlands)	The terminal building and pipelines within the public area are funded by the Government, property owners responsible for installing waste inlet in the building. The equipment manufacturer (CentralNed BV) responsible for system maintenance and operation.	(Vijselaar, 2007)
New York Municipality, RIOC	Roosevelt Island (New York)	The PWC system is owned by a state agency (RIOC), which funded by the sanitation department of New York. RIOC mandated to develop management, operate and maintain the system.	(Gary et al., 2008) (Stephen B., 2004) (Jonas & Anja, 2010)
Developers, Builders, Equipment company, City of Barcelona	Barcelona (Spain)	Developers pay for the capital installation of underground pipes, builders pay for the in-building connections and receptacles, city pays for the central collection terminal. Equipment company has an operation and maintenance contract.	(Gary et al., 2008)
Developer, City of Wembley	Wembley (London, England)	A single developer owns the PWC system. And finances system operation costs.	(Gary et al., 2008)
Developers, Equipment company, city of Stockholm.	Hammarby Sjostad (Stockholm, Sweden)	Sweden uses a consortium model. The developers invest and formed a company which owns the system, including pipes, terminal building, equipment installed inside the buildings. Equipment company has an operation and maintenance contract.	(Gary et al., 2008)
Developer (waste collection company), city of Copenhagen	Havnestat (Denmark)	A local waste company finances the installation plus maintenance and operation of the system, the residents pay an annual rent in addition to the charge for waste collection.	(Kogler, 2007)
Developer, city of Gothenburg	Gothenburg(Sweden)	The system is owned by Eriksberg Cooperative, which awarded an equipment company the operation and maintenance contract.	(Jonas & Anja, 2010)
Property owner, equipment company, city of Malmö	Hyreshem Malmö (Sweden)	Property owner responsible for the PWC system installation, equipment company is in charge of operation and maintenance of system.	(Jonas & Anja, 2010)
Developer, equipment company, city of Stockholm	Sickla Udde (Sweden)	Private property owners are responsible for installing the smaller grids, which connect to the main grid in streets and public land. The city development administration is in charge of procuring and installing the main grid. The equipment company has an operation and maintenance contract.	(Envac Centralsug AB, 2000)
Government	Madrid (Spain)	Pipelines running along the public thoroughfares are being financed with FEIL(state fund for local investment) funds. The connections to each building are financed by Municipal corporation for housing and lands.	(Christer, 2009)

3.4.2 Research approach for decision making

As a decision maker, it is necessary to compare the performance level of various MSW management strategies, to accomplish the defined criteria. Therefore, one decision support framework is needed to be explored to compare the performances between different criterions. In general, through using an effective manner to carry out an integrated support framework, the applicable and available options of MSW management could be selected (Antonio C. & Pacifico M., 2002; Morrissey & Browne, 2004).

Various frameworks have been investigated to support the decision making process in MSW management (Atousa et al., 2014). Multi-criteria decision analysis (MCDA) is the most popular framework that utilized in previous research on municipal solid waste management issue. It can help multiple stakeholders to evaluate the often conflict criteria, intercommunicate different preference, and ranking or prioritizing strategies to reach a consensus on some of these strategies, and making an optimal decision (Wiecek et al., 2008; Zopounidis & Doumpos, 2002; Atousa et al., 2014).

Historically, the location searching for PWC system has been missing for a long time. Hence, similar cases should be investigated for the purpose of selecting the proper MCDA approach.

In table 3, several studies which relate to the evaluation of the optimal waste facility (e.g. Landfill site) location, have been list out. The most frequently used tools for solving optimal facilities locations issue either use MCDA alone or together with GIS (Geographical Information System).

Alternatives of facility location have to be determined in advance, when only MCDA as a tool to be employed. However, the facilities location will be evaluated by GIS software together with MCDA approach, if plenty of waste treatment locations are taken as alternatives (Dosal, Viguri, & Andres, 2013).

It can be observed from Table 3 that the most common approach for searching waste facility location is AHP. AHP methodology could be used to solve decision making issues and select best alternatives. Moreover, it enables the decision makers to integrate both qualitative and quantitative information into a decision model (Isaai et al., 2011). Supported by GIS, the quantitative and qualitative index will be calculated, and the grade diagrams will be generated, in order to conduct the synthesis evaluation in the target region or districts (Xiong et al., 2007).

In this study, identifying location of PWC system which involved in MSW management will be outlined. And this integrated framework could be applied to different scenarios. Therefore, combined AHP with GIS will be regarded as the decision framework for identifying the potential area to deploy the PWC system.

In next section, the relevant factors with respect to selected method will be revealed.

Table 3: Approach summary table regarding to MSW decision making

Tools	MCDA method	Objective	Type of waste	Reference
GIS+MCDA	AHP	Identification of solid waste dumping site	MSW	(Ravindra, Nitin , & Bhalachandra, 2014)
	AHP	Identification of waste dumping site	MSW	(Tirusew & Amare, 2013)
	AHP	Identification of landfill site	MSW	(Sehnaz et al., 2010)
	ANP	Identification of landfill site	MSW	(Abu & Rafee, 2009)
	AHP	Identification of incinerator location	MSW	(Tavares et al., 2011)
	Fuzzy AHP	Identification of landfill site	MSW	(Nazari, Mehdi , & Aghajani, 2011)
	AHP	Identification of landfill site	MSW	(Sumathi, Natesan, & Sarkar, 2008)
MCDA	Promethee	Ranking of recycling plants	EW	(Queiruga, Walther, Gonzalez-Benito, & Spengler, 2008)
	ELECTRE III	Identification of incinerator location	MSW	(Bobbio, 2002)

3.5 Criteria analysis based on research approach

In this chapter, criteria and attributes in PWC system implementation will be discussed. Decisions should be made by the involving parties for accomplishing the defined targets.

The objectives of relevant stakeholders should be broken into various segments, which can be used to constitute the hierarchical structure of AHP model (Falco, 2013). In this study, there are three types of criteria involved, namely, Influential criteria (customer requirements), evaluating criteria, and constraint criteria.

3.5.1 Influential criteria

Various stakeholders will be involved in the process, for the purpose of searching the optimal location for the PWC system. And varieties of consideration and requirements are proposed by them. It can influence the overall goals. Hence, the influential criteria also can be called stakeholder (customer) requirements.

As mentioned in section of stakeholder's identification, there are normally three kinds of stakeholders involved in the decision making process, Municipalities, Investors and Service providers.

3.5.1.1 Municipality

in Netherlands, municipalities have paid more and more attention to protect the environment and improve the living condition, during the process of waste collection and transportation, under the national and EU policy and legislation. Therefore, regarding environmental aspect, municipality's requirements on developing a new waste collection system or improving the current one can be summarized into four categories: Minimum impact on environment (Gas Emission), Minimum impact on environment (Noise), improving the road safety, and reducing the traffic congestion. Moreover, municipalities also want to improve the aesthetics within their territory on social aspects.

3.5.1.2 Investor

Most Investors are profit oriented. Investor allocate their assets in developing a new waste collection system for the purpose of earning as much as possible from their investment, or saving waste collection costs in their own projects. Thus, their considerations towards economic aspects are: reducing payback period, controlling initial investment cost.

3.5.1.3 Service provider

In most of the cases, the equipment manufacturers have an operation and maintenance contract with the responsible party of the project, they can also be called service providers. In order to let the PWC system to fulfill best performance, service providers more concerns about the factors that can influence the system running, for instance, user's behavior and surrounding environments of the system. Consequently, social aspect concerns of the service provider can be concluded to increase sorting activities and awareness of end-users. In environmental aspects, there are more concerns about the accessibility of trucks around central collection terminal building.

To sum up, Considerations of involving stakeholders can be categorized into three aspects: environmental, economic and social. It is detailed accounted by Table 4.

3.5.2 Evaluating criteria

It is to be noted that the customer requirements need to be more specific, in order to select the optimal area from the alternatives. These specific criteria can be treated as certain attribute on behalf of alternatives. Therefore, a connection between customer requirement and alternatives can be generated.

In this model, customer requirements can be regarded as "what would be". Whereas, evaluating criteria are similar to "How to". According to the relevant literature review, there are 13 evaluating criteria that the alternative locations should be presented in order to achieve the customer requirements. The lists of evaluating criteria are revealed in Table 5.

Table 4. Influential Criteria

	Name	Description	Reference
Environmental	Minimum impact on Environment (Gas Emission)	The potential contribution of sustainable waste management to energy use and greenhouse gas emission reduction in Netherlands.	(Marielle et al., 2013),(Schiettecatte et al., 2014), (Kogler., 2007)
	Minimum impact on Environment(Noise)	Strongly correlated to traffic load. Noise is caused by vehicle movements in the collection areas. Noise Duration including vehicle movements in area and loading truck in collection point.	(Stephen B., 2004), (Schiettecatte et al., 2014), (Kogler., 2007)
	Accessibility of trucks in Terminal building	It is of great importance that transportation trucks have free access to the terminal building without any congestion, for the purpose of fast loading and unloading.	(Envac Group., 2012), (Kogler., 2007), (Newham., 2011)
	Improving the safety in community	There are numbers of truck accidents happened in the residential areas. A new system is needed to reduce the number of waste collection trucks on the road. less time and number of trucks on the road, the better for the community safety.	(Envac., 2011), (Kamga et al., 2013) (Nick & Aiden., 2014), (Kwang., 2005)
Economical	Reducing the payback period	The initial investment of the system is huge, therefore, the payback needs to be considered, depends on application size and waste density in the area, alternative waste handing/collection costs.	(Envac Group., 2012), (Kogler, 2007), (Peter & Luiten, 1974),
	Controlling initial investment cost	Construction cost is highly dependent on ground structures. E.g. Value of land for terminal building and pipelines.	(Teerioja et al., 2012), (Nakou, 2014)
	Extension possibility of system	At the initial process of the project, the system couldn't connect all users to the system. Involving additional certain amount of population in system, the performance will increase correspondingly.	(Stephen B., 2004), (Nikolai., 2009)
	Controlling Construction difficulty	Due to requirements of systems characteristics, the underground space of the area will be utilized. The soil need to be considered.	(Nikolai, 2009)
Social	Improving the district aesthetics	Since the refuse will be removed immediately. There will no longer be an unsightly and odorous accumulation of waste along residential or commercial thoroughfares.	(Stephen B., 2004), (Schiettecatte et al., 2014), (Vijselaar, 2007)
	Reducing the traffic congestion	Comparing the different areas, which area is able to decrease the traffic load and congestion in the collection area and regionally. Researching the road condition in each area, if the area has the worst road condition, it will be most benefit from the system, and reducing the congestion.	(Schiettecatte et al., 2014), (Kogler, 2007), (Envac Group., 2012), (Stephen B., 2004)
	Increasing residents sorting activities	In reality, household willingness to separate waste may differ under different waste collection schemes.	(Newham, 2011)(Teerioja et al., 2012),
	Increasing awareness of residents	Users must understand why they should recycle and have full confidence in the recycling system. Improving the awareness of the waste sorting and recycling.	(Envac Group., 2012)), (Kogler, 2007)

Table 5. Evaluating criteria

Name	Description	Reference
Population Density	Population amount per hectare that will be connected to Pneumatic waste collect system.	(Envac Group., 2012), (Ravindra, Nitin , & Bhalachandra, 2014)
Released space volume	Space will be released from current container system, and will be used for parking the car and other uses.	(Envac Group., 2012), (Kogler., 2007)
Land price in terminal area	Normally, the terminal building will be placed near the main road, and it needs occupy a certain space.	(Newham, 2011), (Teerioja et al., 2012)
Land price in Community	Rental income from saved space on the ground floor can be calculated. It can be used to recover the costs of system installation.	(Nikolai, 2009)
Pickup trucks travel distance in Community	The travel distance can decide the duration of trucks travel within the community. The longer travel distance within the neighborhood, more gas emission and congestion caused by pickup trucks will be reduced after PWC system installation.	(Schiettecatte et al., 2014)(Kogler, 2007)
Road Condition level around terminal building	Roads should have foundations and a hard-wearing surface capable of withstanding a fully loaded waste collection vehicles. The higher condition of roads, the less opportunity to arouse traffic congestion around terminal buildings.	(Rodica et al., 2014), (Newham, 2011) (Majlessi & Vaezi, 2014)
Maximum population amount of other connected neighborhood	Normally, the systems design capacity is far higher than the daily usage capacity, therefore, there is great opportunity for system to involving more residents into PWC system.	(Stephen B., 2004)(Nikolai, 2009)
Town house (family house) density in community	The waste from town house and detached house will be collected by a door to door way, which means residents should place their litter bins outside of house and near the road. It will influence the aesthetic of city. After connected to the system, this situation will be changed a lot.	(Vijselaar, 2007), (Stephen B., 2004), (Schiettecatte et al., 2014)
Bus stop covering rate in community	Through public communication ways, resident’s awareness of waste sorting and benefits of system will be increased. Each bus station will be treated as a media in order to ensure as many as possible residents are educated on PWC system.	(Kogler., 2007), (Larsson, 2013), (Christer, 2009)
Degree of road levels in community	The lower level of road condition, the higher possibility of causing congestion during the period of waste collection, therefore, there is higher demand for system in lower road level community.	(Envac Group., 2012), (Kogler., 2007) (Envac AB, 2000)
Building Density	The higher density of buildings, the safety of neighborhood will be improved after system implemented.	(Envac Group., 2012), (David & Niklas, 2010)
Nearest Distance from residential building to terminal building	On the social aspects, the residential areas should isolate from the influence of noise and other adverse issues caused by traffic.	(Nikolai, 2009), (Monnikhof et al., 1999) (Majlessi & Vaezi, 2014)
Soil type	Due to the pipelines should be deployed in underground, the extreme soil condition will increase the difficulty of construction.	(Xia et al., 2013) (Parker, 2008)

3.5.3 Constraint criteria

There are some factors that have the power to restrict the PWC system to install in a specific urban area. It can be called constraint factors. The reasons for the existence of these factors are mainly due to the characteristics of the region and PWC system. In this research, three constraint factors are discovered: the land use plan, occupied space of the central terminal building, and population amount within neighborhood.

3.5.3.1 Land use plan

In Netherlands, there are various limitations on the owner's property rights in regard to land and buildings. Based on the Dutch law, the development of the land must in accordance with municipal planning policies, which are usually reflected in a form of municipal land use plan (Fred & Willem, 2007).

In their study, Verburg et al., (2004) describes ten types of land use in Netherlands, it includes: Grassland, Arable land, Greenhouses, Other agriculture, Residential areas, Industrial/commercial area, Forest /nature area, Recreational area, Airports and water.

Therefore, if the initiator want to develop an area to implement PWC system, for example residential use, a quick scan can be carried out in a city or region, and other types of land use can be directly eliminated from the suitability map. Hence, the potential installation area amount of PWC system can be narrowed.

3.5.3.2 Required space for terminal building

As previously mentioned in Chapter 4, the PWC system includes three parts: central terminal building, underground pipeline network, and waste discharging valves. A certain space area is needed for constructing the central terminal buildings. This building can be placed either above ground or underground (Kogler, 2007). The size of a central terminal building can be decided by two main parameters: the expected volume of users and amount of waste fractions. Other parameters also have the possibility to influence the size of the terminal building, such as: waste collection frequency, ground conditions, location etc. (Envac Group, 2012). A broad indication of the floor space required for terminals are outlined in Table 6.

Table 6. Floor space for collection terminals (Source: Envac Group, (2012))

No of households/dwellings	Two waste fractions	Three waste fractions
8,500	350-400 m2	500-600 m2
6,000	200-250 m2	300-400 m2
>3,000	100-150 m2	180-230 m2

To sum up, there must existence a certain size space in potential installation area of PWC system, for the purpose of constructing the collection terminal building.

3.5.3.3 Population amount within neighborhood

Based on the characteristic of Pneumatic waste collection system, it is normally installed in a large, modern metropolitan areas, as well as airport, hospital, residential and commercial area. If the PWC system used as residential and commercial solution, it is highly recommended that the system should be installed in highly populated area.

The population amount within the system capture area normally is the first parameter to be considered during the process of location identification. Considering the economically feasible of the system, it is not recommended to install the PWC system in a area which only contains a few hundred dwellings, if this is the first installation of the city (Envac Group,. 2012).

Therefore, a quick scan of all the areas should be carried out in the first installation of system. If the population amount of alternative area could not reach the economical feasible level, it will be eliminated at once.

3.6 Conclusion

In this chapter, the topics of waste management and underground waste collection are introduced. The municipality waste management aims at separate, collect, treatment and recycling waste from households, commercial and industrial activities in their own territory; reducing the environmental and health influence of waste. Through detailed comparison and analysis, Pneumatic waste collection system is confirmed to be the optimal option to accomplish the national waste management plan. Stakeholders have the power to make the decision of PWC system installation. In project, stakeholders are divided in "Governmental", "Financial", and "Technical". The first two stakeholders could be as a whole if the Government is the only sponsor. Municipalities (Government) enforcing waste management policy, issuing relevant permit. Technical stakeholders provide design and management services.

Decision making in implementation location of PWC system considers environmental, economic, and social aspects. These considerations were classified into 12 influential criteria further. In order to identify the area that can more achieve the stakeholder's requirements, 13 evaluating criteria are investigated and listed. The stakeholder's requirements could be quantitative measured by using these evaluating criteria. Therefore, a connection between requirements and alternatives are generated. Three constraint criteria also presented which would be used to carry out a quick scan to eliminate the alternative locations within the city.

4. Methodology and process for identifying system location

The previous chapter can be considering as the preparation of constructing the research model. This is mainly due to the background information on Pneumatic waste collection system, waste management and decision making are presented. Besides these background information, it also conducted to identify important stakeholders and decision criteria. These elements will be introduced into the used approach in this chapter.

In this paragraph the methodology for research will be described in detail. Figure 5 presents five main steps in which the research approach problem and corresponding questions are solved.

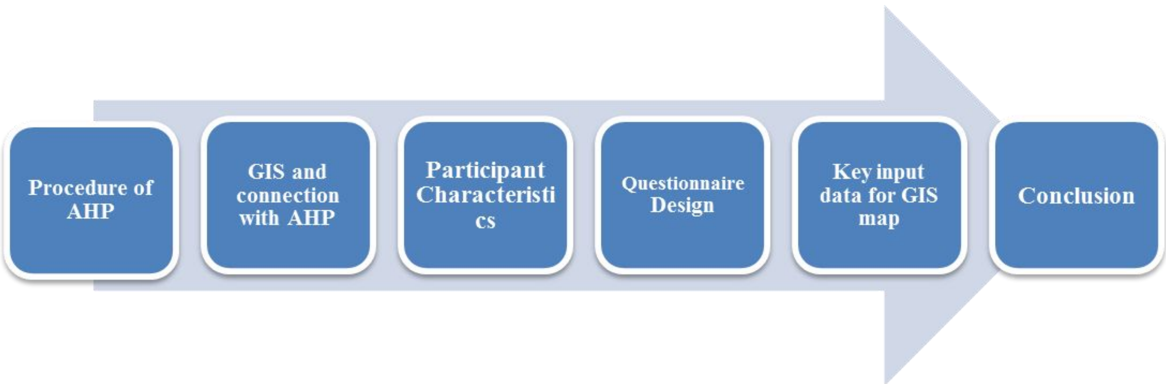


Figure 5: Research Process

It is a complicated process to involve Municipality together with service provides stakeholder in decision making process of waste collection and transportation. Therefore, the structure of AHP is constructed for the purpose of obtaining criteria impacts with respect to both stakeholders. The obtained weight will be imported into GIS map to generate the suitability map.

There are two types of stakeholders participate in research, Municipality and service provider. Their preference could generate great influence on research results. A survey questionnaire is used to gather the data from two type stakeholders towards system location. Experts from both stakeholders will be requested to fill in the questionnaire in which the evaluating criteria weights are evaluated. After gathering relevant data and inputting into GIS map, the optimal location map will be generated through overlay analysis.

4.1 Analytic Hierarchy Process

Through using AHP approach, the research goal will be broken down into several components to develop a hierarchical structure. There are five main levels of the AHP structure in this research, goal, criteria, influential criteria, evaluating criteria and each evaluating criteria level. The whole structure is presented in the Figure 6.

4.1.1 Goal

The overall objective of research will be described in the goal level. The goal of this research is to identify an optimal area for installing Pneumatic waste collection system within the neighborhood of Eindhoven.

4.1.2 Criteria & Influential Criteria

Factors or attributes that influence the decision make of objective can be called criteria. Criteria are normally situated below the goal level.

The literature review has shown that a dozen of influential criteria are consider by the involving party of PWC system project. These criteria can reveal the consideration and desires of stakeholders towards this PWC system installation. Through analysis with compare, these influential criteria can be summed up to three main aspects: environmental, economic and social.

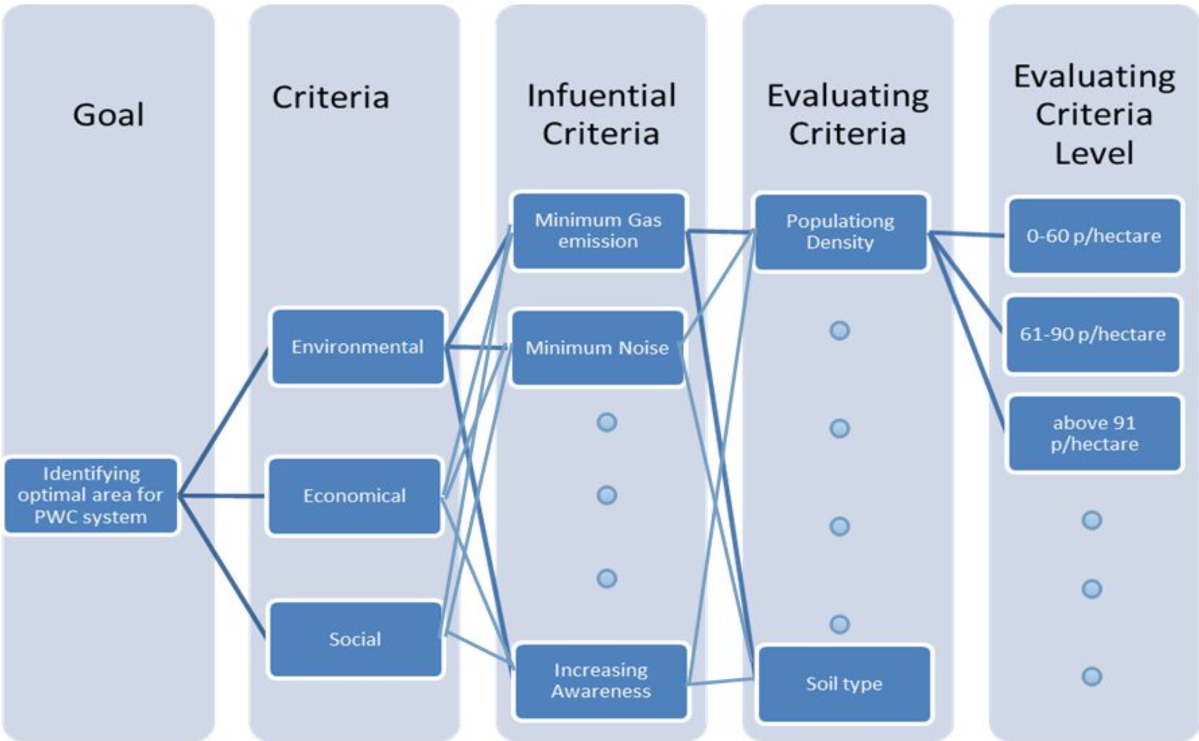


Figure 6: AHP model structure

4.1.3 Evaluating Criteria

As a succession level of influential criteria, the evaluating criteria should make the stakeholder consideration (influential criteria) more specific and generating the link to the alternative area for installation. Through the analysis in previous chapter, it is found that 13 criteria can be used to reflect the features of alternative area, and to connect the level of influential criteria.

However, it is to be noted that not every influential criteria can generated the link to evaluating criteria. This is mainly due to the influential criteria reflect three aspects of stakeholder's requirement, each aspects consideration can only be satisfy by a few area features. For instance, the land price within community or central terminal building has no direct link or relates to minimize the gas emission. The connections between influential criteria and evaluating criteria are presented in table 6.

Table 6: Connection table between Influential criteria and Evaluating criteria

Influential Criteria \ Evaluating Criteria	Population density	Released space from underground waste container	Land price in terminal area	Land price in Community area	Maximum Population amount of other connected community	Highest road conditional level around terminal building	Nearest distance from Residents building to terminal building	Town house (family house) density in community	Bus stop covering rate in community	Degree of road level in community	Building Density	Soil type	Pickup trucks travel distance
Minimum gas emission impact on Environment	X												X
Minimum noise impact on Environment	X						X						X
Accessibility of trucks in terminal building						X	X						
Improving the Community safety	X						X			X	X		X
Decreasing the payback period	X	X	X	X	X							X	
Controlling the initial investment cost			X	X				X		X	X	X	
Extension possibility of system					X	X						X	
Controlling Construction difficulty	X					X	X	X		X	X	X	
Improving the district aesthetics	X	X						X	X				
Reducing the traffic congestion	X	X			X	X				X	X		X
Increasing residents sorting activities	X							X					
Increasing awareness of residents	X								X		X		

4.1.4 Evaluating Criteria Scales

In a city, maybe there are dozens of neighborhood can be treated as the alternatives of PWC system location. For each alternative, the features can have a variety of different change. The influence of these features on identifying optimal area also can be quite different. Moreover, for different alternative, the same area features also can generate different influence on location decision. Therefore, based on the influence degree of each area features on searching optimal location, these 13 evaluating criteria will be given different scale classification in table 7.

Table 7: Scale classification of evaluating criteria

Evaluating Criteria	Classification and values			
	Scale 1	Scale 2	Scale 3	Scale 4
Population Density	0-60 people/hectare	61-90 people/hectare	Above 91 people/hectare	
Released space from underground waste container	0-average Pic/hectare	Above average pic/hectare		
Land price in terminal area	Above average Euro/square meter	0-average Euro/square meter		
Land price in community area	Above average Euro/square meter	0-average Euro/square meter		
Maximum Population amount of other connected community	0-2000 inhabitants	2001-6000 inhabitants	Above 6001 inhabitants	
Highest road conditional level around terminal building	Primary	Secondary	Tertiary	Trunk
Nearest distance from residents building to terminal building	0<D≤20 meters	20<D≤40 meters	Above 40 meters	
Town house (family house) density in community	Above average building/hectare	0-average building/hectare		
Bus stop covering rate in community	0≤R≤10%	10%<R≤20%	Above 20%	
Road level in community	Primary	Secondary	Tertiary	Trunk
Building density in community	Above average building/hectare	0-average building/hectare		
Soil type	Sand	Loamy	Peaty	Clay
Pickup trucks travel distance	0-average KM	Above average KM		

4.1.4.1 Population density

In 2011, Scheel. published a paper in which the urban cells theory is analyzed in detail, for the purpose of achieving more sustainable urban environment. According to this research, it is recommended that the inhabitants within the districts around 25,000-35,000, and with a gross population density of 60 per hectare, would be the considered as planning criteria for sustainable neighborhood.

In addition, envac group (2012) points out that the PWC system should placed into a very compact area. If the PWC system could give service to 4000 units of household with a 1 KM length serve distance pipe, this system performance will be very good.

Therefore, by using statistics from CBS, the average household size of Netherlands is 2.19 in 2013. It can be deduced that the serve population of 1 KM length PWC pipe is 8760 for the sake of very good system performance. Thus, the population density within the serve covering area of PWC system is 111.5 people per hectare.

It is to be noted that the population density of Netherlands is relatively lower than other European city, e.g. Paris and Barcelona. And for making the scales more distinct, the scales for classified the population density would be set 0-60, 61-90 and above 90 people per hectare.

4.1.4.2 Population amount of other connected community

Checking the population amount of other connected community will be treated as a criteria to evaluate the potential amount of inhabitants could participate in the PWC system for future, with the purpose of estimate the extension possibility of system.

Detailed evaluation of economy performance of Pneumatic waste collection system by Envac Group (2012) showed that the breaking point of cost effective is more than 1000 units. Moreover, if the involving amount of inhabitants between 6000 and 8000 units within 2 KM, the economy performance of this system will be very good.

Therefore, the classifications for population amount of other connected community would be settled as 0-2000, 2001-6000 and above 6000 inhabitants.

4.1.4.3 Road condition level

Based on the acquired city road data from Municipality of Eindhoven, there are four type of motor roads in Netherlands can be tell apart, Primary, Secondary, Tertiary and Trunk road.

4.1.4.4 Bus stop covering rate

In the initial phase of installing the PWC system, all inhabitants and users should willing to operate the system properly and understanding the benefits for the environment and public health, due to this system is not familiar with most of residents.

An investigate of increasing the inhabitants awareness on the new pneumatic system by Stephen B., (2004) introduced that the local authorities should run the information campaigns, broadcasting advertisements, and convene numerous neighborhood meetings during the indoctrination period.

In this model, each bus stop will be treated as a transmitting vector to spread the relevant information of PWC system. It is assumed that each bus stop could only broadcast the advertisements within a range of 75 meters. In order to better grading the alternatives, bus stop covering space occupied percentage of whole neighborhood land will be set as 0-10%, 10-20% and above 20%.

4.1.4.5 Nearest distance from residents building to central terminal building

Based on the PWC system own characteristic, there is no need to use trucks to collect household waste within community any more. All the separated waste will be transported to central terminal building by using underground pipeline. The transport trucks will be ready for transport in terminal building area. Therefore, noise influence of transportation trucks on nearby residents should be considered.

Based on the comment made by Bacou-Dalloz (2003), the noise level below 75 dB would non-hazardous for humans health. Moreover, Wakefield (2005) published a paper in which they described that the heavy trucks can generate 90dB noise during its runtime, and the average noise level will be reduced if the distance between receiver and noise maker is increase by reason of spreading of sound waves.

Trucks would be treated as a line noise source on the road during its transport the waste, thus, according to the study made by Wakefield (2005), the noise level will be reduced to 72dB if the receiver is 20 meters far from trucks, and 69 dB truck working noise will be received if the interval is doubled. Thus, in this model, the distance scale between residents and terminal building will be set as 0-20 meters, 20-40 meters, and above 40 meters.

4.1.4.6 Soil type

Hartemink and Sonneveld (2013) reported a paper which detailed analysis and discuss soil maps of the Netherlands. The types of soil normally include: peaty soil, sandy soil, marine clay, young river clay soil, old clay soil, loamy soils, and stony soils. In this research model, only four types of soil will be applied for making the classification of land, named sand soil, loamy soil, peaty soil and clay soil.

4.1.4.7 Other scale classification of evaluating criteria

For other evaluating criteria, only two scales are classified, 0-average and above average. This is mainly due to these figures from dissimilar city could be greatly different. Therefore, the middle interval point for scale classification will be expressed by average figure level of appointed city.

4.2 Geographic Information System and connections with AHP

There are four types of data are required to import into GIS map, for the purpose of generating the suitability map of installing PWC system, they are called: evaluating criteria data, city map, constraint criteria data and questionnaire survey data.

At the beginning, based on acquired city map, all the neighborhoods could be easily viewed. Then, the land use map of target city should to be scanned. Some neighborhoods will be required to be eliminated if its land use plan is not allow to install this system, it is mainly due to the initial purpose of this research that selecting optimal area to implement PWC system for collecting residual household waste.

As previous analyzed in literature review, there are also other two criteria can restrict neighborhood to become alternative locations, vacant land space and inhabitants amount within neighborhood. A certain space area is needed for constructing the central terminal building. Under the threshold of certain inhabitants amount, PWC system will hardly reach economically feasible. The neighborhoods which could not meet this two constraint criteria will also removed from alternative location map.

There are 13 sets of neighborhood features data have to be found. They can be called evaluating criteria data, it contains population density, released space from underground waste container, land price in terminal and community area, maximum population amount of other connected community, highest road conditional level around terminal building, town house density, bus stop covering rate, road level in community, building density, nearest distance from residential building to terminal building, soil type and pickup truck travel distance. After getting all these, each set of data should be categories into difference scales on the basis of preset classify rules which mentioned in Table 7. From these data, 13 layers of GIS map will be generated. Each layer reveal the distributions of criteria scales among the alternative neighborhoods.

According to the pair-wise comparison results from questionnaire survey, each criteria impact and its scales preference will be gained.

Based on literature review and previous section analysis, there are 13 evaluating criteria could influence the location of PWC system when considering environmental, economical and social aspect. Moreover, each evaluating criteria contains several scales. Therefore, in the GIS map, all these evaluating criteria will be preceding a comprehensive analysis. The equation for measuring the possibility degree is :

$$P = \sum_{i=1}^{n} S \times W_i \ . \qquad (1)$$

In the formula, n=13 (numbers of evaluating criteria), P stands for the possibility degree of each alternative land. S represents the scales preference of each criterion. W_i

Stand for the impact of each evaluating criteria. Therefore, the suitability degree of each alternative area for installing the PWC system would be generated. Finally, the optimal area would be selected from the map.

The connection framework between AHP and GIS is presented below (Figure. 7).

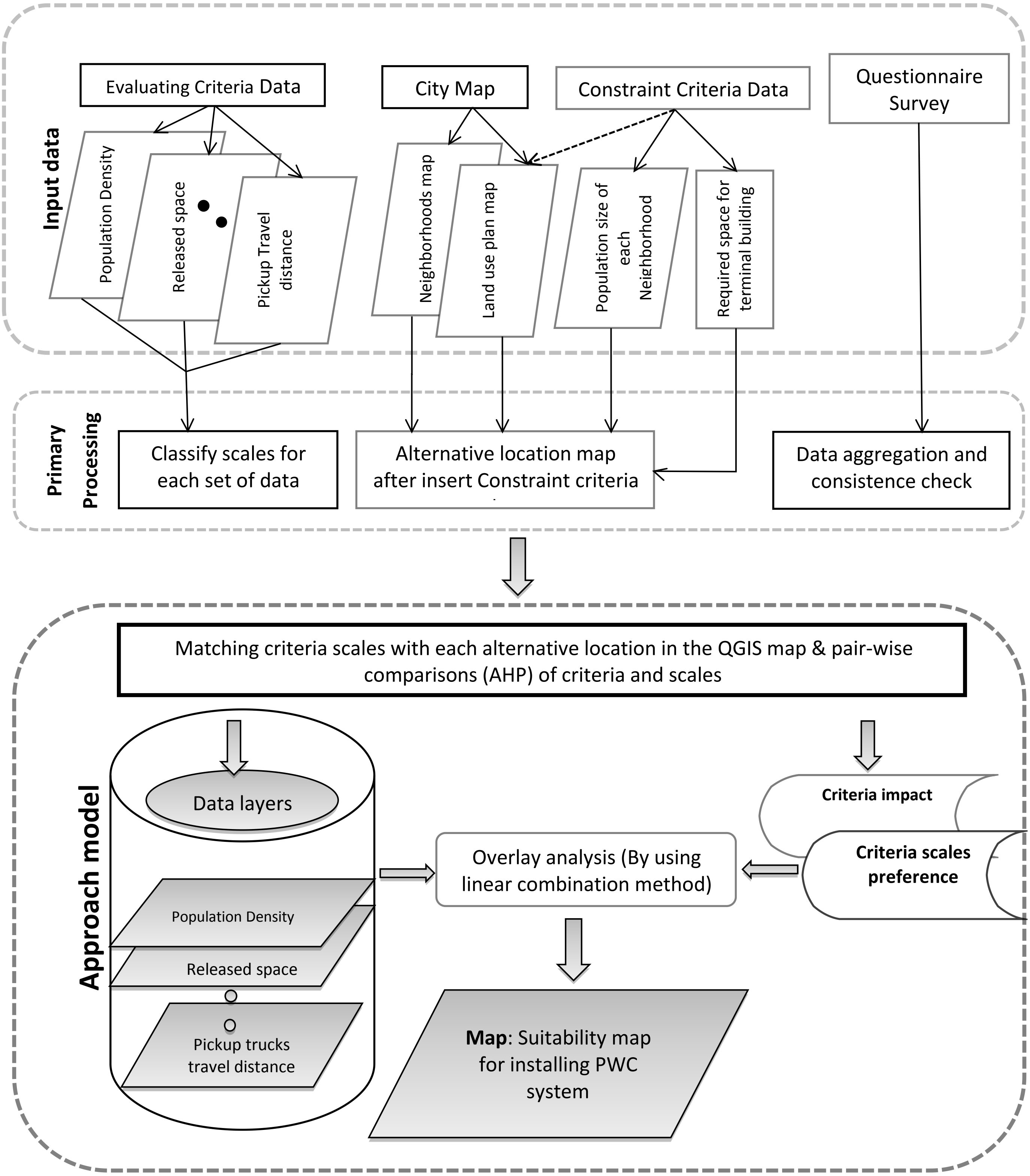


Figure 7. Flow chart of approach model

4.3 Participant Characteristics

As explained in the Literature review, there are three kind of stakeholders participate in the decision making process, Government, Investor and Service provide company.

In Netherlands, decision making in waste management is controlled by the government who develops relate policy, offering fund to involve relevant parties to perform activities with facilities and services. The PWC Company normally provides technical assistance for installing and ensuring system daily operation. These two parties decide the implementation of Pneumatic waste collection system directly. For investors, they are indirectly involved in decision making process by reason of government could replace them. Their relationships to the subject have been revealed in previous chapter (Figure 4).

In this research, expert respondents are only selected from two stakeholder groups: Government and Service Provide Company. The first group contains of experts from Municipalities. Normally, they are the decision maker in the field of municipality waste management. The second group is represented by service provide company in the field of PWC system operation.

4.4 Questionnaire Design

After constructing the AHP hierarchy, the survey questionnaire is developed for the purpose of finding the impact of each criteria and classified scales preference. The questionnaire structure is presented in Figure 8.

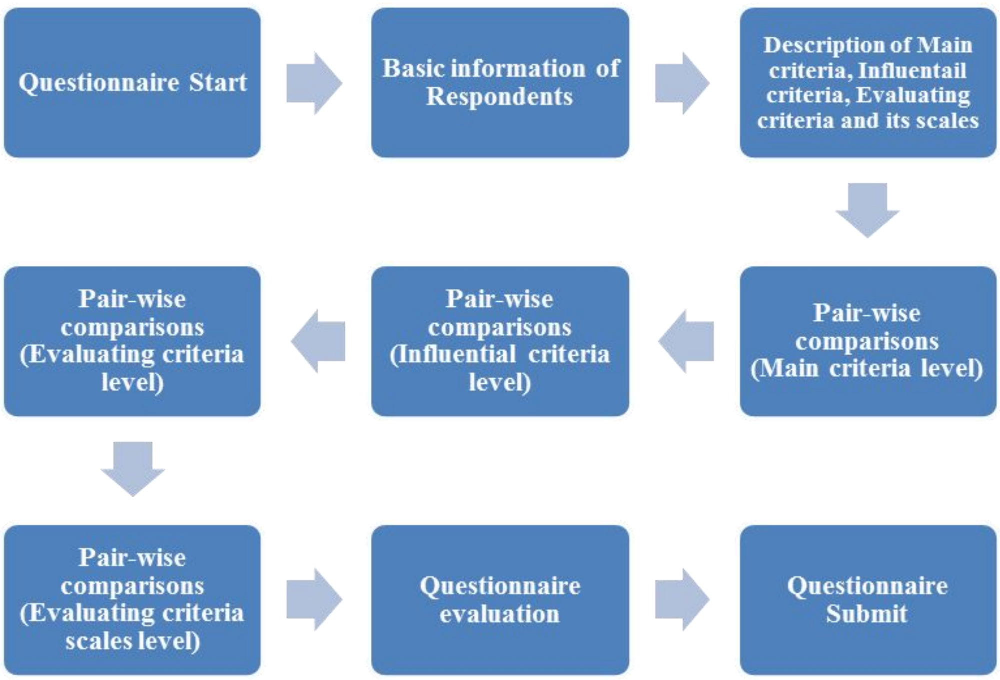


Figure 8. Design process of Questionnaire

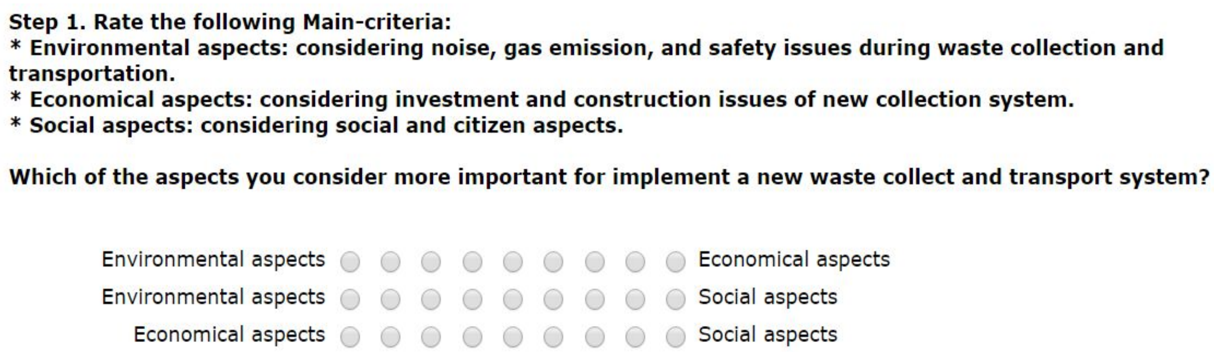
The questionnaire was formulated by using "Thesis Tools Online Surveys", an online survey support tool. The target respondents will receive an invitation Email which includes the link of questionnaire. Through click this link, the respondents will be lead to the online questionnaire. The initial part of the questionnaire includes a brief introduction of the research aim and PWC system. After respondents click the "Start" of Questionnaire, three types of question will be asked, basic information of respondents, pair-wise comparisons and Questionnaire evaluation. These questions will be discussed detailed in the following sections. Enquired sequences of these questions are revealed in Figure 8. After complete fill in all these questions, the respondents will be asked to click the "Submit Survey" button to submit the results.

4.4.1 Basic information of Respondents

This type of question with a view to obtain the position and organization information from respondents. The first question is designed to distinguish the respondents into different stakeholder group, either from local municipality or service provide company. This question includes three options, Authority, PWC System Company and Management Expert-Researcher. The respondents who selected first two options is quite easy to classify into two stakeholders group, the respondents select "authority" option belongs to Municipality stakeholders, "PWC system company" option selector pertains to service provide stakeholder, unquestionable. In this survey, the experts who used to work in PWC system company or involved in the PWC project will choose the option of "Management Expert-Researcher", these experts will also be treated as the service provide stakeholder. Then the current job position of the respondents will be asked, which could be used to investigate the different preference of respondents who serve at different positions. In last question, the name of respondents organization is inquired.

4.4.2 Pair-wise comparisons

According to the study by Saaty (1980), suggests that pair-wise comparisons among the main criteria and sub-criteria level could be used to evaluate the criteria. In Figure 9, the relative importance of each criterion is asked. Afterwards, the respondents' choice will be presented in a form of matrix.


Step 1. Rate the following Main-criteria:
*** Environmental aspects: considering noise, gas emission, and safety issues during waste collection and transportation.**
*** Economical aspects: considering investment and construction issues of new collection system.**
*** Social aspects: considering social and citizen aspects.**

Which of the aspects you consider more important for implement a new waste collect and transport system?

Environmental aspects ○ ○ ○ ○ ○ ○ ○ ○ ○ Economical aspects
Environmental aspects ○ ○ ○ ○ ○ ○ ○ ○ ○ Social aspects
Economical aspects ○ ○ ○ ○ ○ ○ ○ ○ ○ Social aspects

Figure 9: Example of Criteria pair-wise comparison

It is to be noted that the relative importance of each criteria will be evaluated by a numerical scale during the pair-wise comparison phase. Through using these pair-wise comparisons among the criteria, the highest potential features and classified scales will be identified for the purpose of installing PWC system.

In survey questionnaire, 9 points scale will be utilized, [9, 7, 5, 3, 1, 3, 5, 7, 9]. There are four levels of criteria needs to proceed the pair-wise comparisons in this survey, the comparisons in criteria level is 3 times, the comparisons in influential criteria level is 18 times, the comparisons in evaluating criteria level is 94 times based on the connections in table 6, the comparisons in classified scales level is 36 times. Therefore, the total comparison in the questionnaire would be 151 times. If listing all these comparisons in the questionnaire, it would be extremely complicated for respondents to fill in, moreover, the inconsistency of their choice will also very high.

In 2004, Dianting and Dongfang published a paper in which they described a way to reduce the comparison times through analyzing the characteristics of comparison matrix. There are three typical characteristic of comparison matrix P, $p_{ii}=1$, $p_{ji}=\frac{1}{p_{ij}}$ and $p_{ij}=\frac{p_{ik}}{p_{jk}}$ (i,j,k= 1, 2,...n). Based on these features, they points out that only one row or column value is required from comparisons, the others comparison could be derived from three mentioned formula. These formula relation matrixes are revealed in Table 8.

Table 8: Reduced comparisons matrix

P_{11}=1	**P_{12}=1/P_{21}**	.	.	.	.	**P_{1n}=1/P_{n1}**
P_{21}	**P_{22}=1**				.	**P_{2n}**
.		.			.	.
.		**$P_{i-1,j-1}$**	.		.	.
. . .		**$P_{i,j-1}$**	**$P_{i,j}$=** $\frac{p_{i,j-1}}{p_{i-1,j-1}}$	**P_{ii}=1**	. . .	. . .
.					.	.
P_{n1}	**P_{n2}**	.	.	.	.	**P_{nn}=1**

From the matrix, it is obvious that the values of upper triangular could be obtained by calculate the reciprocal of lower triangular value, and first column value of lower triangular could be used to derived other columns value. Therefore, only one column criteria comparison needs to be asked in the questionnaire.

Based on the above analysis, if use the normal pair-wise comparisons, the comparison times in evaluating criteria level would be 94. For the purpose of increasing the efficiency, the approach of reducing comparisons will be utilized in this level. Thus the comparisons in this level will be reduced to 38 times.

4.4.3 Questionnaire evaluation

In this part, the respondents will be welcomed to put forward their comments on this research and questionnaire. This can be seen as a kind of user experience feedback. Based on the comments from the respondents, the layout and way of asking questions will be adjusted accordingly, in order to let other respondents better understand the research, survey aim and making appropriate evaluates.

The inconsistent of respondents choice could be generate by using AHP approach, and in order to increase the survey response rate, respondents are asked to fill in their email address after making the comments. A complete version is attached to this report as Appendix A.

Respondents will be contacted by email or interview to reconsider the choice of pair-wise comparisons when meeting the inconsistent in questionnaire. In order to ensure the CR rate below 0.1 in the second survey, two options of pair-wise comparisons scales will be pre-settled, these comparison scales is mainly come from respondents choice in first survey, only one or two scales are changed in order to reach response consistent. Comparing with first survey choice, the scales will keep be changed as small as possible, for instance, change from moderately more important to largely more important. The respondents, only need to select the preset scales which more fits with their idea from option (a) or (b) in reconsideration survey.

4.5 Key input data for GIS（Generating GIS map）

In order to map alternative location from GIS map, the relevant data should be obtained and input into the map. From Figure 7, it is to be noted that there are two types of data needs to be inserted into GIS map: Criteria data and comparison weights from AHP model. In this section, only criteria data will be discussed, comparison weight can be gained from questionnaire survey. The criteria data that needs to be imported includes constraint criteria data and evaluating criteria. The whole neighborhoods map of Eindhoven is presented in Figure 10.

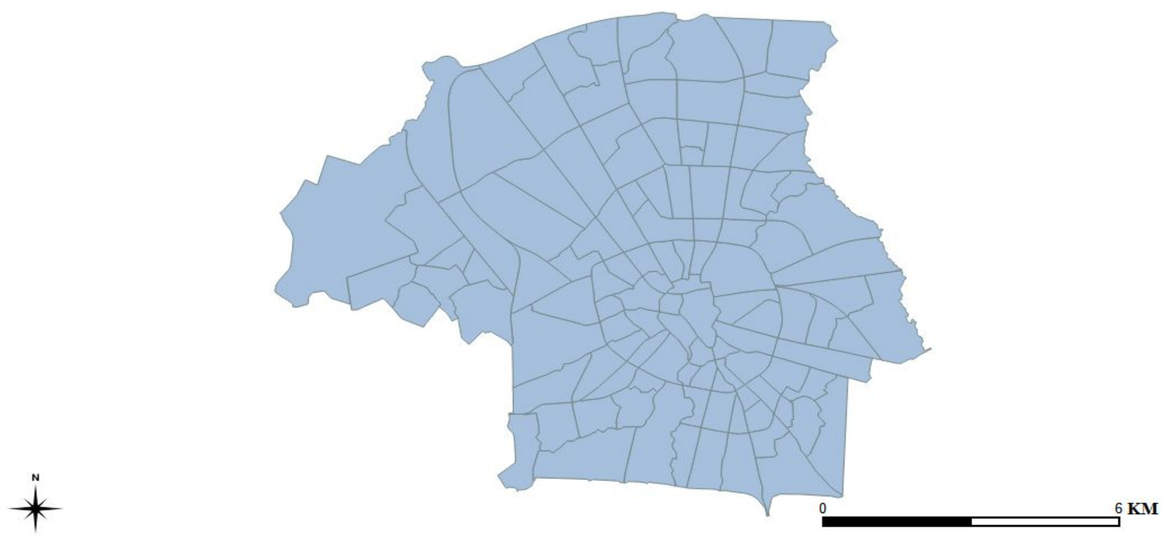


Figure 10. Neighborhoods map of Eindhoven

4.5.1 Constraint Criteria data

In the process of searching the alternative locations, there exists some factors restricted the PWC system installed in an urban area, it's called constraint criteria. As mentioned in literature review, it contains land use plan, required space for terminal building and population amount within neighborhood. These data input sequence are shown in Figure 11.

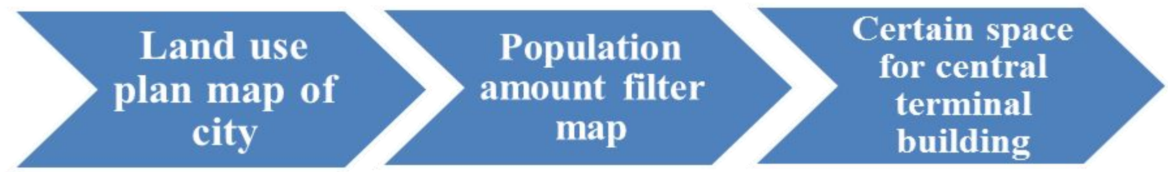


Figure 11. Input sequence of Constraint criteria data

Initially, a land use map of Eindhoven needs to be obtained. This land use map includes every different kind use of land within the city. It is to be noticed that only residential and commercial area will be investigated to install the new system in this research. Therefore, other type of land use will be eliminated from the land use map. The eliminated type of land use include, fast transit roads, airport, mineral extraction and dump site, other roads and associated land, railway and water body. These land use type either could not be used for installing the system or not fit initial purpose of collecting residential waste.

After cutting these non-relevant land use type, the remaining land use map of Eindhoven city is shown in Figure 12.

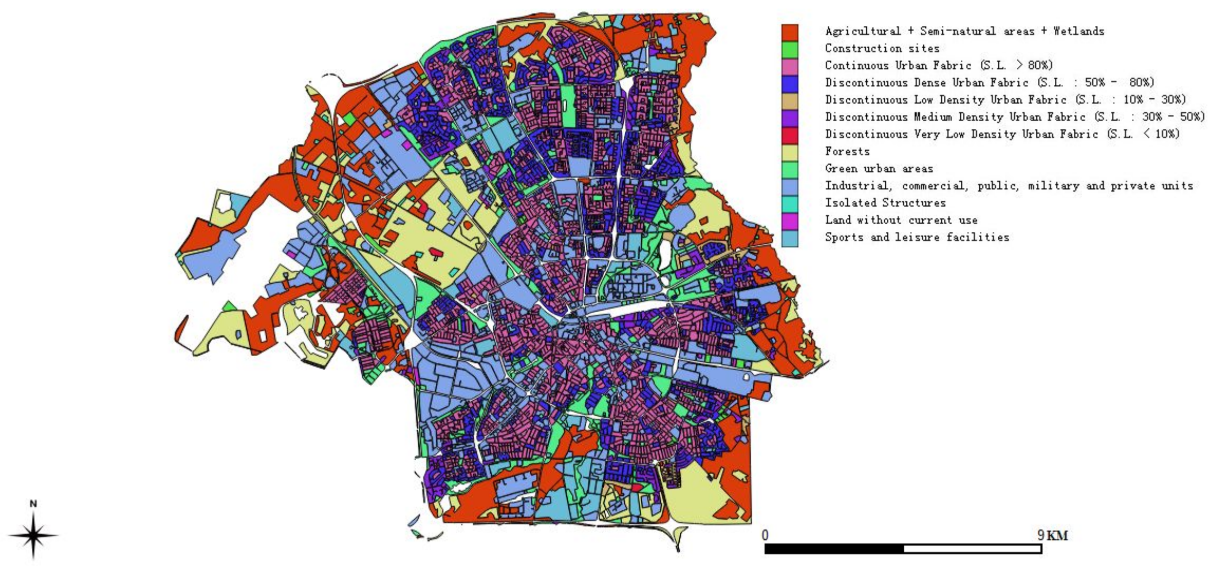


Figure 12. After cut land use map of Eindhoven

Through comparing the fig 10 and 12, it can be learned that the big missing part of city map is Eindhoven airport. After cut land use map is obtained, the population amount of each neighborhood needs to be reviewed. The population amount within the PWC system service area is the primary factor that needs to be considered during the process of alternative location identification. In 2012, Envac Group published a report in which they recommended not to install the PWC system in a area that only contains a few hundred dwellings regarding system economically feasible, if this is the first installation of the city.

Considering this PWC system would be the first time installed in city of Eindhoven, the threshold population amount to ensure economically feasible is set to 1500. Therefore, the neighborhoods map can be divided into two categories, population amount either below 1500 or above 1500. The categorized map is displayed in Figure 13.

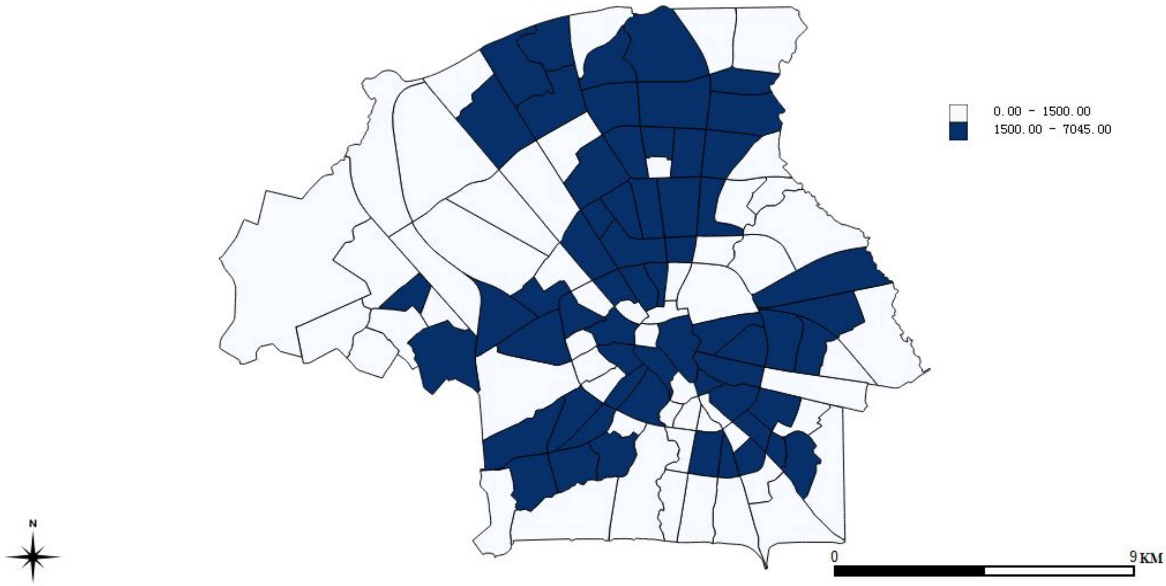


Figure 13. Categorized population map of Eindhoven.

Those neighborhoods that population amount below 1500 will be directly eliminated from the analysis map in view of system economically feasible. Thus, the alternative location (neighborhoods) map of Eindhoven city will be turned into Figure 14.

Once obtained this cut map, the available space within the neighborhood need to be further checked for the purpose of installing the central terminal building. As previous discussed in literature (Table 6), if PWC system aims to involve more than 3000 inhabitants and includes three fractions, the minimum area size for central terminal building should be 180 m2. Therefore, all the remaining neighborhood in Figure 14 should be viewed the land use map again, for the purpose of finding available space to construct central terminal building. In the land use map, it is assumed that only six types of land use could be transformed into public use in order to install terminal building, these six types land include, agricultural, forests, green urban areas, land without current use, public use, sports and leisure facilities area. Merging these six types land use map with Figure 14 map, the available space of each alternative areas map could be generated. It is revealed in Figure 15.

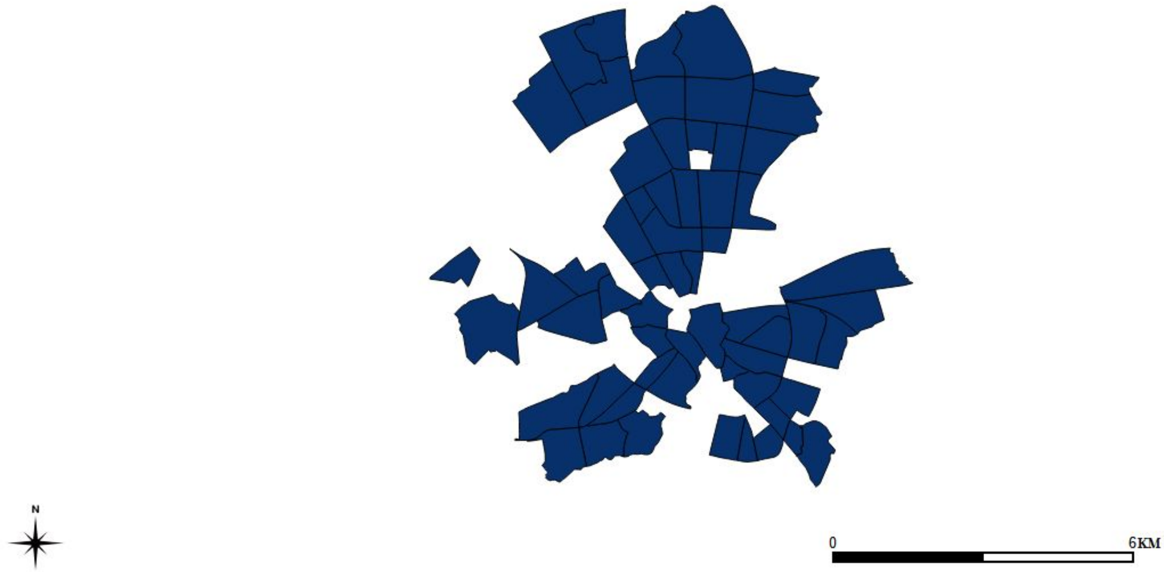


Figure 14. Map of population amount above 1500

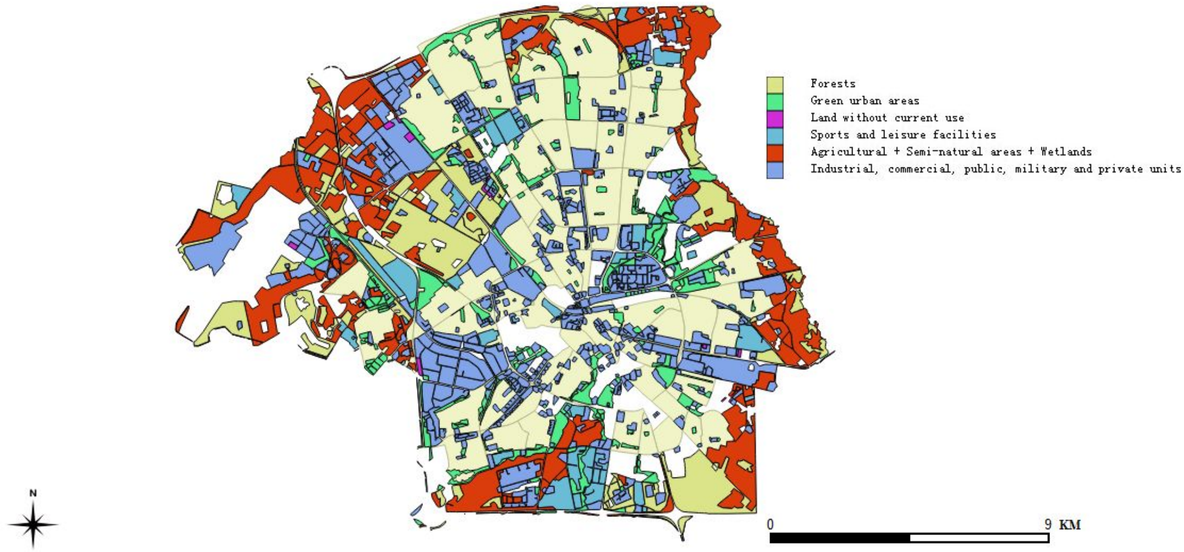


Figure 15. Available space of each neighborhoods

From the map, it can be seen clearly that only two alternative land without proper space to provide to construct terminal building. The name of this two alternative neighborhoods are, 'Rochusbuurt' and 'Eliasterrein en vonderkwartier'. Therefore, the alternative area map of Eindhoven city will eventually become as shown in Figure 16.

Based on these pre-selected alternative areas, all the evaluating criteria data needs to be imported into the GIS map, and match with these areas. These data will be explained details in next section.

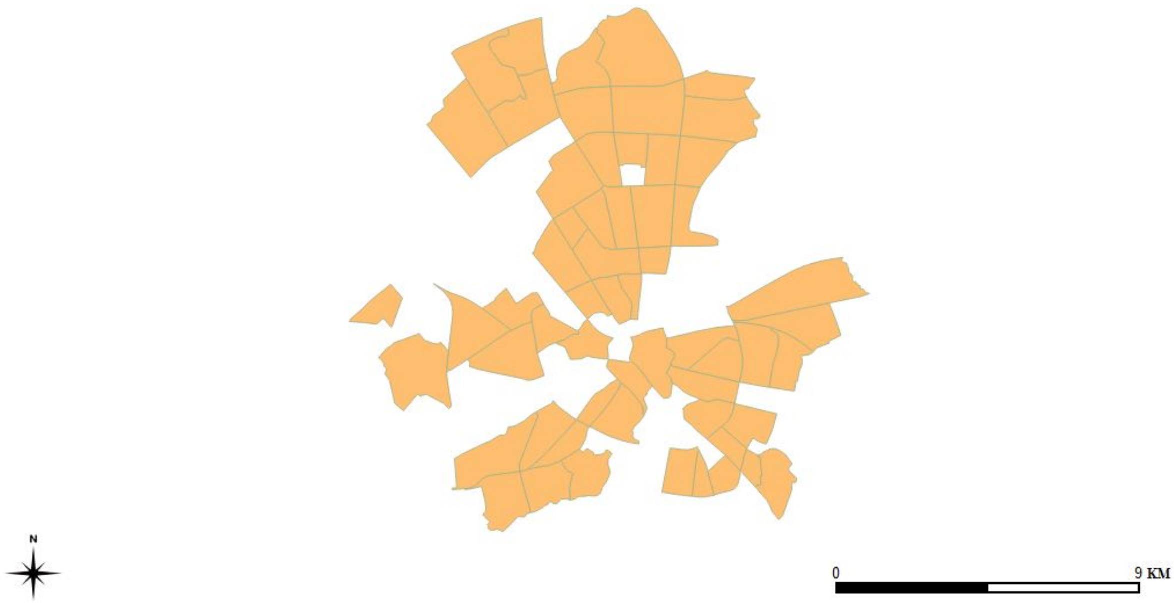


Figure 16. Alternative map after insert Constraint criteria

4.5.2 Evaluating criteria data

Based on the approach framework shown in Figure 7, total 13 kinds of data needs to be obtained and imported into GIS model, normally these data could be divided into two groups, one could be directly download from web site of local municipality, province or CBS, it includes, land price in terminal and community area, maximum population amount of other connected community, highest road conditional level around terminal building, nearest distance from residents building to terminal building, and soil type. The other group should be derived by using other existing data, because there is no available data, it includes, population density, released space from underground waste container, No. of town house density in community, bus stop covering rate, road level in community, building density, and pick up travel distance.

For database that directly obtained from web site, there are some points need to be explained. In Centraal Planbureau web site, they provided a land price map of Eindhoven city which is attached to this thesis as Appendix B. It can be seen clearly from the map that land price in Eindhoven city is divided into several ranges, and the highest land price is in the centre, north, south, and west part of city. These lands price is in the range of 250 to 500 euro per m2. Based on the scales classify setting in table 7, the land use map should be divided into two categories, either price blow or above the average level of city. It is to be noted that the average land price could not be obtained only by using this price range map, and for easier classifying each neighborhood land price, the average land price in this research is set 250 euro per m2.

The data of maximum population amount of other connected community could be easily searched out from QGIS map by checking the property table.

According to the suggestions made by experts from CentralNed BV during the interview, the central terminal building should avoid to construct in central part of community, and the level of motor roads should as high as possible for the sake of easier transport of waste trucks. Therefore, the potential location of central terminal building within the neighborhoods could be mapped out by using the map which has shown in Figure 16. Then, the data of nearest distance from residents building to terminal building can be obtained by using distance measuring tools of QGIS software. Another set of data which called highest road conditional level around terminal building, also could be obtained from road condition map of Eindhoven city by using Mapinfo. In accordance with soil type map published by Ministry of Agriculture, Nature and Food Quality, the soil type of each neighborhood could be easily identified.

For the data that obtained indirectly will be explained in below.

Population density, released space from underground waste container, building density, and town house density within the neighborhoods, all can be gained by using one sets of data divide by another sets of data, both of this two data are easy to get. Their relations are expressed in table 9.

Table 9. Relationship table of acquiring unknown data

Unknown Data	Needed data (one)	Needed data(two)	Relationship
Population Density	Population amount	Neighborhood area size	$Unknown\_data = \frac{Needed\_data(one)}{Needed\_data(two)}$
Building Density	Dwellings amount	Neighborhood area size	
Town House Density	Town house amount	Neighborhood area size	
Released Space from underground Waste Container	Underground waste container amount	Neighborhood area size	

From table 9, it is observed that there are five different sets of data needs to be found in order to get the unknown data, these five sets data consists of population amount, dwellings amount, and town house amount, which can be found from data bank of municipality, and city map.

It should be pointed out that commercial waste container amount could not be searched by municipality or government data bank, due to these waste are collected by private collector. Therefore, commercial waste container amount needs to be estimated. In 2008, Lenthe carried out a research, which investigated the relationship between commercial waste amount and commercial buildings area. It is found that commercial building could generate 150KG residual waste and 200KG cardboard / paper waste per square meter per year. In this research, it is assumed that all the commercial building use the same capacity containers (6 cubic yard) to storage the waste, and shipped away every week. Therefore the amount of commercial waste container could be derived. For the household underground waste container, it can be easier obtained from web site and points map of Eindhoven.

In previous section, the bus stop covering rate has already detailed discussed. It is assumed that each bus stop could only broadcast the advertisements within a range of 75 meters. Therefore, based on the formula of circle area, $S = \pi r^2$, one bus stop covering space is 176.72 hectare. The covering rate of whole bus stop within the neighborhood could calculated based on the formula: $Cr = \frac{Cs_1 \times A}{Nas}$, Cr means total bus stop covering rate, Cs_1 stands for one single bus stop covering rate, A means total bus stop amounts within neighborhood, Nas stands for neighborhood area size. Bus stop amount data can be found from bus stop map of Eindhoven by using QGIS. Neighborhood area size can be downloaded from data bank of Eindhoven municipality.

In Netherlands, municipality normally uses four levels to define the motor roads condition, Primary, Secondary, Tertiary and Trunk. In order to gain the average degree of roads within the neighborhood, the whole road network of city of Eindhvoen needs to be found and imported into mapinfo. Therefore, total distance of each road degree could be worked out. The formula for calculating the average road level can be expressed as:

$$Arl = \frac{L_P \times D_P + L_S \times D_S + L_T \times D_T + L_{TK} \times D_{TK}}{(D_P + D_S + D_T + D_{TK})} \tag{2}$$

Arl means average road level within the neighborhood, $L_P, L_{S,} L_T, L_{TK}$ stands for corresponding values of each road condition level, L_P means the value of primary road, it equals to 1. L_S Means the value of secondary road, it equals 2. L_T Means the value of tertiary road, it equals to 3. L_{TK} Means the value of trunk road, it equals to 4. D_P, D_S, D_T, D_{TK} Stands for the road distance of each degree. Hence, the average road level within the neighborhood will be deduced.

Due to there is no available data of traveling distance of pickup trucks, it should be deduced from other existing data sets. In 2009, Larsen and her co-workers published a paper in which they detailed describe the connections between diesel consumption and residual household waste collection, they points out that it will cost 3.1 liters of diesel while collecting one tonne of residual household waste within the city Centre. However, consumption will decreased to 1.6 liters if the wastes are collected from apartment building outside city Centre. Highest diesel consumption would be the refuse that generated from single-family houses in urban areas, it will consume 3.3 liters diesel for only collecting one tonne waste. Therefore, the pickup trucks travel distance could be measured by using the formula below:

$$TD = \frac{Pa \times f \times Dc}{Dc_{100}} \quad (3)$$

TD stands for pickup trucks travel distance within the neighborhood. Pa means the population amount within neighborhood, f stands for the average waste amount generated per person per week, Dc means diesel consumed per tonne of waste collected. Dc_{100} Stands for the diesel consumed per 100 km of pickup truck traveled. In Netherlands, MSW generation per people per day in 2010 is 1.63KG (Leonidas, 2013). Thus, the value of f is 11.41 kg per week. Based on the research that investigated by Sandhu et al (2014), the diesel consumption of side load waste trucks is 89 liters per 100 km. Thus, pickup trucks travel distance will be elicited.

After obtaining all the evaluating criteria data, the missing threshold value for some sets of data could be worked out. The average released space from underground container would be 0.51 pic/hectare, the mean value of town house and building density within city of Eindhoven are 17 and 25.6 dwellings/hectare respectively, the average distance of pickup trucks travels is 153.06 km. Obtaining all these figures and data, an entire data table will be generated and ready for import to GIS map. In addition to this, each set of data should be classified on the basis of the scales pre-set in table 7. The formulated scales table for inserting GIS map is presented in Appendix C.

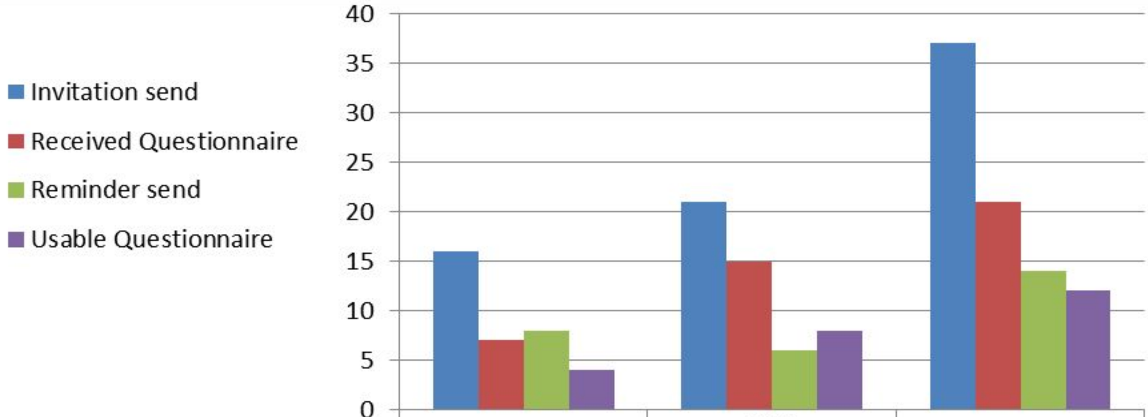
4.6 Results Analysis

In this section, the results of research project will be analyzed. First, survey respondent's rate will be described. AHP analysis delivers the criteria impacts and classified scales preference, after consistency rate check. Finally, respondent's evaluation on implementation location of PWC system will be presented in a suitability map.

4.6.1 Survey response rate

According to the previous explain, survey respondents are selected from two stakeholder group: municipality, PWC Company. In PWC company group, it contains the experts or researcher currently or previously works in correlative fields of PWC system. These experts are asked to fill in the survey questionnaire by using the link in Email. In the following paragraph, the survey response rates will be presented on the basis of different group.

All selected respondents will receive an invitation email, which contains the research aim and link to the questionnaire. Based on the filled questionnaire, experts who did not fill in will be filtered. Then a reminder will be sent in case the invitation email was not noticed or overwritten. In accordance with questionnaire design section revealed, there are dozens of pair-wise comparisons; some experts will be reached again to reconsider their choice for the purpose of decreasing the inconsistency rate. Questionnaire will be identified as unusable if the respondents did not complete the overall pair-wise comparisons. The results of usable questionnaire will be proceeded to compute criteria impact and scales preference. The response rates could be viewed via Figure 17.



	Municipality	PWC company	Total
Invitation send	16	21	37
Received Questionnaire	7	15	21
Reminder send	8	6	14
Usable Questionnaire	4	8	12

Figure 17. Number of reached respondents.

In the survey, total 16 decision makes from local municipality and province are connected, only 7 of them used the link to open the questionnaire, one respondents replied that he would not able to fill out survey due to transferred to another department. Half of the group experts received a reminder. In the end, total 4 (25%) of questionnaires filled by municipalities decision makers are usable.

In PWC company group, 21 experts at system installation, management and maintenance field were reached to fill in the questionnaire. Six reminders were sent. The invitation resulted in 15 (71%) experts filled in, and 8(38%) of them are usable to carry out pair-wise comparison.

To sum up, total 37 experts from both municipalities and PWC Company are reached. The survey turns out to be 12 (32%) usable questionnaire for further analysis. These 12 sets of questionnaire survey results is attached as Appendix D

4.6.2 Consistency rate of pair-wise comparisons

All received pair-wise comparison data will be preceding to consistency rate check by using an predefined Microsoft Excel sheet.

As explained in questionnaire design part, the respondents will be asked to reconsider the pair-wise comparisons if survey results meet inconsistency. There is no consistency check in evaluating criteria level due to the number of pair-wise comparisons among them are reduced. After obtaining the feedback from respondents, there are total 12 questionnaires meet the consistency check requirement. The overall rates of respondents' consistency are presented in below (Figure 18)

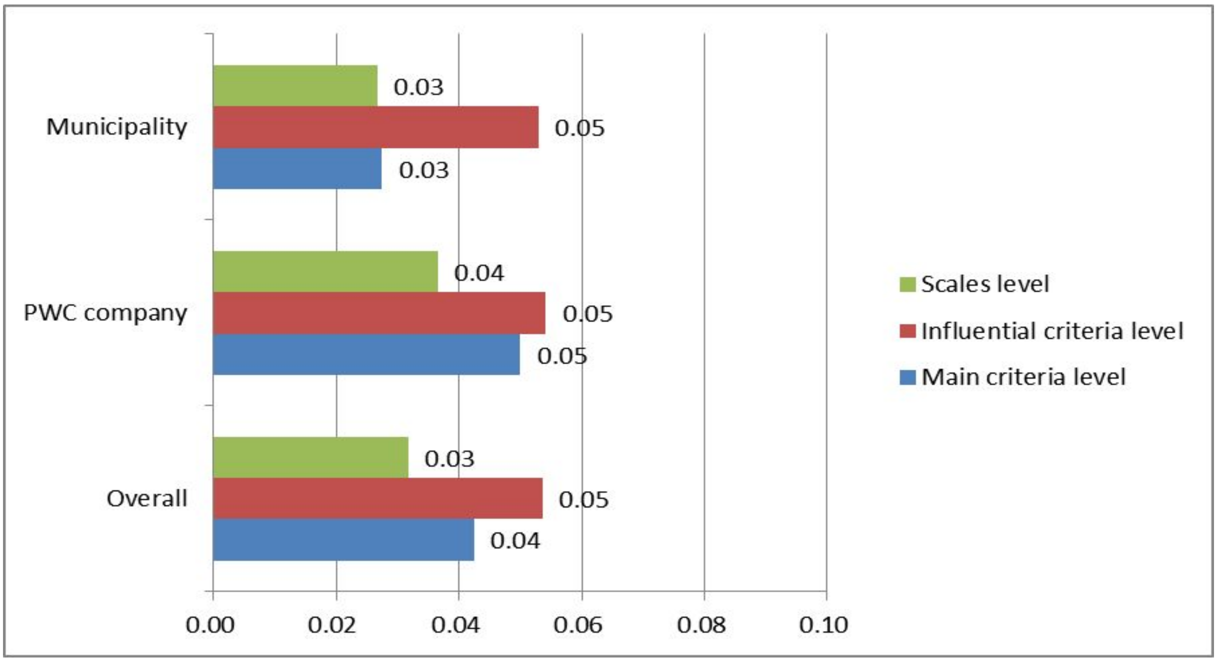


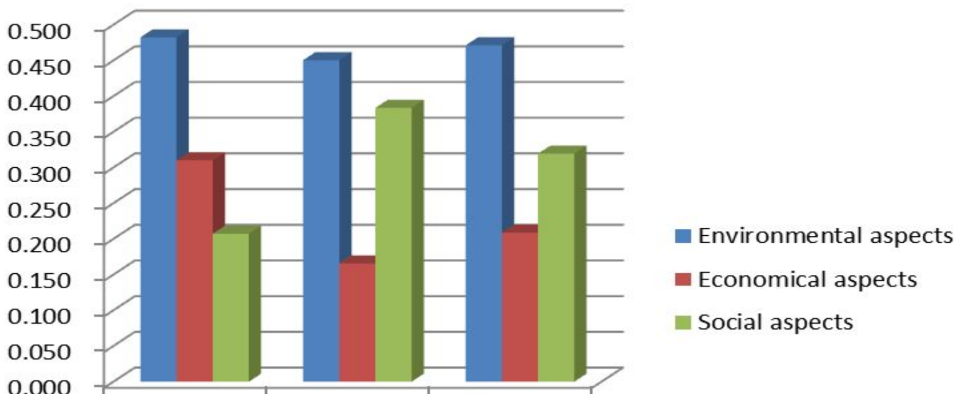
Figure 18. Consistency check for each group

From the figure, it can be known that the consistency rate of scales level is relatively low in two stakeholder groups. This is mainly due to most of the scale only need minimum three or maximum six times pair wise comparison, the respondent's preference could be easily emerged. The consistency rate of influential criteria level is higher than other two levels, it can be expressed that total 12 influential criteria were carried out pair-wise comparison in this level, some impacts of criteria is difficult to choose. Information from this figure need to be aware is that the overall consistency rate in stakeholder group of Municipalities is lower that PWC company group, this maybe because many respondents from PWC Company have involved other different considerations into account during the survey.

4.6.3 Criteria impacts and scales preference

From AHP data manipulate sheets, each criteria impacts and scale preference of two stakeholder groups can be gained. First, criteria impact based on different group will be analyzed, followed by scales preference discussion.

As detailed explained in questionnaire design section, the first step of pair-wise comparison is to identify the impact of criteria in main criteria level. In Figure 19, the impacts of three criteria from municipality are presented. This column chart shows the weights of each main criterion. For decision maker from municipalities, 'Environment aspects' is considered as the most important criterion, which occupies 0.483, 'Economical aspects' as the second criterion (0.310), the lowest influence of criteria is 'Social aspects', which only accounts for 0.207.



	Municipality	PWC company	Overall
Environmental aspects	0.483	0.450	0.471
Economical aspects	0.310	0.166	0.209
Social aspects	0.207	0.384	0.320

Figure 19. Criteria impact of Municipality group

In PWC company group, the result is a little different from municipality group. 'Environment aspects' still keep its top position, but it weights reduced to 0.405. 'Social aspects' is considered as the second important aspects followed by 'Social aspects' (0.166). This is mainly because the PWC company need to consider the involvement of residents, for the purpose of ensuring high system performance and easy maintenance.

By using geometric mean to organize all the respondents result of pair-wise comparisons, it can be found that 'Environmental aspects' still remaining the most important criterion in consideration of implement new waste collection system. 'Social aspects' is ranked second with a weight of 0.320. The lowest priority is given to 'Economical aspects' (0.32).

In the next phase of questionnaire, the pair-wise comparison among influential criteria is asked. Each aspect of main criteria could be divided into four sub criteria, which already explained in literature review part. Through sheet analysis, each influential criteria impacts on decision making is revealed detail in table below (table 10).

The main criteria of Environmental aspects could be divided into four influential criteria: minimum gas emission on environment, minimum noise influence on environment, accessibility of trucks around terminal building, and improving the safety in community. As shown in table 10, 'improving the safety in community' is deemed most important by both stakeholder group. 'Ensuring the truck accessibility' is considered as the second important criterion for municipalities group, followed by 'minimum gas emission', the lowest priority is gained by 'minimum noise'. In respect of PWC company group, there is little priority value difference among rest three criteria, the order is 'minimum noise', 'minimum gas emission' and 'truck accessibility'. After synthesis the results of both group, it prefers 'improving safety' as the most important criterion. 'Minimum noise' is considered the second important criterion followed by 'truck accessibility', 'minimum gas emission' is considered as the last criterion.

Table 10. Impacts of Influential Criteria

Main Criteria	Influential criteria	Weights from Municipalities	Weights from PWC company	Synthesis weights
Environmental aspects	Minimum Gas emissions influence on Environment	0.082	0.081	0.084
	Minimum Noise influence on Environment	0.077	0.095	0.092
	Accessibility of trucks in terminal building	0.110	0.073	0.086
	Improving the safety in community	0.236	0.189	0.210
Economical aspects	Decreasing the payback period	0.060	0.043	0.050
	Controlling Initial investment cost	0.142	0.046	0.069
	High possibility of extension the system	0.058	0.058	0.060
	Easier construction	0.031	0.028	0.030
Social aspects	Improving the district aesthetics	0.042	0.077	0.065
	Reducing the traffic congestion	0.057	0.141	0.107
	Increasing residents sorting activities	0.056	0.085	0.076
	Increasing awareness of residents	0.049	0.082	0.071

The economic aspects include four sub-criteria, which can be view from table 10. The municipalities stakeholders group considers controlling 'initial investment costs' as the most important criteria, the reason for this matter is that municipalities is the main sponsor and investor of PWC project in most of time. 'Decreasing the payback period' and 'possibility of extension the system' are considered almost equally important, 'easier construction' as lowest priority.

The stakeholder group of PWC company prefers 'possibility of extend the system' above the other criteria. Because of the roles that PWC company played in project, they often provides technical support to project, e.g. Operation and maintenance, if involving more end users into the system, the system will be more economically feasible and better performance. A difference between impact of 'decreasing the payback period' and 'controlling initial investment cost' is very little. This situation can easily occur for PWC company group. In most projects, PWC Company not involves in the process of economic analysis, it may cause the lack of understanding of criteria. The lowest priority is given to 'easier construction'. In general, 'controlling initial investment cost' is seen as the most important criterion, with 'high possibility of extension the system' coming second and decreasing the payback period third, 'easier construction' is deem to lowest priority.

In social aspects, respondents of municipalities group consider 'reducing the traffic congestion' and 'increasing residents sorting activities' as the first two criteria. 'Increasing awareness of residents' and 'improving the district aesthetics' took third and fourth important criteria respectively. In the view of respondents from PWC Company, 'reducing the traffic congestion' is seen as more important than other criteria. 'Increasing residents sorting activities' and 'awareness of residents' are ranked second and third respectively. The lowest priority is given to the criterion of 'improving the district aesthetics'. In short, reducing the 'traffic congestion' is deemed the most important criteria, increasing residents sorting activities and awareness are being considered second and third important criteria in the process of new waste collection system implementation. The minimum impact of criteria comes from 'improving the district aesthetics'.

Based on the question asked order which shown in Figure 8. The pair-wise comparison of questionnaire will be proceed to evaluating criteria level after complete in influential level. The connections between these two levels can be viewed by table 6. Evaluating criteria level contains 13 sub-criteria. Different impacts of each criterion are visualized in table 11.

As a succession level, evaluating criteria level needs to translate the influential criteria to correspond locations based on the connection table. Among these 13 criteria, 'population density' is ranked as most important criteria by both stakeholder group, then followed by 'road level in community'. 'Highest road conditional level around terminal building' is ranked third by municipalities group, while 'pickup trucks travel distance' is considered as third important criteria by PWC company group. 'Land price in community area' is seen as the least impacts criteria by both groups. After synthesis two group results, it is found that 'population density', 'road level in community' and 'pickup trucks travel distance' are considered as the top three important criteria.

After obtaining the impacts of each evaluating criteria, their scales also needs to proceed pair-wise comparison in order to investigate the preference of respondents. Scales of each evaluating criteria were detailed explained and list out by table 7.

Table 11. Impacts of evaluating criteria

Evaluating criteria	Weights from Municipalities	Weights from PWC company	Synthesis weights
Population Density	0.276	0.269	0.269
Released space from underground waste container	0.042	0.048	0.048
Land price in terminal area	0.040	0.017	0.017
Land price in community area	0.026	0.011	0.011
Maximum Population amount of other connected community	0.050	0.053	0.053
Highest road conditional level around terminal building	0.093	0.086	0.086
Nearest distance from residents building to terminal building	0.043	0.058	0.058
Town house (family house) density in community	0.040	0.046	0.046
Bus stop covering rate in community	0.067	0.055	0.055
Road level in community	0.120	0.125	0.125
Building density in community	0.074	0.066	0.066
Soil type	0.041	0.040	0.040
Pickup trucks travel distance	0.089	0.124	0.124

The scales preference of two stakeholder group is list out by table 12. The criteria of 'population density' is divided in three further scales, 'scale 3 (population density above 90 people per hectare)' is most preferred by both municipalities and PWC company group, followed by 'scale 2 (population density between 60 and 90 people per hectare)'. 'Scale 1(population density below 60 people per hectare)' has the lowest preference. After synthesis the results of two groups, the preference order of scales remain unchanged.

The orders of scales preference of 'released space from underground waste container' are kept the same by both group, both group prefer 'scale 2 (released space that above 0.51 pic per hectare)' to 'scale 1 (released space below 0.51 pic per hectare)'.

Under the criteria of 'land price in terminal area', there are two different scales, 'below 250 euro/m2' and 'above 250 euro/m2'. The scale of 'below 250 euro/m2' is most favorite by municipalities group. Differences in preference rate of these two scale are very low in PWC company group, 'above 250 euro/m2' (0.009) against 'below 250 euro/m2'(0.008). After synthesis both groups results, 'below 250 euro/m2' is considered more preferred compared to 'above 250 euro/m2'.

The scale preference order of criteria of 'land price in community' keeps same in both group, they consider 'above 250 euro/m2' is much better than 'below 250 euro/m2'.

Table 12. Preference of evaluating criteria scales

Evaluating criteria	Scales	Preference from Municipalities	Preference from PWC company	Synthesis
Population density	Scale 1: 0-60	0.055	0.048	0.037
	Scale 2: 61-90	0.069	0.109	0.070
	Scale 3: 90+	0.149	0.258	0.161
Released space from underground waste container	Scale 1: 0-0.51	0.011	0.024	0.014
	Scale 2: above 0.51	0.031	0.063	0.037
Land price in terminal area	Scale 2: below 250 euro/m2	0.032	0.008	0.010
	Scale 1: above 250 euro/m2	0.010	0.009	0.007
Land price in community	Scale 2: below 250 euro/m2	0.010	0.003	0.004
	Scale 1: above 250 euro/m2	0.014	0.009	0.008
Population amount of other connected community	Scale 1: 0-2000	0.009	0.013	0.009
	Scale 2: 2001-6000	0.017	0.038	0.022
	Scale 3: 6000+	0.024	0.033	0.022
Road condition level around terminal building	Scale 1: Primary	0.021	0.015	0.013
	Scale 2: Secondary	0.021	0.026	0.018
	Scale 3: Tertiary	0.020	0.033	0.021
	Scale 4: Trunk	0.029	0.052	0.032
No.of town house density in community	Scale 2: below 17 d/ha	0.013	0.044	0.022
	Scale 1: above 17 d /ha	0.031	0.066	0.038
No. of bus stop in community	Scale 1: 0-10%	0.007	0.017	0.010
	Scale 2: 10-20%	0.015	0.038	0.021
	Scale 3: 20+%	0.017	0.028	0.018
Road conditional level in community	Scale 1: Primary	0.027	0.039	0.026
	Scale 2: Secondary	0.019	0.021	0.015
	Scale 3: Tertiary	0.011	0.014	0.010
	Scale 4: Trunk	0.010	0.008	0.007
Building density	Scale 2: below 25.6 d/ha	0.055	0.085	0.055
	Scale 1: above 25.6 d/ha	0.073	0.110	0.072
Nearest distance from terminal building to residents building	Scale 1: 0-20m	0.010	0.012	0.009
	Scale 2: 20-40m	0.023	0.029	0.020
	Scale 3: 40+	0.035	0.055	0.035
Soil type	Scale 1: sand	0.017	0.013	0.011
	Scale 2: Loamy	0.007	0.013	0.008
	Scale 3: Peaty	0.005	0.010	0.006
	Scale 4: Clay	0.013	0.020	0.013
Pickup trucks travel distance in community	Scale 1:below153.06 KM	0.034	0.120	0.059
	Scale 2: above 153.06 KM	0.056	0.098	0.061

The criterion of ‘population amount of other connected community’ contains three scales. The municipalities group most prefer population amount ‘above 6000’, prioritizing population amount ‘between 2001 and 6000’ above ‘amount below 2000’. The rank for first and second is opposite for PWC company group, they consider population amount ‘between 2001 and 6000’ is most appropriate.

The criteria of ‘road condition level around terminal building’ consists four scales, the preference degree of municipalities group didn’t show a good discrimination, ‘Trunk’ road around terminal building is relatively higher that other three road types. But it’s different with PWC company group; ‘Trunk’ is the most preferred road type followed by ‘Tertiary’, ‘Secondary’ and ‘Primary’ are considered as third and last preference road type. After integrated both group preference, the order keeps same with PWC company group.

Two scales are compared under the criteria of ‘town house density in community’, either ‘above 17 dwellings/hectare’ or ‘below 17 dwellings/hectare’. Both groups prefer the neighborhood which town house density ‘above 17 dwellings/hectare’ to install PWC system.

In table 12, three scales of bus stop covering rate within the community are described. Even through the degree of scales preference between first two are very low in municipalities group, its still can be seen that they group consider more bus stop covering rate is better. The preference degree of moderate bus stop covering rate by PWC company group is slightly higher compared to covering rate ‘above 20%’, covering rate ‘below 10%’ is considered as last preferred scale.

For ‘road conditional level in community’, both groups have same preference to rank the scales. They believe that the lower degree of road level within the community have the higher need to install the new waste collection system.

These two groups has a different preference on scales of ‘building density’. Municipalities group consider the area which building density ‘above 25.6 dwellings/hectare’ is more appropriate for installing new system. However, in PWC company group’s opinion ‘below 25.6 dwellings/hectare’ is more proper.

Considering the ‘Nearest distance from terminal building to residents building’, both groups prefer the distance between terminal and residents building as far as possible.

With regard to the criteria of ‘soil type’, the municipalities group prefer ‘sand’ as the most proper soil type, which followed by ‘clay’ soil’. ‘loamy’ and ‘peaty’ soil has the third and last preference order. However, comparative group consider ‘clay’ soil as the most appropriate soil type for installing new system. This group also believes ‘sand’ and ‘loamy’ soil can generate the same influence on system installation. ‘peaty’ soil is considered as last preferred scale.

According to the analysis results shown in table 12, municipalities group prefer the area that waste pickup distance used to 'above 153.06 KM'. Nevertheless, the PWC company group rate the preference level of 'below 126.4 KM' over 'above 153.06 KM'.

Based on the analysis mentioned above, it can be known that most order of scales preference keeps same between municipalities and PWC company group, due to they have the same concerns on these evaluating criteria. However, there are some scales of criteria ranked different by this two group, such as: 'land price in terminal building', 'population amount of other connected community', 'road conditional level in community', 'no. of bus stop covering rate', 'pickup trucks travel distance'. The reasons for these differences arise will be explained below.

As the main sponsor and investor, municipalities will have more considerations on the economic aspects, for the purpose of controlling the project budget and increasing acceptance rate. Thus, during the phase of searching the potential locations, municipalities will select the area with the lowest land price to construct terminal building. Even through in most project, municipality have the ownership of the land, they also need to consider the economic profit of land in the future. For instance, the land with higher price could be developed as commercial area in future, not merely a public use function. In contrast, the PWC Company will only consider the technical feasible of the land. They may not have the fully understanding of the criteria and its further influence, because the differences between the scales are very little. The lack of difference also happened in the scales of 'road condition level in terminal building' and 'bus stop covering rate' criteria in municipalities group.

On the side of the municipalities, the system should involve residents into the system as many as possible, if considering extending the system. However, for PWC Company, they need to consider the daily waste handling capacity of system. Therefore, the scales difference generated in the criterion of 'population amount of other connected community'.

The municipalities stakeholder group considers travel distance of pickup trucks by traditional underground container should be reduced as much as possible, in order to increase the community safety, to reduce waste trucks gas emission and road congestion. For PWC company stakeholder group, they need to put more considerations on system performance. It is to be noted that the maximum transport distance of the vacuum pipeline is 2 KM. Hence, the PWC Company should make sure the longest transport distance should not exceed.

In this section, the analysis results of criteria impact and their scales preference is presented. The selection differences of each group are detailed discussed. From the discuss result, it can be drawn that each groups considerations could be expressed accurately by using questionnaire survey, and these figures could be used to carry out GIS map analysis further. Next sections, the respondents preference will be generated via QGIS map, and finally produce the land suitability map of Eindhoven city.

4.6.5 Generated GIS map (Preference marked via GIS)

As explained in Figure 7, three types of data that obtained from previous step will be integrated together for the purpose of generating the suitability map of Eindhoven. These three types data contains, alternative location map, classified scales data of each evaluating criteria, criteria impacts and scales preference. Initially, the classified scales data will be imported into each evaluating criteria map. Then, 13 scales distribution layer will be generated by QGIS map.

It is to be noted that the preference rates shown in table 12 are coming from criteria impact times its scales preference. Therefore, according to formula 1, it's only need to overlay all the evaluating criteria layers and conducting repeated addition that the city's suitability map of installing PWC system will be gained.

It is to be noted that total 12 sets of usable questionnaire data are collected during the questionnaire survey, eight of them are filled out by experts from PWC company, the rest questionnaires are filled out by municipalities experts. For the purpose of generating neighborhoods suitability map of Eindhoven, scales preference of both groups will be synthesized. These synthesis scales preference rate will be embedded into 13 evaluating criteria layers. These layers are presented in Appendix E. Finally, the land suitability map of Eindhoven city will be generated via overlay these 13 layers.

The land suitability map of Eindhoven city is shown in Figure 30. In the neighborhood map, the deeper color of the area, the higher weights it obtained. Therefore, it can be concluded from map that the neighborhood with name 'Kerstroosplein' has the highest potential to be developed to install PWC system, followed by 'Kruidenbuurt' and 'Generalenbuurt'.

In order to analysis the contributing factors of 'Kerstroosplein' becomes most optimal area, the area features and stakeholder's preference will be further investigated. From table 11 and 12, it becomes obvious that the highest evaluating criteria impact is 'population density', and among its three scales, population density above 90 people is most preferred. From listed out data table in Appendix C, 'Kerstroosplein' population density is 93 people/hectare, which had certainly played a great role to let this area becomes most optimal area. Beyond that, other features, such as 'land price in community', 'highest road conditional level around terminal building', 'road level in community', and 'nearest distance from residents building to terminal building', also contributing 'Kerstroosplein' obtain the higher suitability scores.

As the most optimal area of Eindhoven, the land features of 'Kerstroosplein' need to be further revealed and discussed. population density of this neighborhood is 93 people per hectare, released space from traditional underground container is 0.25 pic per hectare, land price range both in community and terminal area is 250-500 euro per square meter, maximum population of connected neighborhood is 2855 people per hectare, highest road conditional level around terminal building is tertiary road, family house density is 37.19 building per hectare, bus stop covering rate is 42.1%, average road level in community is secondary road, building density is 41.19 building per hectare, soil type is sand soil, and pickup trucks travel distance is 85.16km.

From above figures, it can be seen that ‘Kerstroosplein’ have a relative high population density, maximum population amount of connected community maintains in a middle range which could more suitable for considering system capacity, tertiary road around the terminal building could ensure the accessibility and safety of waste outward transport, secondary road level within the community . In addition to this, this area have 42.1 percentage of bus stop covering rate which could increase public awareness and involvement better. Therefore, it can be concluded that ‘Kerstroosplein’ as a most optimal area for PWC system installation is reasonable, also proposed approach could effectively help decision makers to identify the location of new system.

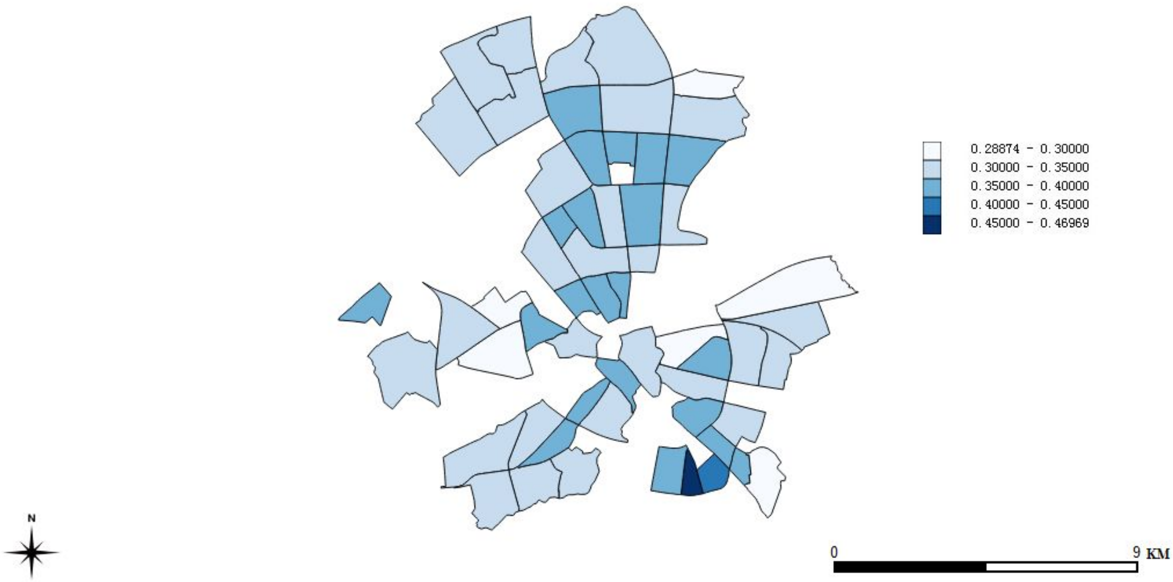


Figure 30. Final neighborhood suitability map of Eindhoven city

For the neighborhood of ‘Kruidenbuurt’, several features have the same preference scales with ‘Kerstroosplein’, such as ‘population density’, ‘released space’, land price both in community and terminal area, ‘town house density’, ‘building density’, ‘soil type’ and ‘pickup trucks travel distance’. Above all these features make the neighborhood of ‘Kruidenbuurt’ becomes the second suitable neighborhood of installing PWC system.

The corresponding values of each features of ‘Kruidenbuurt’ will be demonstrated in order to investigate it forming reason. Population density in this area is 94 people per hectare, every hectare have 0.18 pics of underground waste container, land price range in community and terminal area is 250-500, maximum population amount of other connected community is 1960, highest road level around terminal building is primary road, town house density is 38.97 buildings per hectare, bus stop covering rate is 12.2%, average road condition level within the community is tertiary road, building density is 47.93 buildings per hectare, nearest distance from residential building to terminal building is 12.5 meter, soil type within the area is sand soil, and pickup trucks travel distance is 126.23 km.

Comparing the neighborhood features between 'Kerstroosplein' and 'Kruidenbuurt', it can be known that maximum population amount around neighborhood of 'Kruidenbuurt' is 1960, which could not reach the best performance of system extension. Moreover, the road conditional levels around terminal building with the area of 'Kruidenbuurt' lower than 'Kerstroosplein', which will definitely restrict the transportation of waste. The distance between residential and terminal building in neighborhood of 'Kruidenbuurt' is shorter than 'Kerstroosplein'. All these factors make the neighborhood of 'Kruidenbuurt' obtain the lower suitability score than 'Kerstroosplein'.

4.7 Discussion

The selection of influential criteria and area evaluating criteria in stakeholders decision making of PWC system installation are important results of this research. The selected and defined criteria can be used to evaluate the preference of stakeholders. Through combining with GIS, most optimal area for installing PWC system within a city can be identified. The research results described in previous chapter could be used to answer the last sub-question of this research.

From result analysis of AHP, the most preferred criterion and its scales by both municipalities and PWC company stakeholder groups can be viewed regarding the implement location of PWC system. Both groups consider 'population density' as the most important criteria to identify the location of PWC system, among its classified scales, population density above 90 people per hectare is most preferred.

From the generated suitability map of Eindhoven city, it can be easier mapped out that the neighborhood of 'Kerstroosplein' is the most optimal area to install the PWC system within Eindhoven city. Based on the results analysis mentioned in previous section, each area features of 'Kerstroosplein' can meet the technical and environment requirements that proposed by both stakeholders. Therefore, it is proved that the suggested research approach (AHP combine with GIS) can help decision makers to search optimal installation locations of PWC system successfully.

For further research it is recommended to take the underground facilities into consideration during the planning phase, such as underground cables. This is due to underground infrastructures and facilities could generate some influence on the location of waste pipeline, further influence the construction difficulty and project investment.

5. Conclusion

This chapter will conclude the obtained results from graduation research. The findings of this research will be expatiated from three aspects, societal relevance, scientific relevance and beneficiary relevance.

5.1 Societal relevance

In the chapter of literature review, the formation and development of Netherlands waste management strategy and plans are detailed explained and discussed. For the purpose of achieving the national waste management plan and European union directives, and with the minimum resources input, two kinds of existing waste collection system in Netherlands are carry out a comparison.

The comparison results shown that Pneumatic waste collection system is more conforms to the Netherlands current situation. By utilizing PWC system, the amount of greenhouse gas emission that generated by waste collection trucks will be decreased, household waste will be separated collect and transport, and recycling rate will be increased. It is provide a good direction for Netherlands government to accomplish its desired goal.

The research aim of this paper is to identify an optimal area for installing PWC system. In AHP model, there are 13 different evaluating criteria to reflect the situations of neighborhood. Through these evaluating criteria, a most optimal area for installing PWC system within a city will be picked out. After installing this system, the traffic condition within the area will be improved a lot, also residents could avoid the waste piled up problems due to the limited container capacity, and ensuring end-users will not suffer the malordor pollution, increasing the road safety degree within the neighborhood.

5.2 Scientific relevance

According to the investigate results presented in previous chapter, the methodology of AHP with GIS were confirmed again that this combination could be applied to identify the location of waste management facilities, especially involved multi-stakeholders.

In this research, AHP model appears four different criteria level, two of these levels criteria amount exceed 10. There are 12 criteria in influential criteria level, and 13 criteria in evaluating criteria level. It is proposed to decrease the pair-wise comparison times in accordance with the characteristics of comparison matrix. In this way, the length of the survey questionnaire will be shorter, experts will spend less time. Furthermore, it is not need a CR check to ensure the consistency of respondents selection. Owing to this, the data processing time will be reduced, and model operation efficiency will be increased.

In AHP model, each evaluating criteria are classified into several scales, which ensure the model could be utilized widely. Moreover, intensifying the connections with GIS map. By using GIS software, the scales map of each evaluating criteria could be generated, which can be easily viewed by decision makers for the purpose of realizing the situation of each neighborhood. Finally, a land suitability map could be generated by utilizing overlay analysis. By means of combining AHP with GIS as the research methodology, suitability could reflect the multi-stakeholders considerations into a city map precisely.

5.3 Beneficiary relevance

Based on the investigation of this research, there are three party can obtain the benefit from it, government, system service provide company and end-users.

First, the government will start to recognize the advantage of pneumatic waste collection system. Considering the future waste management strategy, government could easily accomplish a specific goal within a relative low resource input. By means of involving more residents into new system, the cost of system operation and maintenance will be decreased. Through doing this, government can shorter the payback period, and save a part of annual waste mange fee for other purpose. Moreover, a large amount of greenhouse gas emission will be reduced due to high vehicle productivity. This means that government not only protects the environment but also improves own public image.

This research could let service provide company pay close attention to government's concern, rather than just focus on maximum technical performance of system. Taking government and investors considerations into account could more easily to persuade them to participate in the new system project. Though considering the multi-stakeholders requirements to planning system location, the comprehensive performance of system can achieve the best level, and it's helpful for pneumatic waste collection system promotion.

After installing the new waste collection system, the local residents will no longer need to worry about the community road safety and congestion caused by heavy waste collection trucks. Meanwhile, the phenomenon of waste piled up arise from limited capacity of waste container, could be greatly improved. Owing to the limited transportation of heavy trucks within community, residents will no longer need to suffer the waste vehicle exhaust and noise, hence, living condition will be improved.

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JvR **ThesisTools**

Preview Survey

Create a survey in 4 steps:

Step 1: *Survey Settings*
Step 2: *Survey Overview*
Step 3: *Survey Preview*
Step 4: *Publish Survey*

Homepage: *Main menu*
Additional: *Additional services*

Page: 1

Questionnaire to identify optimal area for installing PWC system

Description:

The Municipality of Eindhoven and CentralNed Company wants to perform a locational analysis for the city of Eindhoven, for installing the Pneumatic waste collection system to improve the efficiency of City waste management. In order to do this, the first step is to identify the most important evaluating criteria.

This questionnaire aims to rate, among the different stakeholders of waste collection system installation, the most significant waste collection and transport criteria in the Netherlands. The goal is identify the most vital site evaluating criteria that should be analyzed by authorities.

This questionnaire is part of a Thesis research of the Eindhoven University of Technology (TU/e) for the Master of Construction Management & Engineering.

Pneumatic waste collection system: transporting waste in underground pipelines through the use of vacuum to a central waste collection terminal.

This questionnaire will take you approximately 10 minutes

Start

Page: 2

Questionnaire to identify optimal area for installing PWC system

1.

Which sector suits you best?

- Authority
- Management Expert-Researcher
- PWC system company

2.

Which is your current position ? *

- Director
- Project Manager
- Professor
- Other

3.

what is the name of your organization ?

Operation mode of Pneumatic Waste Collection(PWC) system

next page

Page: 3

Instructions:

You will be asked to compare different concepts according to their importance.

Please select the option that best describe your opinion about the degree of importance of one element respect to the other.

Please Notice:

-The Closest circle to the concept = the concept is extremely more important than the other.

-In between circles are :
Very largely more important
Largely more important
Moderately more important

-The middle circle = concepts are equally important.

Step 2. Rate all the following Sub-criteria with respect to the Environmental aspect:

* Minimum Gas emissions influence on Environment: reducing the gas emission during the process of waste collection and transportation.

* Minimum Noise influence on Environment: reducing the noise generation during the process of waste collection and transportation.

* Accessibility of trucks to collection center: ensuring the waste ship out process smooth.

* Improve the safety in community: reducing potential traffic danger caused by heavy waste trucks.

* Population density in the community: within the covering space of Pneumatic waste collection system population amount per hectare, more population needs more truck trips to collect and transport waste

* Road condition level around collection center: highest level of roads around terminal, can be used by waste transportation

trucks

* Nearest distance from residents building to collection center: linear distance between residents building and terminal building

* Road condition level in community: average level of roads in the community

* Building density in the community: average building numbers per hectare

* Pickup trucks travel distance in community: total drive distance of waste collection trucks(Traditional way of waste collection) within the community

4.

Step 1. Rate the following Main-criteria:
*** Environmental aspects: considering noise, gas emission, and safety issues during waste collection and transportation.**
*** Economical aspects: considering investment and construction issues of new collection system.**
*** Social aspects: considering social and citizen aspects.**

Which of the aspects you consider more important for implement a new waste collect and transport system?

Environmental aspects	○ ○ ○ ○ ○ ○ ○ ○ ○	Economical aspects
Environmental aspects	○ ○ ○ ○ ○ ○ ○ ○ ○	Social aspects
Economical aspects	○ ○ ○ ○ ○ ○ ○ ○ ○	Social aspects

5.

Step 2a. Rate the following Sub-criteria:
Which of the elements you consider more important for installing a new waste collection and transportation system ?

Minimum gas emissions influence on environment	○ ○ ○ ○ ○ ○ ○ ○ ○	Minimum Noise influence on environment
Minimum gas emissions influence on environment	○ ○ ○ ○ ○ ○ ○ ○ ○	Accessibility of trucks to collection center
Minimum gas emissions influence on environment	○ ○ ○ ○ ○ ○ ○ ○ ○	Improve the safety in Community
Minimum noise influence on environment	○ ○ ○ ○ ○ ○ ○ ○ ○	Accessibility of trucks to collection center
Minimum noise influence on environment	○ ○ ○ ○ ○ ○ ○ ○ ○	Improve the safety in community
Accessibility of trucks to collection center	○ ○ ○ ○ ○ ○ ○ ○ ○	Improve the safety in community

6.

Step 2b. Rate the following sub-criteria:
Which of the elements you consider more important for minimize the gas emission influence on environment ?

Population density in the community	○ ○ ○ ○ ○ ○ ○ ○ ○	Pickup trucks travel distance in community

7.

Step 2c. Rate the following Sub-criteria:
Which of the elements you consider more important for minimize the noise influence on environment ?

Nearest distance from residents building to collection center	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community
Pickup trucks travel distance in community	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community

8.

Step 2d. Rate the following Sub-criteria:
Which of the elements you consider more important for accessibility of trucks in terminal building?

Road condition level around collection center	○ ○ ○ ○ ○ ○ ○ ○ ○	Nearest distance from residents building to collection center

9.

Step 2e. Rate the following Sub-criteria:
Which of the elements you consider more important for Improving the safety in community?

Nearest distance from residents building to collection center	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community
Road condition level in community	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community
Building density in the community	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community
Pickup trucks travel distance in community	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community

10.

Step 2f. Rate the following sub-criteria level:
Which of the level you consider more important for Population density within the covering area of PWC system?

Level 1: 0-60 people per hectare	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 2: 61-90 people per hectare
Level 1: 0-60 people per hectare	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 3: above 91 people per hectare
Level 2: 61-90 people per hectare	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 3: above 91 people per hectare

11.

Step 2g. Rate the following sub-criteria level:
Which of the level you consider more important for Road condition level around collection center regarding waste transport?

Level 1: Primary	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 2: Secondary
Level 1: Primary	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 3: Tertiary
Level 1: Primary	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 4: Trunk
Level 2: Secondary	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 3: Tertiary
Level 2: Secondary	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 4: Trunk
Level 3: Tertiary	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 4: Trunk

12.

Step 2h. Rate the following Sub-criteria level:
Which of the level you consider more important for distance from residents building to PWC collection center ?

Level 1: 0-20m	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 2: 21-40m
Level 1: 0-20m	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 3: above 41m
Level 2: 21-40m	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 3: above 41m

13.

Step 2i. Rate the following Sub-criteria level:
Which level of the road condition do you consider more important for demanding a new way of waste transportation in community ?

Level 1: primary	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 2: secondary
Level 1: primary	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 3: tertiary
Level 1: primary	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 4: Trunk
Level 2: secondary	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 3: tertiary
Level 2: secondary	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 4: Trunk
Level 3: tertiary	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 4: Trunk

14.

Step 2j. Rate the following Sub-criteria level:
Which level of Building density do you consider more important for demanding a new way of waste collection and transportation in community ?

Level 1: above 25.6 building per hectare	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 2: below and equal to 25.6 buildings per hectare

15.

Step 2k. Rate the following Sub-criteria level:
Which level of Pickup trucks travel distance in community do you consider more important for demanding a new waste collection and transportation way ?

Level 1: below and equal to 153.06 KM	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 2: above 153.06 KM

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Step 3. Rate the following Sub-criteria with respect to Economical aspects:

* Decrease the payback period: reducing the investment recovery year.
* Less Initial investment cost: controlling initial investment cost
* High possibility of extend the system: capability of involving more end users
* Easier construction: constructing the collection center and pleasing underground pipeline.

* Population density in the community: population amount per hectare, more population needs more truck trips to collect and transport waste

* Released space from traditional waste container: after the installation of new waste collection system, previous space occupied by waste containers can be use for other functions.

* Land price in collection center area: a certain area size needs to be occupied for constructing collection center

* Land price in community: could be used to calculate the revenue of released space

* Population amount of other connected community: total population amount in neighborhood community

* Road condition level around collection center: highest level of roads around collection center, can be used by waste transportation trucks

* Nearest distance between residents building and collection center: linear distance between residents building and collection center

* No. Of town house(family house) in the community: adding additional one household into system needs more length of underground pipelines than in the apartment. Moreover, their waste need to be placed into plastic litter bins and collected by specific trucks every week

* Road condition level in community: average level of roads in the community

* Building density in the community: average building numbers per hectare

* Soil type: type of soil within the community

16.

Step 3a. Rate the following Sub-criteria:
Which of the elements do you consider more important for installing a new waste collection and transportation system ?

Decrease the payback period	Less initial investment cost
Decrease the payback period	High possibility of extend the system
Decrease the payback period	Easier construction
Less initial investment cost	High possibility of extend the system
Less initial investment cost	Easier construction
High possibility of extend the system	Easier construction

17.

Step 3b. Rate the following Sub-criteria:
Which of the elements do you consider more important for Decreasing the payback period of project?

Released space from traditional waste container	Population density in the community
Land price in collection center area	Population density in the community
Land price in community	Population density in the community
Population amount of other connected community	Population density in the community
Soil type	Population density in the community

18.

Step 3c. Rate the following Sub-criteria:
Which of the elements do you consider more important for Controlling the initial investment cost ?

Land price in community	Land price in collection center area
No. Of town house (family house) in community	Land price in collection center area
Road condition level in community	Land price in collection center area
Building density in the	Land price in collection center

Building density in the community ○ ○ ○ ○ ○ ○ ○ ○ ○ Land price in collection center area

Soil type ○ ○ ○ ○ ○ ○ ○ ○ ○ Land price in collection center area

19.

Step 3d. Rate the following Sub-criteria:
Which of the elements do you consider more important for Extension the system ?

Road condition level around collection center ○ ○ ○ ○ ○ ○ ○ ○ ○ Population amount of other connected community

Soil type ○ ○ ○ ○ ○ ○ ○ ○ ○ Population amount of other connected community

20.

Step 3e. Rate the following Sub-criteria:
Which of the elements do you consider more important on influencing the construction difficulty?

Road condition level around collection center ○ ○ ○ ○ ○ ○ ○ ○ ○ Population density in the community

Nearest distance from residents building to collection center ○ ○ ○ ○ ○ ○ ○ ○ ○ Population density in the community

No. Of town house (family house) in community ○ ○ ○ ○ ○ ○ ○ ○ ○ Population density in the community

Road condition level in community ○ ○ ○ ○ ○ ○ ○ ○ ○ Population density in the community

Building density in the community ○ ○ ○ ○ ○ ○ ○ ○ ○ Population density in the community

Soil type ○ ○ ○ ○ ○ ○ ○ ○ ○ Population density in the community

21.

Step 3f. Rate the following Sub-criteria level:
Which of the level do you consider more important for Released space from traditional waste container within the covering area of PWC system?

Level 1: below and equals 0.51 pics per hectare ○ ○ ○ ○ ○ ○ ○ ○ ○ Level 2: above 0.51 pics per hectare

22.

Step 3g. Rate the following Sub-criteria:
Which level of the land price in collection center do you consider more important for installing the PWC collection center ?

Level 1: above €250 per square meter ○ ○ ○ ○ ○ ○ ○ ○ ○ Level 2: below and equal to € 250 per square meter

23.

Step 3h. Rate the following Sub-criteria level:
Which level of the land price in community do you consider more important for released space ?

Level 1: above € 250 per square meter ○ ○ ○ ○ ○ ○ ○ ○ ○ Level 2: below and equal to € 250 per square meter

24.

Step 3i. Rate the following Sub-criteria level:
Which level of the other connected community population do you consider more important for involving more users into PWC system ?

Level 1: 0-2000 ○ ○ ○ ○ ○ ○ ○ ○ ○ Level 2: 2001-6000

Level 1: 0-2000 ○ ○ ○ ○ ○ ○ ○ ○ ○ Level 3: above 6001

Level 2: 2001-6000 ○ ○ ○ ○ ○ ○ ○ ○ ○ Level 3: above 6001

25.

Step 3j. Rate the following sub-criteria level:
Which level of town house (family house) in community do you consider more important for implementing new waste collection and transportation way ?

Level 1: above 17 Per hectare ○ ○ ○ ○ ○ ○ ○ ○ ○ Level 2: below and equal to 17 Per hectare

26.

Step 3k. Rate the following Sub-criteria level:
Which level of soil type you consider more important for installing the collection center and pipelines in community ?

Level 1: sand soil ○ ○ ○ ○ ○ ○ ○ ○ ○ Level 2: loamy soil

Level 1: sand soil ○ ○ ○ ○ ○ ○ ○ ○ ○ Level 3: peaty soil

Level 1: sand soil ○ ○ ○ ○ ○ ○ ○ ○ ○ Level 4: clay soil

Level 2: loamy soil ○ ○ ○ ○ ○ ○ ○ ○ ○ Level 3: peaty soil

Level 2: loamy soil ○ ○ ○ ○ ○ ○ ○ ○ ○ Level 4: clay soil

Level 3: peaty soil ○ ○ ○ ○ ○ ○ ○ ○ ○ Level 4: clay soil

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Step 4. Rate the following Sub-criteria with respect to Social aspect:

* Improving the district aesthetics: increasing the city beauty.
* Reducing the traffic congestion: increasing the travel convenience and reduce congestion caused by heavy trucks.
* Increasing residents sorting activities: letting residents to separate the waste from waste source.
* Increasing awareness of residents: enhancing new system awareness among the residents.

* Bus stop covering rate in community: posting ads at the bus stop, bus stop covering rate can be treated equal as PWC system ads covering rate within community

27.

Step 4a. Rate the following Sub-criteria:

Which of the elements do you consider more important for installing a new waste collection and transportation system ?

Improving the district aesthetics	○ ○ ○ ○ ○ ○ ○ ○ ○	Reducing the traffic congestion
Improving the district aesthetics	○ ○ ○ ○ ○ ○ ○ ○ ○	Increasing residents sorting activities
Improving the district aesthetics	○ ○ ○ ○ ○ ○ ○ ○ ○	Increasing awareness of residents
Reducing the traffic congestion	○ ○ ○ ○ ○ ○ ○ ○ ○	Increasing residents sorting activities
Reducing the traffic congestion	○ ○ ○ ○ ○ ○ ○ ○ ○	Increasing awareness of residents
Increasing residents sorting activities	○ ○ ○ ○ ○ ○ ○ ○ ○	Increasing awareness of residents

28.

Step 4b. Rate the following Sub-criteria:
Which of the elements do you consider more important for improving the district aesthetics ?

Released space volume from traditional waste container	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community
No. Of town house (family house) in community	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community
Bus stop covering rate within community	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community

29.

Step 4c. Rate the following Sub-criteria:
Which of the elements do you consider more important for Reducing the traffic congestion ?

Released space volume from traditional waste container	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community
Population amount of other connected community	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community
Road condition level around collection center	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community
Road condition level in community	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community
Building density in the community	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community
Pickup trucks travel distance in community	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community

30.

Step 4d. Rate the following Sub-criteria:
Which of the elements do you consider more important for increasing residents sorting activities ?

Population density in the community	○ ○ ○ ○ ○ ○ ○ ○ ○	No. Of town house (family house) in community

31.

Step 4e. Rate the following Sub-criteria:
Which of the elements do you consider more important for Increasing awareness of residents ?

Bus stop covering rate in community	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community

Building density in the community	○ ○ ○ ○ ○ ○ ○ ○ ○	Population density in the community

32.

Step 4f. Rate the following Sub-criteria Level:
Which of the level do you consider more important for Bus stop covering rate in community ?

Level 1: 0-10%	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 2: 10-20%
Level 1: 0-10%	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 3: above 21%
Level 2: 11-20%	○ ○ ○ ○ ○ ○ ○ ○ ○	Level 3: above 21%

33.

In case of a single inconsistent answer that prevents the entire questionnire to be used as input for the research method, we would like to contact you back for re-considering the value of that answer

What is your E-mail ?

34.

We would like to hear the voice from your side,any comments for further improvement ?

Submit survey

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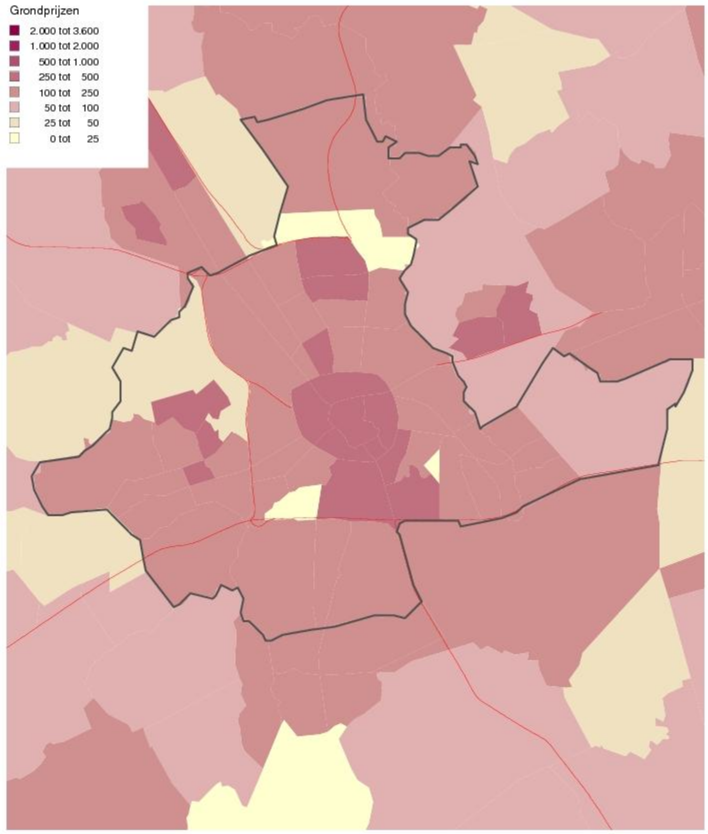
Thank your very much for your kindly help and cooperation.

Appendix-B



Eindhoven

Appendix-C

Community Name	Area size(hectare)	Population amount	Population Density (p/hectare)	Classified scales of Population Density	Releasedspace from traditional waste container (pic/hectare)	Released space Scale	Scales of Land price in terminal building area	Scales of Land price in community area	Population amount of other connected community	Scales of Population amount	Highest road conditional level around terminal building	Scales of road condition in Terminal	No. of town house(family house) in community (pic/hectare)	Scales of Town house	Bus stop covering rate in community (%)	Scales of Bus stop covering rate	Road level in community	Building Density in community (Dwellins/hectare)	Scales of Building Density	Nearest distance from residents building to terminal building (meter)	Scales of Nearest distance	Soil type	Scales of Soil type	Pickup travel distance (KM)	Scales of Pickup travel distance
Binnenstad	67	2900	43	Scale 1	0.99	Scale 2	Scale 1	Scale 1	2400	Scale 2	Secondary	Scale 2	2.18	Scale 2	34.3%	Scale 3	Scale 3	22.09	Scale 2	6.7	Scale 1	Sand	Scale 1	154.60	Scale 2
Bergen	35	2400	69	Scale 2	1.28	Scale 2	Scale 1	Scale 1	3545	Scale 2	Primary	Scale 1	6.97	Scale 2	30.3%	Scale 3	Scale 3	33.00	Scale 1	13.62	Scale 1	Sand	Scale 1	119.42	Scale 1
Irisbuurt	54	2005	37	Scale 1	1.07	Scale 2	Scale 1	Scale 1	3200	Scale 2	Trunk	Scale 4	10.02	Scale 2	13.1%	Scale 2	Scale 3	18.15	Scale 2	21.2	Scale 2	Sand	Scale 1	178.64	Scale 2
Tuindorp	45	2955	66	Scale 2	0.83	Scale 2	Scale 1	Scale 1	2891	Scale 2	Trunk	Scale 4	12.71	Scale 2	15.7%	Scale 2	Scale 2	27.78	Scale 1	23.93	Scale 2	Sand	Scale 1	99.12	Scale 1
Kerstroosplein	21	1960	93	Scale 3	0.24	Scale 1	Scale 1	Scale 1	2855	Scale 2	Teritary	Scale 3	37.19	Scale 1	42.1%	Scale 3	Scale 2	41.19	Scale 1	21.39	Scale 2	Sand	Scale 1	85.16	Scale 1
Gerardusplein	46	2990	65	Scale 2	0.09	Scale 1	Scale 1	Scale 1	1960	Scale 1	Secondary	Scale 2	22.43	Scale 1	23.0%	Scale 3	Scale 2	20.65	Scale 2	55.78	Scale 3	Sand	Scale 1	109.95	Scale 1
Burghplan	50	2935	59	Scale 1	0.48	Scale 1	Scale 2	Scale 2	2980	Scale 2	Primary	Scale 1	18.86	Scale 1	17.7%	Scale 2	Scale 2	29.20	Scale 1	20.39	Scale 2	Sand	Scale 1	122.50	Scale 1
Sintenbuurt	26	1770	68	Scale 2	0.27	Scale 1	Scale 1	Scale 1	2980	Scale 2	Secondary	Scale 2	27.19	Scale 1	20.4%	Scale 3	Scale 2	32.69	Scale 1	18.18	Scale 1	Sand	Scale 1	79.93	Scale 1
Tivoli	18	1520	84	Scale 2	0.40	Scale 1	Scale 2	Scale 2	2701	Scale 2	Primary	Scale 1	36.06	Scale 1	0.0%	Scale 1	Scale 3	44.72	Scale 1	27.78	Scale 2	Sand	Scale 1	74.16	Scale 1
Gijzenrooi	59	1960	33	Scale 1	0.01	Scale 1	Scale 2	Scale 2	1579	Scale 1	Primary	Scale 1	12.07	Scale 2	15.0%	Scale 2	Scale 1	12.29	Scale 2	20.33	Scale 2	Sand	Scale 1	73.41	Scale 1
Kruidenbuurt	29	2725	94	Scale 3	0.18	Scale 1	Scale 1	Scale 1	1960	Scale 1	Primary	Scale 1	38.97	Scale 1	12.2%	Scale 2	Scale 3	47.93	Scale 1	12.5	Scale 1	Sand	Scale 1	121.25	Scale 1
Villapark	56	2065	37	Scale 1	0.15	Scale 1	Scale 1	Scale 1	3554	Scale 2	Secondary	Scale 2	11.25	Scale 2	15.8%	Scale 2	Scale 3	14.11	Scale 2	26.86	Scale 2	Sand	Scale 1	73.21	Scale 1
Lakerlopen	49	3200	65	Scale 2	0.55	Scale 2	Scale 1	Scale 1	3554	Scale 2	Secondary	Scale 2	18.84	Scale 1	18.0%	Scale 2	Scale 1	29.29	Scale 1	8.48	Scale 1	Sand	Scale 1	125.80	Scale 1
Doornakkers-West	71	3510	49	Scale 1	0.27	Scale 1	Scale 2	Scale 2	3907	Scale 2	Secondary	Scale 2	17.73	Scale 1	7.5%	Scale 1	Scale 3	20.92	Scale 2	21.82	Scale 2	Sand	Scale 1	160.65	Scale 2
Doornakkers-Oost	51	2870	56	Scale 1	0.97	Scale 2	Scale 2	Scale 2	3907	Scale 2	Secondary	Scale 2	19.37	Scale 1	17.3%	Scale 2	Scale 3	25.39	Scale 2	45.16	Scale 3	Sand	Scale 1	207.20	Scale 2
Muschberg,Geestenberg	77	4055	53	Scale 1	2.42	Scale 2	Scale 2	Scale 2	3554	Scale 2	Teritary	Scale 3	18.55	Scale 1	9.2%	Scale 1	Scale 3	24.09	Scale 2	11.72	Scale 1	Sand	Scale 1	625.43	Scale 2
't Hofke	151	3530	23	Scale 1	0.15	Scale 1	Scale 2	Scale 2	3907	Scale 2	Teritary	Scale 3	6.99	Scale 2	11.7%	Scale 2	Scale 2	10.30	Scale 2	22.47	Scale 2	Sand	Scale 1	132.56	Scale 1
Limbeek-Noord	31	2305	74	Scale 2	1.60	Scale 2	Scale 1	Scale 1	3559	Scale 2	Teritary	Scale 3	7.39	Scale 2	5.7%	Scale 1	Scale 2	39.68	Scale 1	16.37	Scale 1	Sand	Scale 1	77.56	Scale 1
Hemelrijken	37	3300	89	Scale 2	1.02	Scale 2	Scale 1	Scale 1	3860	Scale 2	Primary	Scale 1	22.76	Scale 1	9.6%	Scale 1	Scale 2	40.14	Scale 1	18.81	Scale 1	Sand	Scale 1	127.09	Scale 1
Gildebuurt	21	1620	77	Scale 2	1.15	Scale 2	Scale 1	Scale 1	3860	Scale 2	Secondary	Scale 2	15.24	Scale 2	16.8%	Scale 2	Scale 2	39.05	Scale 1	7.07	Scale 1	Sand	Scale 1	59.03	Scale 1
Woensel-West(Groenewoud)	70	4090	58	Scale 1	0.23	Scale 1	Scale 2	Scale 2	3860	Scale 2	Primary	Scale 1	20.56	Scale 1	7.6%	Scale 1	Scale 2	25.93	Scale 1	42.84	Scale 3	Clay	Scale 4	164.25	Scale 2
Kronehoef	67	3875	58	Scale 1	0.90	Scale 2	Scale 1	Scale 1	4011	Scale 2	Primary	Scale 1	12.57	Scale 2	15.8%	Scale 2	Scale 2	31.79	Scale 1	16.29	Scale 1	Sand	Scale 1	151.36	Scale 1
Barrier	26	2170	83	Scale 2	0.20	Scale 1	Scale 2	Scale 2	4011	Scale 2	Primary	Scale 1	28.38	Scale 1	13.6%	Scale 2	Scale 2	28.08	Scale 1	21.13	Scale 2	Clay	Scale 4	80.97	Scale 1
Mensfort	46	3070	67	Scale 2	0.60	Scale 2	Scale 1	Scale 1	4515	Scale 2	Primary	Scale 1	18.67	Scale 1	7.7%	Scale 1	Scale 3	31.85	Scale 1	13.81	Scale 1	Sand	Scale 1	117.79	Scale 1
Rapenland	53	2235	42	Scale 1	0.61	Scale 2	Scale 2	Scale 2	5187	Scale 2	Secondary	Scale 2	11.09	Scale 2	23.3%	Scale 3	Scale 2	19.15	Scale 2	12.32	Scale 1	Sand	Scale 1	115.35	Scale 1
Generalenbuurt	82	5290	65	Scale 2	0.57	Scale 2	Scale 2	Scale 2	3526	Scale 2	Trunk	Scale 4	18.82	Scale 1	19.4%	Scale 2	Scale 2	31.22	Scale 1	17.84	Scale 1	Sand	Scale 1	208.69	Scale 2
Oude Toren	26	1520	58	Scale 1	1.07	Scale 2	Scale 2	Scale 2	5290	Scale 2	Secondary	Scale 2	9.65	Scale 2	6.8%	Scale 1	Scale 2	33.08	Scale 1	20.96	Scale 2	Sand	Scale 1	56.04	Scale 1
Oude Gracht-West	51	2800	55	Scale 1	0.75	Scale 2	Scale 2	Scale 2	5187	Scale 2	Teritary	Scale 3	12.76	Scale 2	20.8%	Scale 3	Scale 2	29.22	Scale 1	20.82	Scale 2	Sand	Scale 1	108.23	Scale 1
Prinsejagt	95	4605	48	Scale 1	0.39	Scale 1	Scale 2	Scale 2	3552	Scale 2	Teritary	Scale 3	14.64	Scale 2	7.4%	Scale 1	Scale 2	22.79	Scale 2	22.95	Scale 2	Sand	Scale 1	182.87	Scale 2
Jagershoef	55	3505	64	Scale 2	0.50	Scale 1	Scale 2	Scale 2	5037	Scale 2	Teritary	Scale 3	20.67	Scale 1	25.7%	Scale 3	Scale 2	31.64	Scale 1	21.13	Scale 2	Sand	Scale 1	146.13	Scale 1
t Hool	34	2100	62	Scale 2	0.63	Scale 2	Scale 2	Scale 2	4974	Scale 2	Teritary	Scale 3	16.09	Scale 2	10.4%	Scale 2	Scale 3	29.71	Scale 1	57.69	Scale 3	Sand	Scale 1	79.09	Scale 1
Vlokhoven	54	3555	66	Scale 2	0.59	Scale 2	Scale 2	Scale 2	5187	Scale 2	Teritary	Scale 3	19.72	Scale 1	6.5%	Scale 1	Scale 2	31.02	Scale 1	21.18	Scale 2	Sand	Scale 1	150.06	Scale 1
Kerkdorp Acht	136	3530	26	Scale 1	0.04	Scale 1	Scale 2	Scale 2	4755	Scale 2	Primary	Scale 1	9.81	Scale 2	10.4%	Scale 2	Scale 1	10.77	Scale 2	26.01	Scale 2	Clay	Scale 4	141.99	Scale 1
Achtse Barrier-Gunterslaer	102	3800	37	Scale 1	1.02	Scale 2	Scale 2	Scale 2	4755	Scale 2	Primary	Scale 1	14.39	Scale 2	17.3%	Scale 2	Scale 3	15.34	Scale 2	42.55	Scale 3	sand	Scale 1	426.51	Scale 2
Achtse Barrier-Spaaihoef	102	4685	46	Scale 1	0.04	Scale 1	Scale 2	Scale 2	4260	Scale 2	Secondary	Scale 2	17.68	Scale 1	6.9%	Scale 1	Scale 2	18.53	Scale 2	23.21	Scale 2	sand	Scale 1	188.25	Scale 2
Achtse Barrier-Hoeven	74	4160	56	Scale 1	0.16	Scale 1	Scale 1	Scale 1	4755	Scale 2	Primary	Scale 1	19.91	Scale 1	11.9%	Scale 2	Scale 3	23.85	Scale 2	23.11	Scale 2	sand	Scale 1	163.66	Scale 2
Woenselse Heide	81	5075	63	Scale 2	0.38	Scale 1	Scale 1	Scale 1	4974	Scale 2	Primary	Scale 1	21.77	Scale 1	19.6%	Scale 2	Scale 2	26.73	Scale 1	40.61	Scale 3	sand	Scale 1	235.47	Scale 2
Tempel	119	4990	42	Scale 1	0.93	Scale 2	Scale 1	Scale 1	7118	Scale 3	Teritary	Scale 3	16.92	Scale 2	4.5%	Scale 1	Scale 2	19.58	Scale 2	43.62	Scale 3	sand	Scale 1	486.20	Scale 2
Blixembosch-West	73	2100	29	Scale 1	0.00	Scale 1	Scale 1	Scale 1	7118	Scale 3	Teritary	Scale 3	10.62	Scale 2	9.7%	Scale 1	Scale 3	10.62	Scale 2	97.35	Scale 3	sand	Scale 1	79.15	Scale 1
Blixembosch-Oost	168	7045	42	Scale 1	0.06	Scale 1	Scale 1	Scale 1	4974	Scale 2	Teritary	Scale 3	13.15	Scale 2	5.3%	Scale 1	Scale 2	14.46	Scale 2	46.41	Scale 3	sand	Scale 1	237.45	Scale 2
Eckart	68	4345	64	Scale 2	0.52	Scale 2	Scale 2	Scale 2	5234	Scale 2	Secondary	Scale 2	18.81	Scale 1	15.6%	Scale 2	Scale 2	30.22	Scale 1	32.87	Scale 2	sand	Scale 1	169.25	Scale 2
Vaartbroek	101	5200	51	Scale 1	0.36	Scale 1	Scale 2	Scale 2	4974	Scale 2	Trunk	Scale 4	16.86	Scale 2	10.5%	Scale 2	Scale 3	24.65	Scale 2	43.55	Scale 3	sand	Scale 1	213.05	Scale 2
Heesterakker	52	2830	54	Scale 1	0.00	Scale 1	Scale 2	Scale 2	5234	Scale 2	Primary	Scale 1	20.67	Scale 1	13.6%	Scale 2	Scale 2	20.58	Scale 2	16.34	Scale 1	sand	Scale 1	109.89	Scale 1
Philipsdorp	42	2205	53	Scale 1	0.36	Scale 1	Scale 1	Scale 1	3078	Scale 2	Teritary	Scale 3	19.69	Scale 1	8.4%	Scale 1	Scale 3	26.31	Scale 1	79.12	Scale 3	sand	Scale 1	100.95	Scale 1
Schoot	39	2555	66	Scale 2	0.35	Scale 1	Scale 1	Scale 1	3966	Scale 2	Primary	Scale 1	17.18	Scale 1	18.1%	Scale 2	Scale 2	24.74	Scale 2	44.1	Scale 3	sand	Scale 1	83.48	Scale 1
Het Ven	88	3955	45	Scale 1	0.21	Scale 1	Scale 2	Scale 2	2608	Scale 2	Primary	Scale 1	16.55	Scale 2	14.1%	Scale 2	Scale 2	20.85	Scale 2	29.38	Scale 2	sand	Scale 1	169.01	Scale 2
Lievendaal	89	3090	35	Scale 1	0.19	Scale 1	Scale 2	Scale 2	4727	Scale 2	Trunk	Scale 4	11.29	Scale 2	7.9%	Scale 1	Scale 3	15.45	Scale 2	104.82	Scale 3	Clay	Scale 4	121.16	Scale 1
Drents Dorp	45	1975	44	Scale 1	0.14	Scale 1	Scale 2	Scale 2	3966	Scale 2	Secondary	Scale 2	19.11	Scale 1	7.9%	Scale 1	Scale 3	21.78	Scale 2	17.85	Scale 1	sand	Scale 1	94.86	Scale 1
Grasrijk	126	5080	40	Scale 1	0.14	Scale 1	Scale 2	Scale 2	2608	Scale 2	Trunk	Scale 4	11.54	Scale 2	7.0%	Scale 1	Scale 3	14.29	Scale 2	88.37	Scale 3	Sand	Scale 1	167.81	Scale 2
Zandrijk(Bos- en Bos- en Zandrijk)	38	3035	80	Scale 2	0.24	Scale 1	Scale 2	Scale 2	<2000	Scale 3	Primary	Scale 1	24.63	Scale 1	9.3%	Scale 1	Scale2	29.87	Scale 1	65.55	Scale 3	Sand	Scale 1	105.70	Scale 1
Schrijversbuurt	60	3545	59	Scale 1	0.29	Scale 1	Scale 1	Scale 1	2217	Scale 2	Teritary	Scale 3	16.47	Scale 2	8.8%	Scale 1	Scale 2	21.83	Scale 2	43.39	Scale 3	Sand	Scale 1	120.07	Scale 1
Oude Spoorbaan	27	1755	65	Scale 2	0.67	Scale 2	Scale 1	Scale 1	2384	Scale 2	Teritary	Scale 3	17.00	Scale 2	13.1%	Scale 2	Scale 2	31.48	Scale 1	8.31	Scale 1	Sand	Scale 1	66.54	Scale 1
Genderdal	60	2810	47	Scale 1	0.62	Scale 2	Scale 2	Scale 2	3639	Scale 2	Primary	Scale 1	12.08	Scale 2	14.7%	Scale 2	Scale 2	25.58	Scale 2	23.58	Scale 2	Sand	Scale 1	209.44	Scale 2
Blaarthem	36	2430	68	Scale 2	0.69	Scale 2	Scale 2	Scale 2	3334	Scale 2	Secondary	Scale 2	19.00	Scale 1	9.8%	Scale 1	Scale 2	33.33	Scale 1	16.21	Scale 1	Sand	Scale 1	96.80	Scale 1
Bennekel-Oost	59	3325	56	Scale 1	0.42	Scale 1	Scale 2	Scale 2	2847	Scale 2	Teritary	Scale 3	17.63	Scale 1	12.0%	Scale 2	Scale 3	25.93	Scale 1	41.48	Scale 3	Sand	Scale 1	132.91	Scale 1
Bennekel-West,Gagelbosch	61	3170	52	Scale 1	0.12	Scale 1	Scale 2	Scale 2	3725	Scale 2	Teritary	Scale 3	18.02	Scale 1	11.6%	Scale 2	Scale 3	20.66	Scale 2	43.99	Scale 3	Sand	Scale 1	120.46	Scale 1
Genderbeemd	98	3610	37	Scale 1	0.20	Scale 1	Scale 2	Scale 2	3725	Scale 2	Teritary	Scale 3	12.41	Scale 2	16.2%	Scale 2	Scale 3	16.73	Scale 2	43.14	Scale 3	Sand	Scale 1	312.79	Scale 2
Hanevoet	73	3795	52	Scale 1	0.15	Scale 1	Scale 2	Scale 2	3639	Scale 2	Teritary	Scale 3	19.45	Scale 1	24.2%	Scale 3	Scale 2	22.88	Scale 2	55	Scale 3	Peaty	Scale 3	157.36	Scale 2

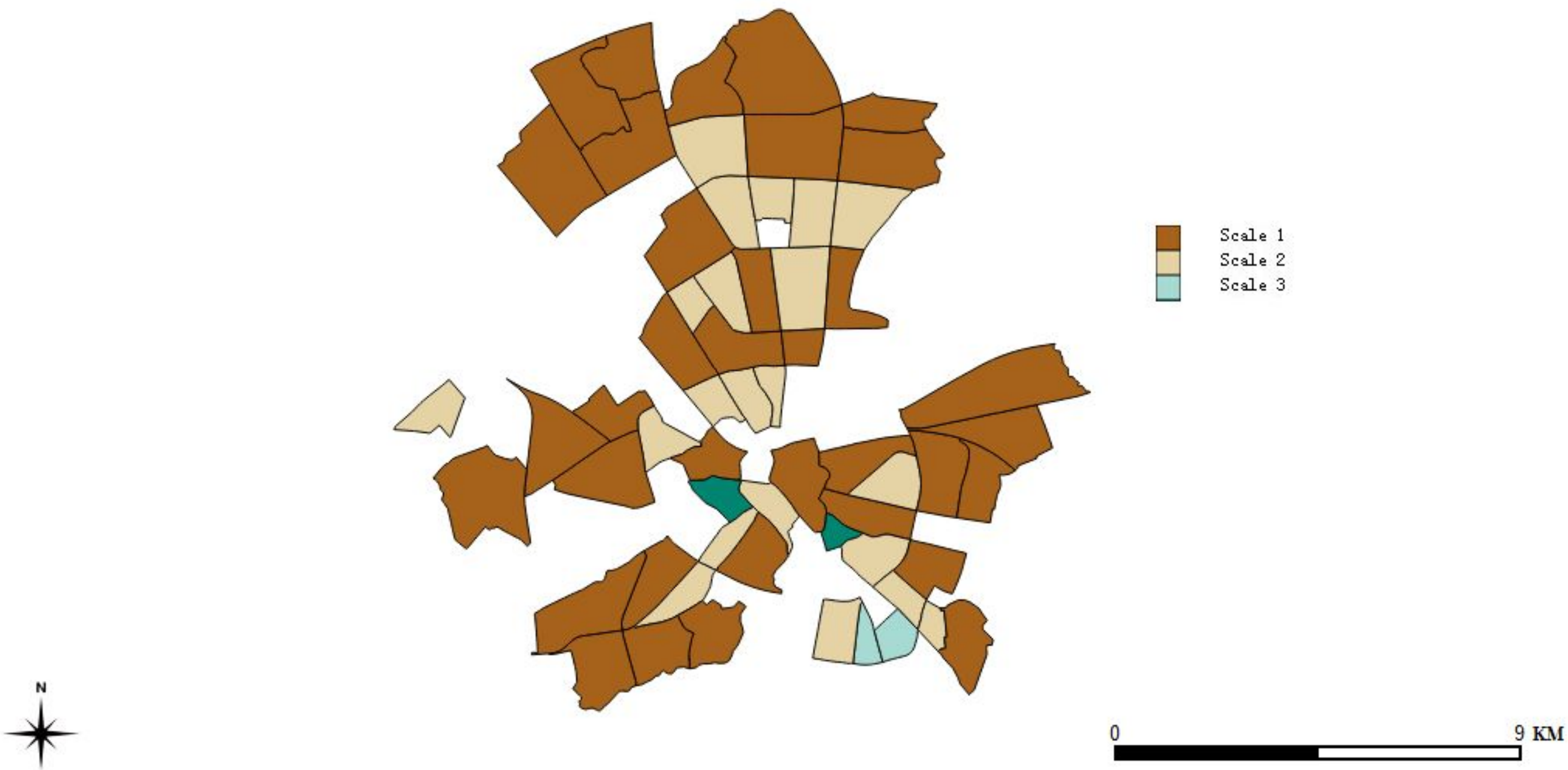
Appendix -D

Questions \ Respondents		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R12
Q1.	what is the name of your organization	Gemeente Almere	Dura Vermeer Beton- en Waterbouw	Gemeente Arnhem	CentralNed	Archicom	Gemeente Almere	Bureau Veritas	Energy Project Management BV	Dura Vermeer	Central Ned	Province Noord-Brabant	CentralNed	Dura Vermeer
Q2.	which sector suit you best	Authority	Management Expert-Researcher	Authority	PWC system company	Management Expert-Researcher	Authority	Management Expert-Research	Management Expert-Research	PWC company	PWC company	Authority	PWC company	PWC company
Q3.	what is your current postion	Team manager	Project Manager	Project Manager	Project Manager	Consultant	Centrum Manager Almere Centrum	Project manager	Director	Process coördinator	Project Manager	Project manager	Engineering	Sales manager
Q4.	Step 1.	4	4	3	4	4	6	5	1	2	6	5	7	2
		6	2	4	8	6	3	4	5	3	7	2	6	4
		7	3	6	9	7	1	3	9	6	6	2	4	7
Q5.	Step 2a	3	5	4	7	5	5	2	9	5	3	7	6	6
		5	3	5	6	3	5	2	9	3	6	8	6	7
		7	7	6	8	7	5	3	9	2	6	8	5	8
		5	3	5	6	3	5	4	5	3	6	6	6	7
		7	7	6	7	7	5	5	5	2	7	8	4	8
		7	8	5	7	7	5	7	5	5	5	6	4	5
Q6.	Step 2b	7	7	4	8	7	2	8	5	2	6	2	5	8
Q7.	Step 2c	7	3	6	5	5	1	3	9	8	5	1	4	8
		3	3	5	2	3	5	3	9	8	5	1	4	8
Q8.	Step 2d	3	7	4	3	5	1	3	1	8	7	8	5	2
Q9.	Step 2e	7	3	5	5	5	2	5	1	8	5	8	4	8
		4	7	4	2	7	2	4	1	8	6	8	4	6
		7	7	5	4	3	1	4	1	5	4	8	4	3
		4	3	5	1	3	5	6	1	8	6	8	5	3
Q10.	Step 2f	5	4	6	6	9	5	6	5	8	6	5	0	6
		5	6	7	8	7	5	9	9	7	5	9	0	8
		5	7	6	7	5	5	9	9	5	4	9	0	7
Q11.	Step 2g	6	6	4	6	6	5	6	9	6	4	5	0	5
		6	6	4	6	7	5	6	9	7	4	5	0	3
		9	6	4	6	9	5	8	9	8	5	5	0	2
		5	6	5	6	6	5	7	5	5	5	5	0	3
		6	6	5	6	7	5	7	6	6	5	5	0	4
		9	5	5	5	7	5	3	6	6	5	5	0	4
Q12.	Step 2h	5	6	6	6	5	5	4	9	8	7	8	0	6
		9	8	7	7	9	5	3	9	7	8	6	0	7
		9	7	6	6	9	5	4	5	5	6	3	0	6
Q13.	Step 2i	4	5	4	5	5	5	5	3	4	3	5	0	4
		1	3	4	5	3	5	4	3	3	4	5	0	3
		1	2	4	5	3	5	5	1	2	4	5	0	2
		4	3	4	5	3	5	5	5	5	5	5	0	4
		1	3	4	5	3	5	5	4	4	5	5	0	2
		5	3	5	5	5	5	5	1	4	5	5	0	3
Q14.	Step 2j	5	3	4	4	5	5	5	9	5	5	5	0	3
Q15.	Step 2k	5	3	5	7	5	5	3	5	7	5	8	0	3
Q16.	Step 3a	7	4	7	5	7	8	6	5	3	4	2	0	6
		5	4	6	6	4	4	5	5	7	7	4	0	7
		4	4	6	5	4	5	4	4	5	4	2	0	7
		4	4	4	5	3	1	4	5	7	7	6	0	7
		2	4	4	5	3	1	4	5	5	4	3	0	7
		5	5	4	4	5	5	5	3	3	3	2	0	5
Q17.	Step 3b	7	7	6	7	5	9	6	5	7	6	3	0	3
		3	7	5	4	7	9	5	5	8	6	7	0	3
		3	6	6	7	7	9	4	5	8	6	7	0	3
		7	8	5	6	7	9	3	5	7	5	5	0	3
		5	8	4	7	7	5	4	5	8	6	8	0	2
Q18.	Step 3c	7	7	5	7	9	9	4	5	2	7	6	0	3
		7	7	5	7	9	9	5	5	2	4	7	0	3
		7	7	4	7	9	9	6	5	7	5	8	0	4
		7	7	4	7	9	9	7	5	5	5	3	0	2
		7	7	4	3	3	9	5	5	7	5	8	0	3
Q19.	Step 3d	3	7	5	7	9	9	4	5	8	6	8	0	7
		7	7	4	7	9	9	5	5	8	6	8	0	6

Questions	Respondents	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R12
Q20.	Step 3e	7	3	5	4	1	5	6	5	3	6	2	0	4
		7	3	5	3	1	5	5	5	3	6	7	0	4
		5	3	5	4	9	5	4	5	5	5	7	0	3
		7	3	5	3	5	5	4	5	3	5	7	0	3
		4	3	4	3	1	5	5	5	5	5	6	0	2
		5	3	4	2	1	5	6	5	1	5	6	0	3
Q21	Step 3f	9	7	8	5	5	5	5	5	7	6	5	0	7
Q22	Step 3g	7	1	7	7	5	5	6	5	5	5	7	0	3
Q23	Step 3h	7	1	2	3	5	5	1	5	5	5	6	0	3
Q24	Step 3i	8	8	6	5	5	5	7	5	8	6	5	0	7
		7	8	8	9	3	5	6	5	7	6	5	0	6
		5	5	7	7	3	5	4	5	4	6	5	0	5
Q25	Step 3j	3	7	5	6	5	5	4	5	5	5	2	0	3
Q26	Step 3k	3	3	4	4	5	5	5	5	6	4	4	0	7
		3	3	4	4	3	5	6	5	7	4	3	0	8
		3	3	4	6	3	5	8	5	8	4	6	0	9
		5	5	5	4	3	5	5	5	6	4	4	0	6
		5	5	6	7	3	5	6	5	7	4	6	0	7
		7	5	6	7	5	5	6	5	6	6	9	0	6
Q27	Step 4a	4	5	5	8	7	5	7	5	4	7	6	0	4
		5	3	5	8	5	5	5	5	2	7	7	0	6
		3	1	6	7	5	5	5	5	2	7	7	0	7
		5	3	4	4	3	5	4	5	3	7	6	0	6
		3	3	4	3	3	5	4	5	3	7	7	0	7
		3	3	5	4	5	5	6	5	5	5	6	0	6
Q28	Step 4b	3	3	5	5	3	5	3	5	2	7	2	0	3
		5	5	5	5	5	5	4	5	5	4	4	0	3
		3	5	5	4	5	5	7	5	8	5	3	0	3
Q29	Step 4c	7	7	4	4	3	5	7	5	8	4	8	0	3
		7	7	4	4	5	5	8	5	5	5	8	0	4
		3	3	4	5	5	5	6	5	7	6	8	0	5
		3	3	5	5	5	5	5	5	6	6	8	0	4
		5	3	5	4	5	5	7	5	5	6	8	0	3
		5	3	5	2	5	5	5	5	3	6	8	0	2
Q 30	Step 4d	3	5	6	3	5	5	6	5	5	6	3	0	8
Q 31	Step 4e	7	5	5	5	3	5	3	5	6	6	4	0	7
		3	5	3	5	5	5	6	5	5	6	7	0	3
Q 32	Step 4f	7	5	7	6	7	5	7	5	8	5	5	0	5
		9	5	6	6	5	5	6	5	7	5	5	0	5
		6	5	4	5	4	5	5	5	4	5	6	0	5

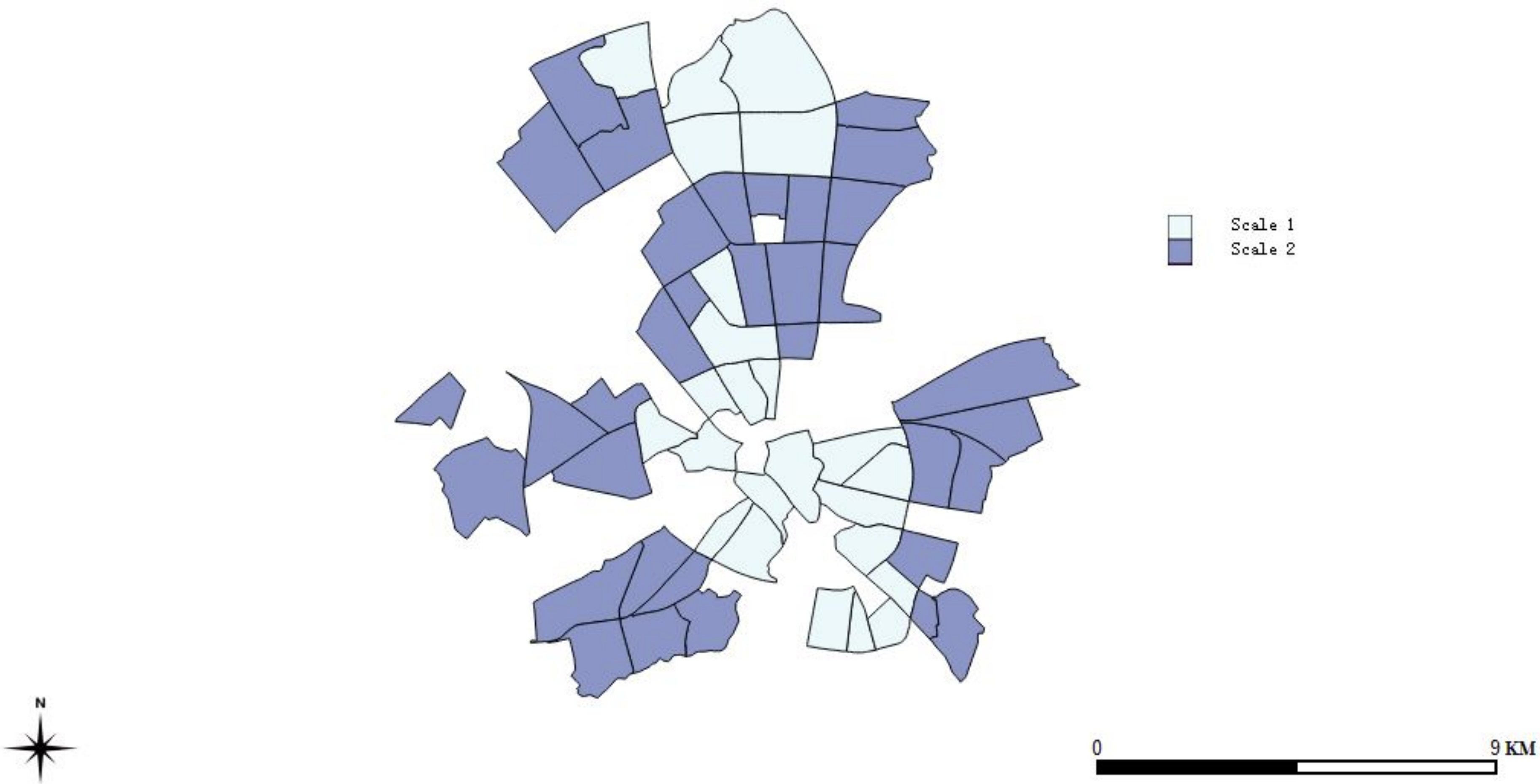
Appendix-E

Population Density Map

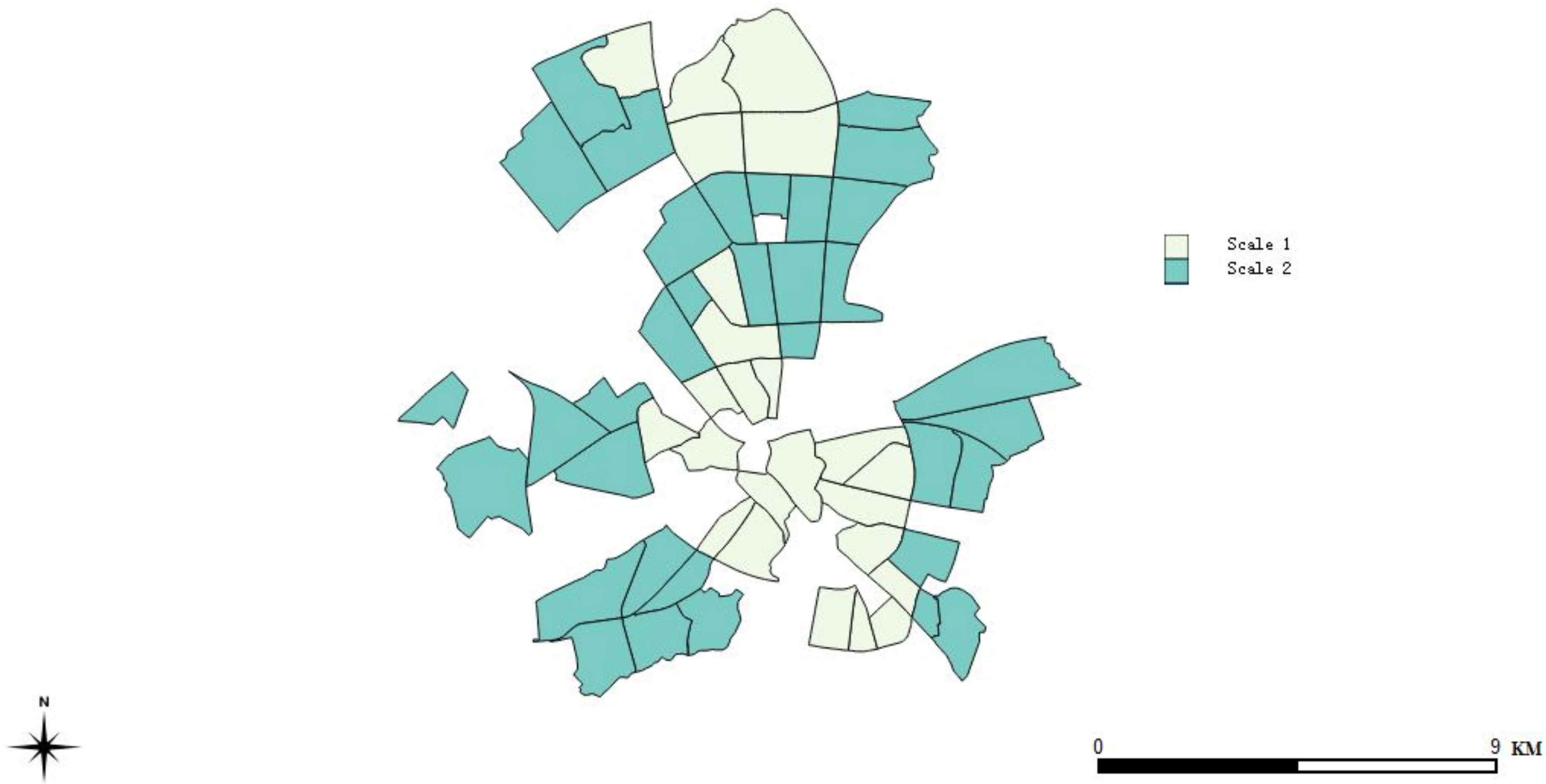


Released Space Map

Land Price in Terminal Building Area



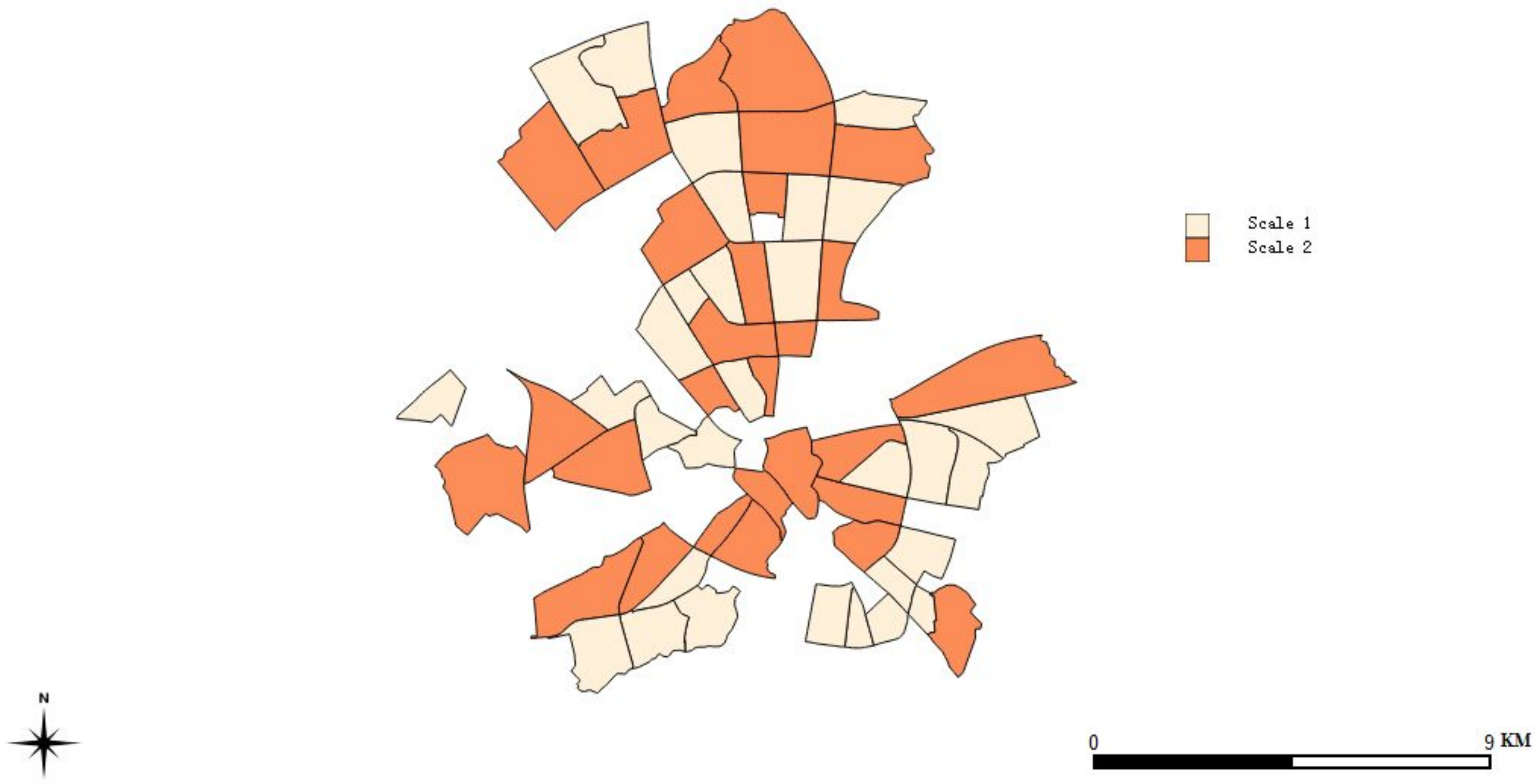
Land Price in Community



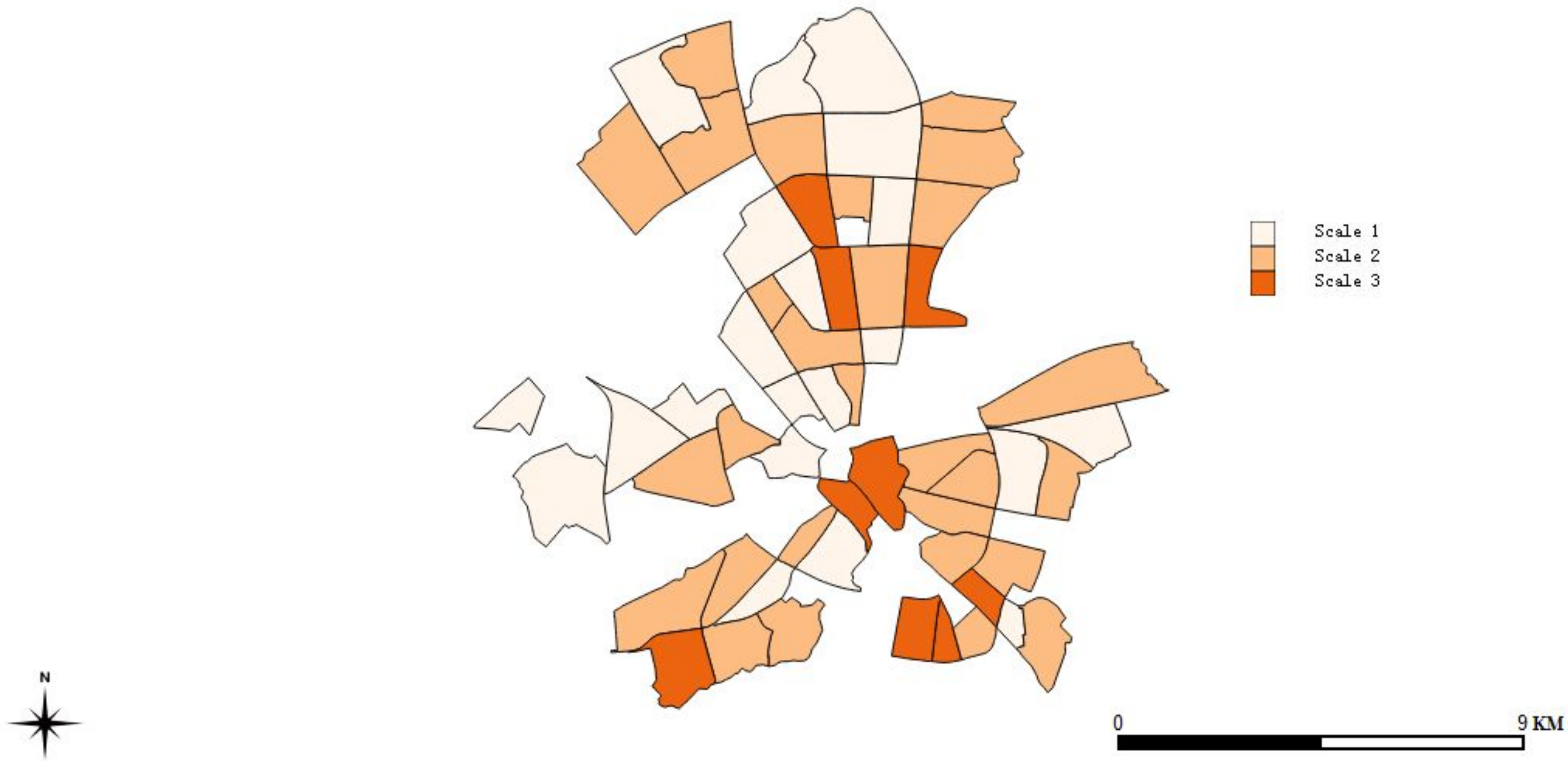
Maximum Population Amount of Other Connected Neighborhood

Highest Road Conditional Level Around Terminal Building

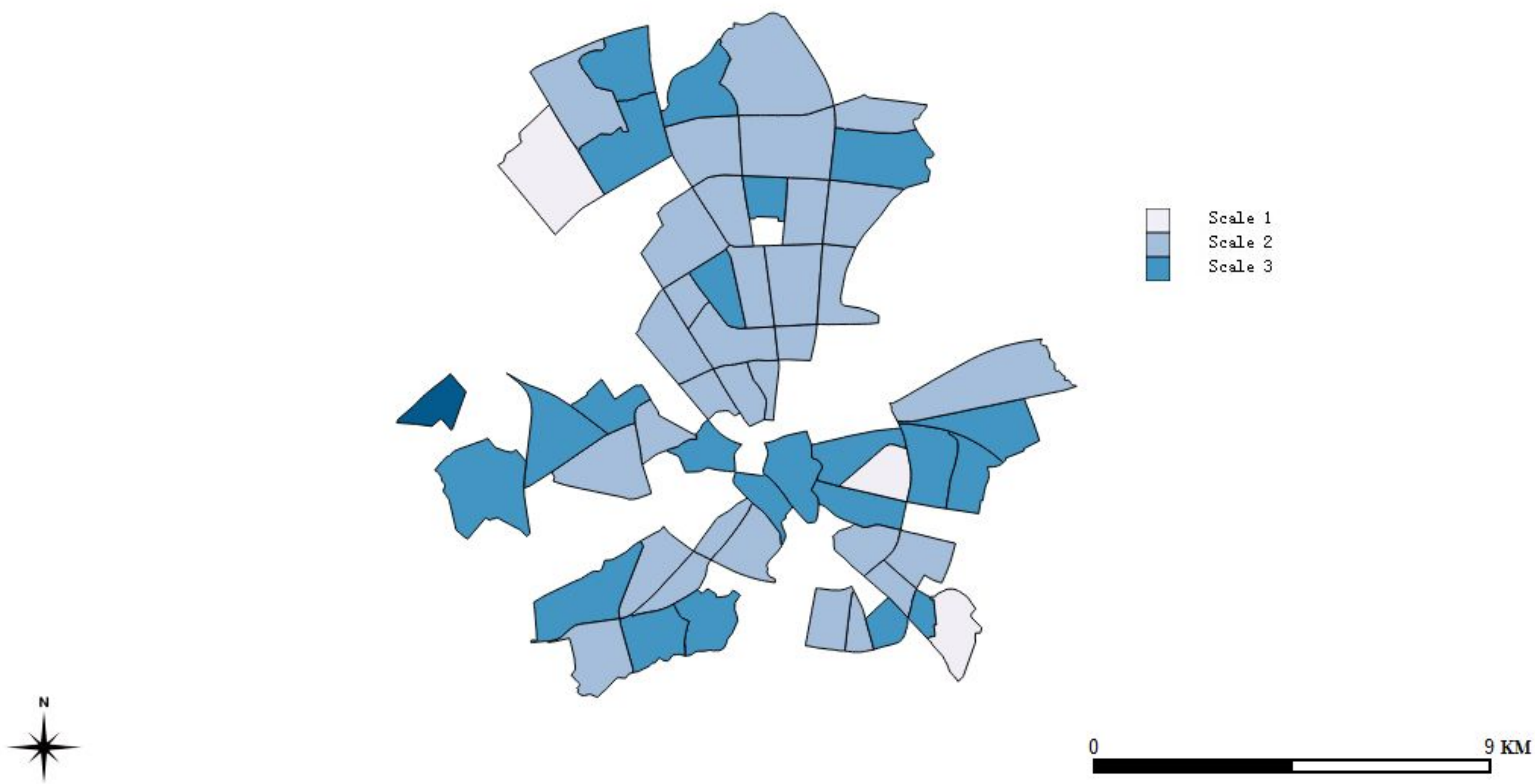
Town House Density



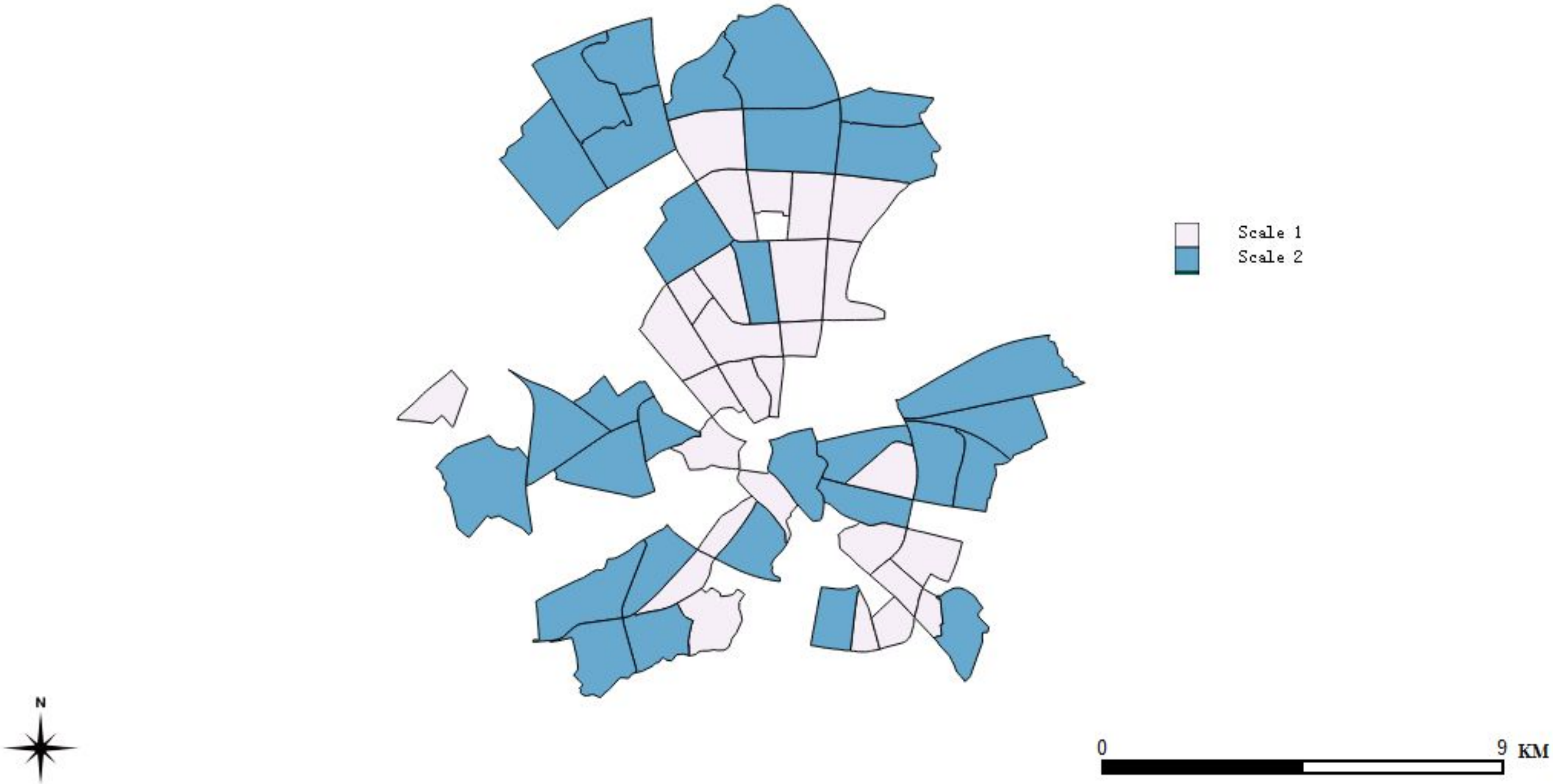
Bus Stop Covering Rate



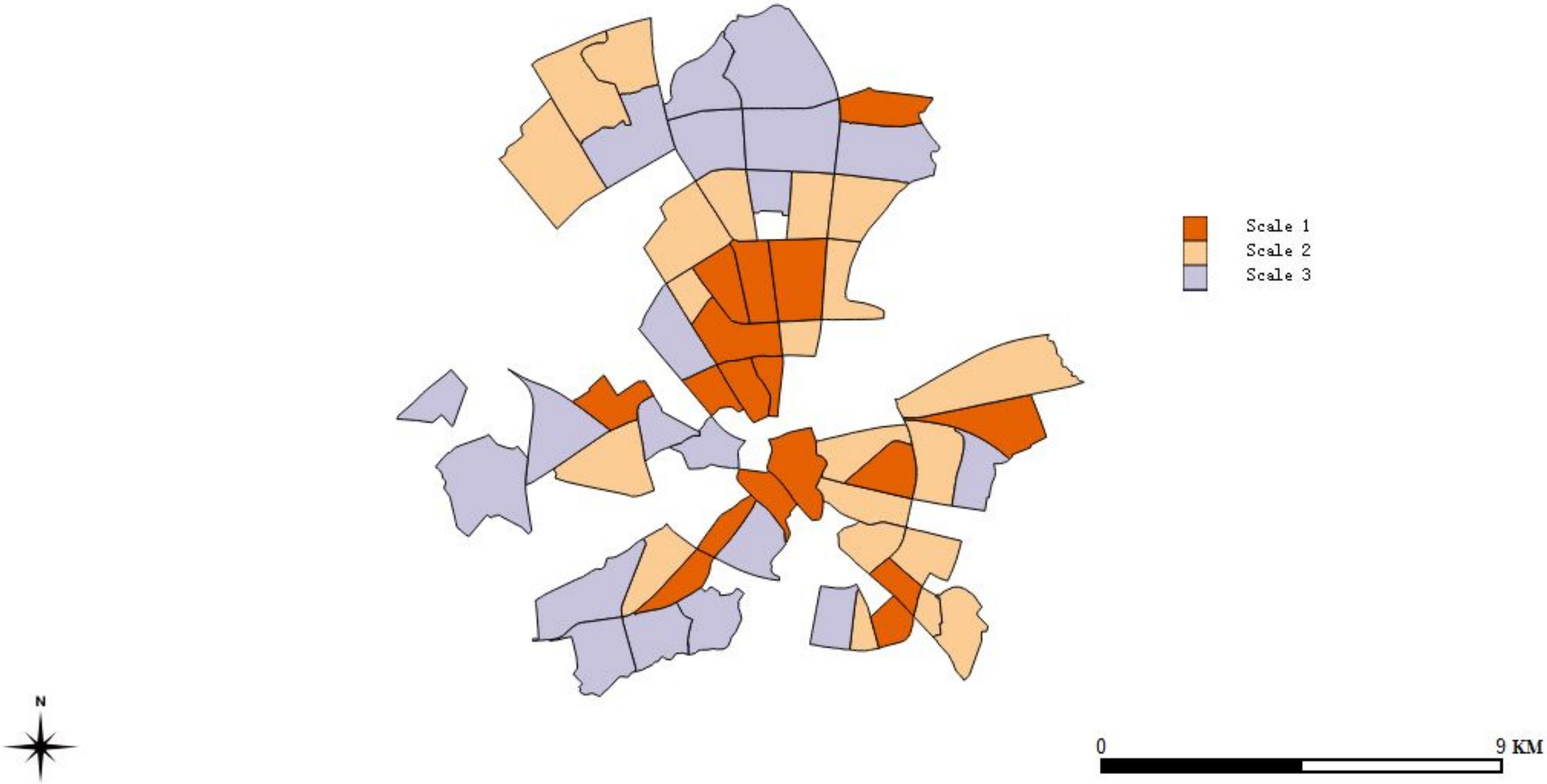
Road Conditional Level in Community



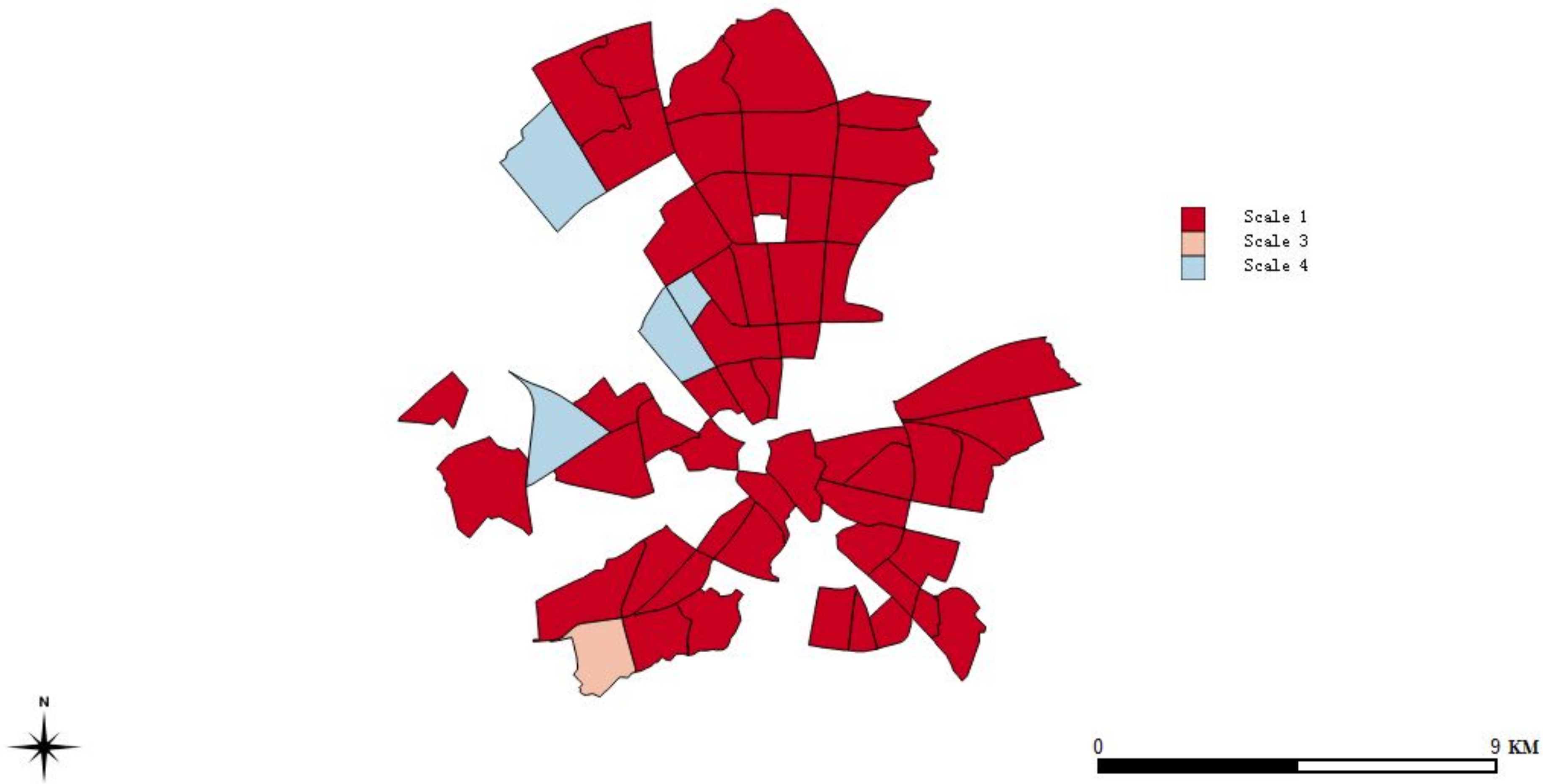
Building Density



Nearest Distance From Residential Building to Terminal Building



Soil Type Map



Pickup Trucks Travel Distance