



ESTABLISHING AN OBJECT IDENTIFICATION METHOD BASED ON THE DESCRIPTION OF NEIGHBOURING ELEMENTS

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ESTABLISHING AN OBJECT IDENTIFICATION METHOD
BASED ON THE DESCRIPTION OF NEIGHBOURING
ELEMENTS

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By:

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Cathelijne Kleijwegt: *Establishing an object identification method based on the description of neighbouring elements* (2019)

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ABSTRACT

Broken glass from a bus stop, litter on the ground, a broken lamppost, and more things like this can be encountered in a municipality. To improve the process of mapping the issues and fixing them Fixi is developed by Decos. Fixi is an application in which citizens can report issues in public space. A citizen can report the issue he or she encounters in Fixi and the handlers of the municipality will use this inventory to improve the quality of the municipality.

The issues are mapped using GNSS or pin-pointing it out on the map, but these options are not always available. This thesis research explores object identification based on the description of neighbouring elements. By providing a method to identify the object by a description, an additional option for reporting issues is made available in Fixi.

The neighbouring elements which are described by the user will function as reference points for the method. By combining the information, a suggestion of one or more objects can be presented to the user which should include the described object. The flow from description to output consists of five different elements: *data input, preprocessing of the data, user input, processing, and output*. Three versions of input and processing are developed and tested in this thesis research. (1) With spatial relationships and distances indicated by the user, (2) with spatial relationships, and (3) with distances indicated by the user. The type of elements that can be described by the user are based on the theory of Lynch [1960] and can be categorised in five different types: path, edge, district, node, and landmark.

To test the method, the selectivity of the elements is tested and the output of the process is evaluated. This last test is done based on six criteria: (1) number of questions, (2) presence of object, (3) amount of suggested objects, (4) average distance to elements, (5) covered area of suggested objects, and (6) completion time of description. The tests have been executed on thirty scenarios spread over three municipalities: Westervoort, Amsterdam, and Joure.

All scenarios presented the described object as one of the suggested objects, which means the object has been identified. In general scored version 3 with the distances indicated by the user the best results in the tested cases. Improvements are possible in elements like number of questions, average distance, and completion time.

Keywords: object identification, description, Fixi, elements of a city, public space

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CONTENTS

1	INTRODUCTION	1
1.1	Problem statement	1
1.2	Research questions and scope	2
1.3	Research methodology	3
1.3.1	Phase 1 - Theoretical research	3
1.3.2	Phase 2 - Development method	4
1.3.3	Phase 3 - Testing	4
1.3.4	Phase 4 - Conclude	4
1.4	Reading guide	4
2	LITERATURE REVIEW	5
2.1	Indoor positioning based on landmarks	5
2.2	Elements of a city	7
2.2.1	Theory of Lynch	7
2.2.2	CityGML	8
2.2.3	IMGeo	9
2.3	Geocoding	9
2.4	Map matching	10
2.5	Spatial relationships	11
2.5.1	4-Intersection Model	11
2.5.2	9-Intersection Model	12
2.5.3	Dimension Extended Model	12
2.5.4	Calculus Based Model	13
2.6	Conclusion	13
3	METHODOLOGY	15
3.1	Input: data	15
3.2	Preprocess data	16
3.3	Input: user	16
3.4	Process	17
3.5	Output	18
3.6	Test method	18
3.6.1	Testing elements upon their selectivity	18
3.6.2	Testing the method on requirements	18
4	IMPLEMENTATION AND RESULTS	21
4.1	Implementation for the Fixi case	21
4.1.1	Data	21
4.1.2	Preprocess data	23
4.1.3	Input of the user	23
4.1.4	Process	27
4.1.5	Output	35
4.2	Results of tests	36
4.2.1	Test of elements	36
4.2.2	Test three versions of method	36
5	CONCLUSIONS	43
5.1	Answers to research questions	43
5.1.1	Sub-questions	43
5.1.2	Main research question	45
5.2	Contribution	45

5.3	Reflection and discussion	46
5.4	Recommendations and future work	46
A	SELECTED OBJECTS FOR TESTING	51
B	OBJECT DESCRIPTIONS FOR TESTING	55

LIST OF FIGURES

Figure 1.1	Phases of methodology	3
Figure 2.1	Examples of landmarks	5
Figure 2.2	Geometric representation of landmarks	6
Figure 2.3	Elements of a city	7
Figure 2.4	Five different Levels of Detail	8
Figure 2.5	Example of geocoding	10
Figure 2.6	Example of map matching	10
Figure 2.7	2x2 matrix of the 4 Intersection Model	12
Figure 2.8	3x3 matrix of the 9 Intersection Model	12
Figure 3.1	Schematic overview of the implementation	15
Figure 4.1	Form for version 1: spatial relationships and distance	25
Figure 4.2	Form for version 2: spatial relationships	26
Figure 4.3	Form for version 3: distance indicated by the user	27
Figure 4.4	General overview of the selection process	28
Figure 4.5	Process for selection neighbourhood	29
Figure 4.6	Process neighbourhood	29
Figure 4.7	Process for selection first street	30
Figure 4.8	Selection of first street	31
Figure 4.9	Process for selection second street	31
Figure 4.10	Selection of second street	31
Figure 4.11	Process for selection first feature	32
Figure 4.12	Selection of first feature	32
Figure 4.13	Process for selection second feature	33
Figure 4.14	Process for selection railroad	34
Figure 4.15	Process for railroad selection	34
Figure 4.16	Process for selection roadtype	35
Figure 4.17	Process for selection roadtype	35
Figure 4.18	Remaining percentage of objects after first selection	37
Figure 4.19	Outcomes test version 1	39
Figure 4.20	Outcomes test version 2	40
Figure 4.21	Outcomes test version 3	41
Figure 4.22	Overview six criteria	41
Figure A.1	Selection of 10 objects in Westervoort	52
Figure A.2	Selection of 10 objects in Amsterdam	52
Figure A.3	Selection of 10 objects in Joure	53

LIST OF TABLES

Table 2.1	Spatial relationships between objects in the CBM	13
Table 3.1	Elements of Lynch [1960] and examples of them	16
Table 3.2	Test matrix of m scenarios and n elements	18
Table 3.3	Requirements to test the developed method	19
Table 4.1	Types of Lynch and their elements	21
Table 4.2	Amount of elements before and after preprocessing	23
Table 4.3	Spatial relationships in Fixi notifications (in Dutch)	24
Table 4.4	Overview three different versions of the developed method	24
Table 4.5	Selectivity order of elements per municipality	36
Table 4.6	Count of scores per version	42

ACRONYMS

4-IM	4-Intersection Model	11
9-IM	9-Intersection Model	11
ADE	Application Domain Extension	9
BAG	Basisregistraties Adressen en Gebouwen	22
BGT	Basisregistratie Grootchalige Topografie	7
BRK	Basisregistratie Kadaster	22
BRT	Basisregistratie Topografie	22
CBM	Calculus Based Model	11
CBS	Centraal Bureau Statistiek	22
DEM	Dimension Extended Model	11
DSM	Digital Surface Model	47
GIS	Geographic Information System	4
GML	Geography Markup Language	9
GNSS	Global Navigation Satellite Systems	1
LBS	Location Based Services	1
LoD	Level of Detail	8
NWB	Nationaal Wegen Bestand	22
OGC	Open Geospatial Consortium	8
OSM	Open Street Map	15
PDOK	Publieke Dienstverlening Op de Kaart	15
PDR	Pedestrian Dead Reckoning	6
XML	eXtensible Markup Language	9

1

INTRODUCTION

In case you find a broken lamppost, you would like to inform the municipality about this so they can fix it. The company Decos has developed an application called Fixi in which these kind of issues in public space can be reported. Other examples are broken glass from a bus stop, litter on the ground or a tree which has fallen down after a storm. Fixi provides an easy way of reporting these issues through a mobile phone application and a website. The citizen does not have to make a phone call to the municipality and feedback about the progress of fixing the issue is automated. In the current system, the notifications are identified by a position which is determined using the Global Navigation Satellite Systems (GNSS) function of the mobile phone or computer of the user. In case there is no GNSS signal available the citizen can pin-point the issue manually on a map, but this is not always possible.

In this thesis research the possibility of object identification for the Fixi case is explored. The objects will be identified based on the description of neighbouring elements. This method is then tested and compared to requirements to see whether the method is concerned useful and applicable.

1.1 PROBLEM STATEMENT

The example of the lamppost is a specific case, since it is not visible for the handler to see exactly which one is not working during the day. For this reason, it is important that the object can be identified and reported instead of a position (which has a certain accuracy error) that can represent the lamppost. This is also applicable for other issues of which it is important for the handlers to have extra information about the object (like which tools they need to bring to fix it).

Often, the position of the object is reported by the user. But the team of Fixi also encounters issues in which people have turned off their GNSS function on their mobile phone or they are not present at the position of the issue at the moment they report it (the issue can be on the other side of a lake or busy road, or the citizen has seen it on the route to work). Besides that, not all people are used or trained at positioning themselves, or an object, on a map. An alternative way of reporting an object could be by identifying the object based on the description of the surroundings. After the object has been identified, the position can be retrieved and reported together with a unique ID. Therefore the aim of this thesis research is:

To research the possibility of object identification based on the description of neighbouring elements

The described surrounding elements function as reference points for both the reporter and receiver and are used to identify the object. By developing a method of identifying an object based on the description of the surrounding elements, a third way of reporting an object is made available in Fixi (besides GNSS positioning and pointing out on a map).

Next to use within Location Based Services (LBS) applications like Fixi, other examples that take advantage of this research are when your car breaks down, or when an ambulance has to be navigated to an emergency scene. Either the position

cannot be determined by GNSS, or the position of the GNSS device is not relevant and a different position has to be reported. These two cases can be solved by identification based on the description of the surrounding elements. This method is based on the information of the existing surrounding elements to identify the object.

Social benefits of providing the opportunity to describe the surroundings are related to the professional fields that benefit from it. The above mentioned cases of the broken down car and ambulance can provide a better service for the users and therefore they benefit from it. A person with a broken down car can be found, the ambulance personnel is provided with a position which is aligned with the description of the user or the issue can be reported and the broken bus stop can be fixed.

1.2 RESEARCH QUESTIONS AND SCOPE

This thesis research explores the possibility of identifying an object based on the description of the surrounding elements. To reach this aim, the following research question is formulated:

“Can an object identification method be established based on the description of neighbouring elements?”

This research question covers different aspects and to be able to address them all, the following five sub-questions are formulated:

1. *What type of surrounding elements can be considered for the description of an object?*
There are many elements available in the outdoor environment that can be applied in this method to describe an object. This research question assesses which type could be considered.
2. *Which datasets are available that provide the position of those elements?*
In order to use the neighbouring elements as a reference point the position of those elements must be known.
3. *What kind of spatial relationships can be used as an input?*
Each element has a certain spatial relationship with the object that has to be reported. This can be of great value for the method.
4. *What method can be used to process the input?*
After the input (data and description) is complete, the different information elements have to be combined to identify the object which the user would like to report.
5. *To what extent does the developed method meet certain requirements?*
In order to test the usability and reliability of the method, it will be tested according to set requirements.

Since time and resources are limited, this thesis research is scoped down in order to reach the main aim. The following paragraphs describe what will be included into the research scope and what will be held out of the scope of the research.

Spatial - This thesis research is firstly spatially restricted to the municipality of Westervoort. This is due to the coverage and completeness of their (open) data. The municipality of Westervoort is a customer of Decos and therefore easy to contact and ask for additional information in case this is required.

After the methodology is developed and tested for the municipality of Westervoort, the methodology is also tested upon the municipality of Amsterdam and

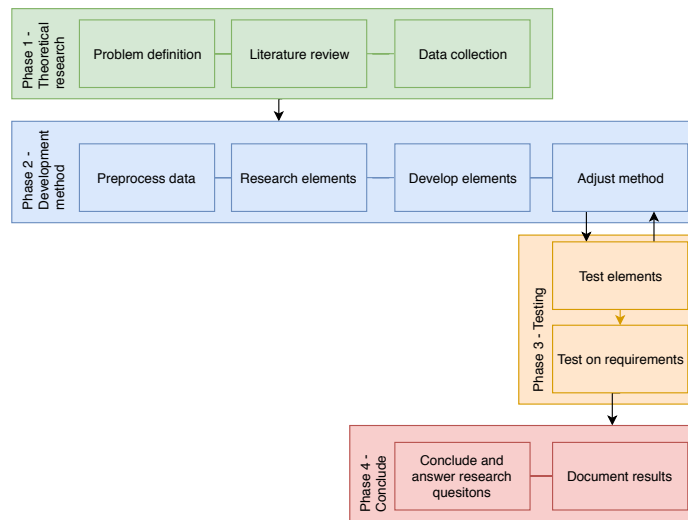


Figure 1.1: Phases of methodology

Joure to test the method on different regions and compare the outcomes.

Data - The data used in the method and to test the method is considered ground truth. Meaning it is considered that the data is both correct and complete if compared to the real world.

Input of the user - There are several techniques to apply for the input of the user in this method, but only input with written text will be considered. Other types of input, like pictures or speech, will be held out of scope. A form is created for the user which can be filled in by both the process and the user. Besides the type of input, it is also considered that the input of the user can be trusted completely and that the user can estimate distance between objects correctly.

Implementation - Due to the main aim of this thesis research, a method will be developed that translates the description of the surroundings to an object. This will be a method that can work independently from Fixi in order to function as a test case and therefore the method will not (yet) be implemented into the application.

In order to test the method, requirements have been set on which the method will be tested upon after the method is implemented. These requirements are presented in [Chapter 3](#).

1.3 RESEARCH METHODOLOGY

In order to answer the research questions presented in [Section 1.2](#), the methodology is divided into four phases: *theoretical research*, *developing method*, *testing and concluding*. [Figure 1.1](#) shows an overview of these phases and each of them will be discussed in the following paragraphs. In theory, a phase seems to end as the next one starts. But in practice, there is an iterative process between the phases and elements are executed, if needed, multiple times, to get the desired result.

1.3.1 Phase 1 - Theoretical research

In the first phase the theoretical research is conducted. First, the problem of the research is defined and the research questions are formulated. Next, a literature

review is done on researches related to this thesis research. In order to get a better understanding of researches and concepts that have been conducted on topics related to this research. An overview of these researches can be found in [Chapter 2](#). The last part of this phase was data collection and data evaluation. During the process of this phase, but also the rest of the research, the research questions changed based on the gained insights during the thesis research.

1.3.2 Phase 2 - Development method

After theoretical research, the collected data is pre-processed. Then, the elements that will be part of the method are researched. A closer look is taken on what they are, how they can be implemented and what kind of context they need before they can be operational. Then, the elements are developed in the needed context.

The method is developed in QGIS, which is an open source Geographic Information System (GIS) that can visualise, manage, edit and spatially analyse data. QGIS has been chosen because of previous experience of the author in creating an interactive and (partly) automated process in this software. QGIS also provides a big range of tools for spatial analysis which can be called from a script.

The development phase is strongly iterative with the next phase: testing. After testing elements, they are improved or changed according to the outcome.

1.3.3 Phase 3 - Testing

In the process, elements of the method are tested whether they function as expected. These outcomes are used to improve the elements and the method, and this is then tested again. After the iterative process of developing and testing has finished, the method is tested according to the requirements that have been set. For this test three different versions of the method are developed and tested based on six requirements.

1.3.4 Phase 4 - Conclude

This phase is focused on concluding, answering research questions and documenting. Based on the conducted research, this thesis report is written. The process, outcomes and conclusions of the thesis research are documented and evaluated in this phase.

1.4 READING GUIDE

This thesis report is structured the following way:

- [Chapter 2](#) provides an overview of researches which are related to this thesis research. The methods and concepts which are relevant or required to understand this thesis research will be presented.
- [Chapter 3](#) describes the method in theory. The five main elements: the data input, the preprocessing of the data, the input of the user, the process and the output.
- [Chapter 4](#) presents the implementation in the context of the Fixi case and the results of the tests upon this implementation.
- At last, [Chapter 5](#) concludes by answering the research questions, a reflection and discussion, and recommendations and future work.

2 | LITERATURE REVIEW

The following sections provide an overview of a literature review of researches that are related to this thesis research. [Section 2.1](#) elaborates on conducted research on indoor positioning based on landmarks. [Section 2.2](#) discusses the elements of which a city consists. After that, [Section 2.3](#) provides insight on geocoding and the main elements of a geocoder. Then, [Section 2.4](#) continues on map matching, what it is and how available information can improve the output. [Section 2.5](#) presents the different types of technical spatial relationships between objects. At last, a conclusion is presented on this chapter in [Section 2.6](#).

2.1 INDOOR POSITIONING BASED ON LANDMARKS

[Willems \[2017\]](#) and [Yu and Shen \[2018\]](#) research positioning based on landmarks. Landmarks can be defined in many different ways, but in most researches: unique, salient, different from surroundings can be extracted. This can be on a bigger (world or national) scale or on a local scale, examples of this can be seen in [Figure 2.1](#). Landmarks are described to be the most salient elements in the surrounding of a user. According to [Kattenbeck \[2017\]](#), the salience of a landmark is based on six criteria: visual salience, cognitive salience, structural salience, visibility in advance, prototypicality and uniqueness.

[Willems \[2017\]](#) assesses a pure-landmark approach for indoor positioning. A fingerprinting method is developed in which landmarks from an indoor environment are used for positioning. These landmarks are manually selected based on their salience. [Willems \[2017\]](#) takes into account the visibility of an object and the presence of obstacles which can block the visibility. Each landmark is generalised into one of the geometric representations: point, line, polygon, and set of lines (see [Figure 2.2](#)). For each of these geometric representations is the visibility defined and analysed. The selection and classification of these landmarks is done manually. This manual processing is not possible in the process conducted in this thesis research, since it is meant for a bigger scale. The selection and collection of all elements must be available already by the municipality. [Willems \[2017\]](#) applies ray-casting algorithms to calculate the area from which the landmark is visible. The obstacles are



Figure 2.1: Landmark examples: (a) Eiffel tower, a landmark on world scale and (b) a bench in a park, a landmark on local scale. Source: WikiCommons

Geometry	When to use	Example
Point	If an object is 360 degrees visible and size doesn't matter	
Line	If an object is only visible from front and/or backside	
Polygon	If the size of an object is sufficiently large that it affects visibility calculation	
Set of lines	If the size of an object is sufficiently large and the sides are visible from a certain angle	

Figure 2.2: Geometric representation of landmarks [Willems, 2017]

taken into account to check from where each landmark is visible, this requires not only information of the landmarks but also about the obstacles.

The research of [Willems \[2017\]](#) is similar to this thesis research, both researches focus on positioning based on the description of the surroundings. Even though they seem very alike and elements from the research are considered for this thesis research, there are some differences. The main difference is the area in which the method is applied. The area of interest of [Willems \[2017\]](#) is an indoor environment while in this thesis research the area of interest is an outdoor environment. This outdoor environment has the size of a municipality and must have the potential to be extended to a bigger area (and ultimately country wide coverage). Therefore must the mapping and selection of the elements be done automatically. Besides that, [Willems \[2017\]](#) uses elements that are considered landmarks, while in this thesis research other elements can be considered useful for the positioning as well.

[Yu and Shen \[2018\]](#) develop an analytic framework for landmark learning in localisation. In this method, a position is determined and then refined by inter-landmark measurements. The measurements are signals as displacements between landmarks and users. Which means that, from the last detected landmark, the user is tracked by Pedestrian Dead Reckoning (PDR). These measurements are processed by an algorithm which improve the precision of the position.

Besides the fact that [Yu and Shen \[2018\]](#), like [Willems \[2017\]](#), only use landmarks as reference points, the research makes use of the distance to each landmark. For [Yu and Shen \[2018\]](#) the measurements are made by sending signals, but in this thesis research these distances can be estimated by the user. By knowing distances between the object and the surrounding elements, cases which do not align with these distances can be excluded from the outcomes. Whilst the cases that have similar distances can be taken into account.

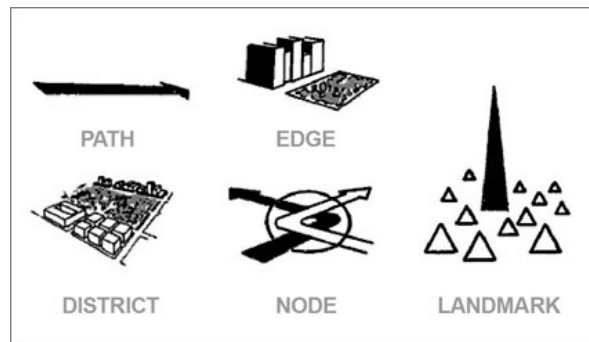


Figure 2.3: Elements of a city [Scholarship, 2010]

2.2 ELEMENTS OF A CITY

To describe the neighbouring elements, theories and data models are possible to categorise the elements. Lynch [1960] describes the public space in five different types. CityGML is a standard international data model with the focus on semantics of objects. The IMGeo is a Dutch data model in which these elements can be stored and the Basisregistratie Grootschalige Topografie (BGT) is a part of this. Each of these representations of the public space can function as a categorisation method for the described elements.

2.2.1 Theory of Lynch

The elements that are used in this method function as reference points for the object that is identified. The elements considered in this thesis research are based on the elements that are present in public space. According to Lynch [1960], a city can be decomposed into five different elements: *paths*, *edges*, *districts*, *nodes*, and *landmarks* (see Figure 2.3). Lynch [1960] limits its research to the physical objects. Other influences as (social) meaning or history are not taken into account. How each of these five elements are characterised according to Lynch [1960] is discussed in the following paragraphs.

The first element Lynch [1960] defines is *paths*. These are the linear elements of the city along which a user can move. Examples of these are streets, walkways, canals, and railroads. Paths take a prominent place in the image of the user since it is used as a network to move upon.

The second element discussed in the research is *edges*. Like paths, edges are linear elements but they are not used or considered to move upon and seen as boundaries. Edges split two elements and function as breaks between them. Examples of edges are shores, railroad cuts, and walls. Edges can be crossed or penetrated but can also be physical barriers which close off one region from another. Edges are important organising elements, mainly to hold together generalised areas such as a playground with a fence around it. If an edge is not only visually prominent but also impossible to penetrate, it is considered as a more prominent element.

The elements of *district* are sections of a city that are medium to large sized. They have a 2-dimensional extent and the observer can be in the 'interior' or 'exterior' of this element. This element can be used as a reference for the interior and, if visible from the outside, as a reference for the exterior. This can be useful if a person goes inside a district, passes by, or is moving towards it.

Nodes are point-like elements, that can be considered as strategic spots in a city. These points can be considered intensive focus points for the observer from or to which it travels. It is possible for the observer to enter these nodes, but not necessary. Often nodes are junctions, breaks in transportation, crossings or splitting paths,

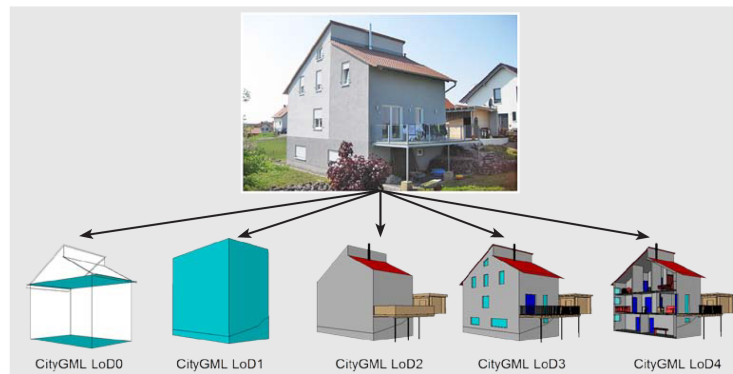


Figure 2.4: Five different Levels of Detail [Löwner et al., 2012]

or places in which a structure is changed. It could also be that a node gets its importance from its use or physical character, like a meeting point. A node can function as a junction point as well as a concentration point.

At last, Lynch [1960] describes the element *landmark*. Landmarks are, like nodes, point references, but the user cannot enter them: a landmark can only be observed as an external element. Often a landmark is a simply defined physical object, elements such as a building, sign, mountain, and statue. The character of a landmark becomes stronger by uniqueness and specialisation: some aspect that is unique or memorable in the context (Lynch [1960]). Landmarks become more prominent if they have a clear form, contrast with their background, and are prominent in their spatial location (Al-Kodmany [2001]). Landmarks can vary in scale, therefore they can be visible locally or globally. Local landmarks are only visible from certain areas or angles. Examples are storefronts, trees, or other urban details. Global landmarks are elements that are visual from a greater distance that provide a constant direction. Isolated towers, golden domes, and the sun are examples of global landmarks. Landmarks are often used to structure and to provide clues and are relied upon more after a journey becomes more familiar to a person.

2.2.2 CityGML

CityGML is a standard international data model of the Open Geospatial Consortium (OGC) with the main focus on 3D city models (Gröger and Plümer [2012]). For the topographic objects in public space, the data model defines the 3D geometry, topology, semantics, and appearance (Löwner et al. [2012]). The data can be represented in Level of Detail (LoD) 0 to 4, and the detail of geometry representation increases with the LoD (see Figure 2.4).

Not only the geometry of an object is stored in the data model, but also the semantic definitions of the objects, their relationship to other objects, structure, and taxonomy. This additional information of an object provide the possibility for advanced analysis and visualisation. These additional functionalities are not available in purely geometrical models like VRML, X3D, and KML because they do not provide enough semantics (Kolbe [2009]).

CityGML models different kinds of topographic objects in public space, not only buildings. Each of those elements are organised into modules and a semantic definition, attributes, relationships, and a 3D spatial representation are provided. The following elements are part of the standard modules:

- Core
- Building
- Relief
- Tunnel

- Bridge
- Transportation
- Water body
- Vegetation
- City furniture
- Land use
- Group
- Generics

The geometry and topology of the objects are represented Geography Markup Language (GML) which is an other standardised model model of OGC and based on eXtensible Markup Language (XML). It is possible to extend CityGML for specific applications. Feature types and properties can be added to the existing data model by Application Domain Extension (ADE).

2.2.3 IMGeo

IMGeo is the information model which includes the legally required registration BGT (Geonovum [2018]). A greater amount of object types can be stored in the IMGeo in addition to the BGT (Ministerie [2018]). The IMGeo has been developed since the need to store more than the standard objects of the BGT was detected at organisations. The IMGeo is a common standard for these organisations and municipalities. If a common standard would not be available, the different organisations will use different names for the same type of object (like lamppost or streetlight).

The BGT stores mainly the buildings, roads, water and green elements etc. The IMGeo provides the opportunity to store the objects in public space like bins, street furniture, bridges, and street signs. More about the BGT can be found in Section 4.1.1.

2.3 GEOCODING

The method that is developed in this thesis research translates a description of an object (by its surrounding elements) to the location of that object. This process is similar to geocoding, therefore insights on geocoding and its elements can be relevant.

An example of a reverse-geocoder is What3Words (translating a coordinate to three words). Google Maps includes a geocoder that is one of the better known, in Google Maps one can search on an address and retrieve the coordinates or vice versa (see Figure 2.5). Different interpretations and definitions of geocoding exist, but in general geocoding is a geospatial operation that converts addresses or any other description to a geographic position. If literally interpreted from Latin, geocoding has the meaning 'to assign a geographic code'. This interpretation does not constrain or prescribe any elements of the geocoding system (Goldberg et al. [2007]).

Geocoding has developed in the past decades. When in the past it was very expensive to do so, now geocoding can be done for free with online services and the process is even of a better quality than before Goldberg et al. [2007]. The research of Goldberg et al. [2007] describes the four fundamental elements of a geocoder: the input, output, processing algorithm, and reference dataset.

- *Input* - the location the user wants to have geographically referenced.
- *Reference dataset* - the data to which the input is compared.
- *Processing algorithm* - determines the geographic code.
- *Output* - the geographically referenced position.

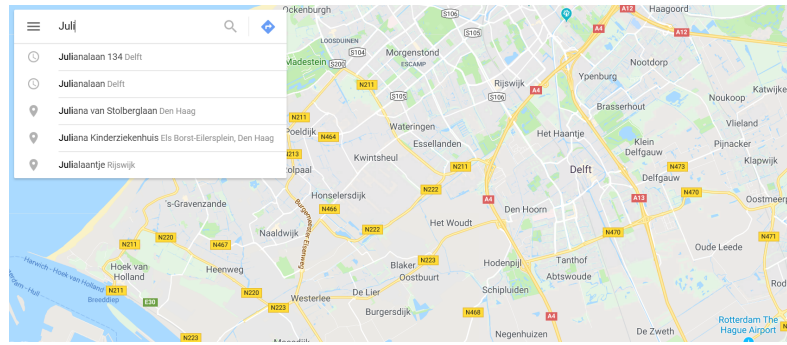


Figure 2.5: Example of geocoding: finding coordinates based on street names. Source: Google Maps

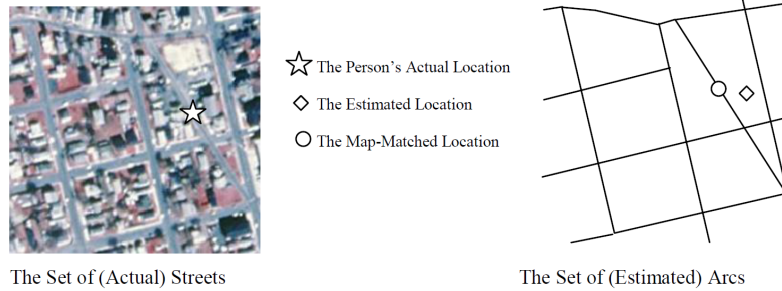


Figure 2.6: Example of map matching [Greenfeld, 2002]

2.4 MAP MATCHING

In the process of identifying an object based on the description of neighbouring elements, information can be processed in the procedure in order to provide the user with relevant options. By using prior knowledge in the procedure, a better outcome can be expected. This is also done in map matching.

Map matching is a method driven by an algorithm that improves the retrieved position of a user by referencing the position to a map (White et al. [2000]). By this map, prior knowledge is available on possible positions of the user. Several strategies are available to develop a map matching algorithm, but this is dependant on the amount of prior knowledge. There are three scenarios which can be considered with a different amount or kind of prior knowledge. The first scenario is when a user is travelling on a fixed network. This can be a network of trains or busses, they both travel on a predetermined network. This network provides all possibilities for the position, and excludes other options outside the network. The second scenario is when a user provides a destination and a travelling route is suggested. In this case, the assumption is that the user follows this route but this is not guaranteed since the user is free to follow any other route. Matching is primarily done on the suggested route and as soon as the user deviates from this route a new one will be computed. Then, the matching is done based on this new route. The last scenario is one without any prior knowledge regarding to the possible position of the user. The matching is done in this case by the coordinates and the known street network. This last scenario is taken into account in the research of Greenfeld [2002]. An example of a map matched position without any prior knowledge besides street network can be found in Figure 2.6.

The proposed map matching procedure in the research of Greenfeld [2002] is based on topological analysis and the only coordinate information that is used is the observed position of the user. No prior knowledge of expected routes, speed information and GNSS determined orientation are implemented. Matches between a

coordinate and a position on the network are made by analysis on the shortest distance and the possibility rate based on previously determined positions. As soon as an initial match is found from the first coordinate, matches based on this information and the next coordinates that follow will be looked for. Exceptions are made and the search is reset if the distance between two fixes is too big, or if the time difference between two measurements is too big.

The method that is developed in this thesis research uses, like map matching, the available information to improve the outcome. By having prior knowledge of the elements and the type of object that will be identified, analysis will be done to determine an object. The fact that an object will be reported can be exploited this way, only the positions that belong to this kind of object are possible to be returned. For example, if a street lantern is reported only the positions of a street lanterns are possible positions and not the ones of bus stops or manholes.

2.5 SPATIAL RELATIONSHIPS

By describing an object based on its neighbouring elements, spatial relationships can be described by the user to provide additional information about the relationship between the object and the element. These spatial relationships are then to be translated into technical topological relationships to be processed in the method.

Topological relationships between objects are often used in GIS and several researches have been conducted on this topic. Four different methods have been developed to categorise these topological relationships which are the 4-Intersection Model (4-IM), the 9-Intersection Model (9-IM), the Dimension Extended Model (DEM) and the Calculus Based Model (CBM). Each object is generalised into either a point, line or area element according to the following definitions of Egenhofer and Herring [1990]. A *point* is defined as a single 0-cell in \mathbb{R}^2 . A *line* is a sequence of connected 1-complexes in \mathbb{R}^2 in such way that they never cross each other or form closed loops. A line can be a simple line (a line with two disconnected boundaries) or a complex line (a line with more than two disconnected boundaries). An *area* is defined as a 2-complex in \mathbb{R}^2 with a non-empty, connected interior. The subsets of an area are: area without holes (an area with connected exterior and connected boundary) or area with holes (an area with a disconnected exterior and a disconnected boundary). From these three elements six different combinations can be made to consider in the model:

1. Point / point
2. Point / line
3. Point / area
4. Line / line
5. Line / area
6. Area / area

In the four models, which are described in the following sections, the six combinations are evaluated based on relations between elements of each object. On which elements of the objects they are evaluated is specific to the model.

2.5.1 4-Intersection Model

The 4-IM evaluates the topological relations in \mathbb{R}^2 , considering the interior and boundaries of the objects. These elements are defined in Egenhofer and Herring

$$M = \begin{pmatrix} \partial\lambda_1 \cap \partial\lambda_2 & \partial\lambda_1 \cap \lambda_2^\circ \\ \lambda_1^\circ \cap \partial\lambda_2 & \lambda_1^\circ \cap \lambda_2^\circ \end{pmatrix}.$$

Figure 2.7: 2x2 matrix of the 4 Intersection Model [Clementini and Di Felice, 1995]

$$\begin{pmatrix} (A^\circ \cap B^\circ) & (A^\circ \cap \partial B) & (A^\circ \cap B^-) \\ (\partial A \cap B^\circ) & (\partial A \cap \partial B) & (\partial A \cap B^-) \\ (A^- \cap B^\circ) & (A^- \cap \partial B) & (A^- \cap B^-) \end{pmatrix}$$

Figure 2.8: 3x3 matrix of 9 Intersection Model [Egenhofer and Herring, 1990]

[1990]. The boundary of a feature λ is presented as $\partial\lambda$ and the interior as λ° . This results in the 2x2 matrix as is shown in Figure 2.7. For each combination in the matrix the topological relation can be either empty (no relation) or non-empty (a relation). The combination of this 2x2 matrix and two options results in total in $2^4 = 16$ combinations per type of object combinations, which means a total of $16 \times 6 = 96$ combinations. After evaluating the 96 spatial combinations for the six different combinations of features it can be concluded that only 37 of those are distinct, mutually exclusive and geometrically possible. Point/point (2), point/line (3), point/area (3), line/line (12), line/area (11), area/area (6) (Clementini and Di Felice [1995]).

2.5.2 9-Intersection Model

The 9-IM is an extended version of the 4-IM, which can distinguish more details (Egenhofer and Herring [1990]). In the 9-IM the topological relations are described according to the boundary ($\partial\lambda$) and interior (λ°) like the 4-IM but also according to the exterior. The exterior of a feature λ is presented as λ^- . These three elements for each feature result in a 3x3 matrix as shown in Figure 2.8. For each of these combinations is also the option to be either empty or non-empty, resulting in a total of $2^9 = 512$ combinations per object combination. Out of those combinations there are only 56 actually distinct, mutually exclusive and geometrically possible. These are distributed as follows: point/point (2), point/line (2), point/area (3), line/line (23), line/area (19), area/area (6) (Clementini and Di Felice [1995]). If the 9-IM is compared to the 4-IM, the main difference is that it provides the possibility to distinguish more relations for the line/line and line/area cases.

2.5.3 Dimension Extended Model

In the DEM, not only the intersection of two features is taken into account but also their dimension. According to Clementini and Di Felice [1995] can the DEM be described as an extension to the 4-IM. The 2x2 matrix as in Figure 2.7 is applied and four values can be considered for each possible intersection of the two features: - = no intersection, 0 = 0D intersection (point), 1 = 1D intersection (line) and 2 = 2D intersection (area). These four possibilities result in theoretically $4^4 = 256$ different cases. For each combination the following rule is defined by Clementini and Di Felice [1995]: "the dimension of the intersection cannot be higher than the lowest dimension of the two operands of the intersection". This rule and other restrictions considering geometry result in total in 52 different cases for the six combinations of features, which is four less combinations than the 9-IM.

	Point/point	Point/line	Point/area	Line/line	Line/area	Area/area
Touch		X	X	X	X	X
In	X	X	X	X	X	X
Cross				X	X	
Overlap				X		X
Disjoint	X	X	X	X	X	X

Table 2.1: Spatial relationships between objects in the CBM

2.5.4 Calculus Based Model

The **CBM** is an other method to classify topological relationships based on object calculus (Clementini and Di Felice [1995]). Five relationships are defined in this method which are mutually exclusive and cover all possible combinations. The five relations are: *touch*, *in*, *cross*, *overlap* and *disjoint*. Not each relation is applicable for each feature combination, on which of the feature combinations the definitions apply is visualised in Table 2.1 and result in a total of 21 distinct combinations for all feature combinations. According to tests of Clementini et al. [1993] is the **CBM** able to describe all cases of the **DEM**, but some of the cases in the **CBM** cannot be represented in the **DEM**. Therefore is the **CBM** more expressive.

2.6 CONCLUSION

Positioning based on landmarks is possible, as Willems [2017] and Yu and Shen [2018] discuss. Not only landmarks but also other objects in public space can be considered in this thesis research. There are five elements of a city described by Lynch [1960]: *paths*, *edges*, *districts*, *nodes*, and *landmarks*. Other types of classifications are CityGML and IMGeo.

For the development of a method to identify an object based on the description of its neighbouring elements the same four elements as a geocoder are needed: *input*, *reference dataset*, *processing algorithm*, and *output* (Goldberg et al. [2007]). These four elements together represent the chain of the method. Each of these elements will have to be evaluated and implemented for the method.

By using the information that is available, the output can be improved. Options can be excluded based on the information that is available by the data or by the input of the user.

At last, are spatial relationships available to describe the objects and the neighbouring elements. The most descriptive is the **CBM** according to Clementini and Di Felice [1995]. The **CBM** presents 21 distinct combinations which are described by five terms: *touch*, *in*, *cross*, *overlap*, and *disjoint*. These five terms will be included by defining the spatial relationships for the implementation in Section 4.1.3.

3 | METHODOLOGY

This chapter describes the methodology of the method. The method generally exists of five elements as can be seen in [Figure 3.1](#): *input and preprocessing of the data, input of the user, the process and the output*. The following sections elaborate more on these five elements. [Section 3.1](#) will discuss the type of data that is needed. Then, [Section 3.2](#) presents how this data must be preprocessed before it can be used. [Section 3.3](#) elaborates on the user input and [Section 3.4](#) on how the input is processed. [Section 3.5](#) discusses the output and at last, [Section 3.6](#) describes how to test the method.

3.1 INPUT: DATA

According to [Lynch \[1960\]](#), a city exists of five different types: path, edge, district, node and landmark. For each of these five types, elements can be used to describe an object. Examples of each type can be found in [Table 3.1](#). For the implementation, elements can be selected which are relevant and of interest of the user concerning the case. In the Fixi case, the elements would be objects that could be reported by the application or other structural elements. Besides the relevance of the elements, it is important that the position of the elements is known in a dataset. The elements will be used as reference points for both the user and the method. Only if the position of the element is known, it can be used as a reference point.

There are several datasets available that provide information about elements in public space. The official Dutch geo-portal, [Publieke Dienstverlening Op de Kaart \(PDOK\)](#), provides a lot of those datasets as open data. The data of this portal is accessible through a viewer, download and web services. The data in this geoportal are official datasets collected by and for the municipalities and government and therefore trustworthy and standardised.

An alternative to the datasets from [PDOK](#) could be the dataset of [Open Street Map \(OSM\)](#), which is also an open source map but covers the entire world. The information is mapped completely by volunteers around the world that can freely

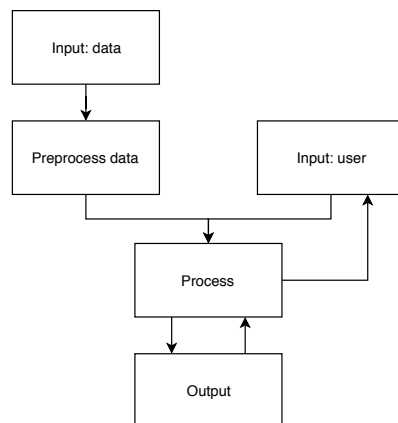


Figure 3.1: Schematic overview of the implementation

Type	Example
Path	Streets, walkways, canals
Edge	Shores, walls, fence
District	Neighbourhood, park, shopping mall
Node	Junctions, crossings, splitting paths
Landmark	Building, statue, sign

Table 3.1: Elements of Lynch [1960] and examples of them

edit and contribute to the [OSM](#) map. The content of the dataset is dependant on which elements are provided by the volunteers. To reduce the amount of element types that are mapped, 32 types are available for the user to map. Since [OSM](#) is completely built and maintained by volunteers which means the map is updated frequently. The disadvantage is that official mapping parties are not included in the process and thus the data is less reliable and complete. The advantage of this dataset that it has a high update frequency which is beneficial since more up-to-date information about the public space is available.

3.2 PREPROCESS DATA

Before the data can be used, some of the the datasets have to be preprocessed, this is dependant on which datasets are used. To begin with, the datasets must be explored in order to see what (type of) elements are available and how the dataset is structured. After inspection, elements which are not of need for the method can be excluded from the dataset to increase the processing speed and to save storage space. For instance, the dataset must be spatially restricted to the boundary of the area in which the method is applied. Also, elements which do not exist anymore, which means elements that have an end date, are removed from the datasets.

Processing the datasets while executing the method could be an alternative to preprocessing, but this takes more time while executing the method. An advantage of processing on-the-fly is that the most actual datasets can be used instead of downloading and preprocessing the datasets in advance.

3.3 INPUT: USER

Between the input of the user and the process, information will go back and forth. As discussed in [Section 2.4](#), a better prediction can be given if all information available is used. After the user has provided some information, the process phase will use this information to provide the next possibilities for the next input. So, based on the input of the user different things are presented to the user to continue with.

As a start, the type of object that will be reported has to be provided as input for the process. By knowing which type of object will be reported, a layer of the input datasets can be used as a suggested object layer from which objects will be selected. Then some (general) indication of the position can be used as a start input. This indication can either be on a map, a neighbourhood or a street. After this indication a first selection can be made of the suggested objects layer. Other information that has to be provided by the user are the actual surrounding elements, which can be the type of elements as described in [Lynch \[1960\]](#) and are available in the datasets which are used in the process.

The elements that are described by the user have a spatial relationship in reference to the object that will be reported. By implementing this spatial relationship or indicate a distance between the object and the element will provide more information on which the process can filter the objects in the suggested objects layer.

Examples of options for the type of input can be free text, question-answer model, a form, structured or unstructured, speech and visual (photo) input.

3.4 PROCESS

According to [Mitchell and Minami \[1999\]](#) there are three types of geographic elements: (1) discrete elements, (2) continuous phenomena and (3) elements summarised by area. For discrete elements, an exact position can be pin-pointed and at any point in space the element is present or not present. Continuous phenomena can be determined at any point and cover the entire mapping area. Elements can also be summarised by area, in which an area represents the count of individual elements within this area and elements do not have any specific position. Besides these three types of geographic elements, there are two approaches to conduct analysis upon the data: a raster approach and a vector approach. For these two approaches, methods and functions are available in GIS that can combine the data and the input of the user.

Raster approach - in a raster approach is the data is analysed based on a grid and map algebra is applied to the data. Type (3) elements summarised by area of the above mentioned types is best handled in a raster approach. The cell size that is used in the raster approach has great influence on the result of the analysis and the process ([Mitchell and Minami \[1999\]](#)). In case of a cell size that is too large, information will be lost. While in the case of a cell size that is too small, too much storage space will be used and the process will take longer without providing more information.

[DeMers \[2002\]](#) describes that a vector approach works better than raster in cases where networks and polygonal data are handled, which is the type of data that is handled in this thesis research. Therefore is a vector approach implemented in this thesis research and is a raster approach considered as future research to compare it with, see [Section 5.4](#).

Vector approach - a vector approach is done by executing spatial analysis upon the elements. Each element has an exact position described by a point, line or area with a defined x,y position ([Mitchell and Minami \[1999\]](#)). The data that is used in this thesis research is vector data and the exact position of the elements and their attributes is relevant for the output of the process.

There are several functions and methods available for spatial analysis like buffers, clipping tool or map overlay. These functions can be used to process the input information.

During the process, the suggested options will be presented to the user on a map for visual control and feedback. Also, the options from which the user can provide input will be based on the process and only options which are possible based on the given information will be presented to ease the process for the user.

	Element 1	Element 2	Element 3	Element n
Scenario 1	..%	..%	..%	..%
Scenario 2	..%	..%	..%	..%
Scenario 3	..%	..%	..%	..%
Scenario m	..%	..%	..%	..%

Table 3.2: Test matrix of m scenarios and n elements

3.5 OUTPUT

After the user has filled in the information and the process element has processed the information, the (preliminary) outcomes are shown on a map. Which are the suggested options so far and the total amount of these objects are shown to the user. This way, it is possible for the user to terminate the process as soon as only one or a few objects have been suggested. At the end it can be possible for the user to visually evaluate the suggested objects and select one of them.

3.6 TEST METHOD

Two tests will be executed upon elements of the method. First, the selected elements that are implemented in the method are tested upon their selectivity. Second, the method itself can be tested upon the requirements. The two tests are based on scenarios of which the description.

3.6.1 Testing elements upon their selectivity

The elements that are considered for the input by the user have a certain degree of selectivity. Based on these elements, a selection is made out of the suggested objects layer. To test the selectivity of the elements, certain scenarios can be tested. For each scenario the selectivity of the elements will be tested and each element on which a selection will be made, a test is ran. In the case of m test scenarios and n input elements it results in a matrix as in [Table 3.2](#) having m x n tests. Each test is a first selection upon the entire dataset of objects based on the input element. The amount of objects that remain after this first selection is represented in percentage in order to compare the selectivity of each element per scenario. An element is better suitable for implementation if it scores high on selectivity in multiple scenarios. If an element is not selective enough, it can be considered to choose a different element which scores higher on selectivity.

3.6.2 Testing the method on requirements

In order to test the method, certain requirements are set. This is done based on the criteria given by the product-owner of Fixi: Sander van der Klugt. The criteria that will be evaluated can be found in [Table 3.3](#). The criteria are classified into three levels:

- *High score* - the most ultimate case
- *Middle score* - the middle case
- *Low score* - the least desired case

	Low score	Middle score	High score
Number of questions	> 5	3 - 5	< 3
Is the object present?	Yes	x	x
Amount of suggested objects	> 15	3 - 15	< 3
Average distance to elements	> 15m	5 - 15m	< 5m
Covered area of suggested objects	> 500m ²	200 – 500m ²	< 200m ²
Completion time of description	> 45 sec	20 - 45 sec	< 20 sec

Table 3.3: Requirements to test the developed method

The following paragraphs present what these criteria mean and how they are assessed.

Number of questions

The criteria number of questions refers to the amount of information that has to be provided by the user. To make it as simple as possible for a user to use the method, it is requested that he/she has to provide as less information as possible. After the type of object that has to be reported is provided to the process, it is desirable to answer less than three questions (high score). The lowest score is that the user has to answer more than five questions. And the middle score is in between three and five questions. The amount of questions answered can be reported by counting them until one object is suggested or the entire input of the user is processed.

Is the object present?

Since the method concerns object identification one of the assessment criteria is whether the object that is described is present in the suggested objects. In all cases this must be true in order to consider the object identification a success. In order to confirm whether the object is present in the suggested objects it has to be known in advance. Therefore is it only possible to test in a test environment in which the object is known.

Amount of suggested objects

After the entire input of the user is processed, a suggestion is made for objects which match the description of the user. From the suggestions, the user can either visually select one object or report the entire selection. The amount of suggested objects must be as low as possible to make the selection process easier for the user and for the reliability of the selection. The best score is the case that less than three objects are suggested and presented to the user. The middle score is in between three and 15 objects, and the lowest (least desirable) score is more than 15 suggested objects.

Average distance to elements

For all the elements that are described, a distance between the object and that element is provided by the user. From all these distances an average can be calculated after the process has completed. If the average distance is smaller, it is considered a more reliable description than the scenario in which the average distance is bigger. The highest score is an average of less than five meter to the described elements, while the lowest score is an average of more than 15 meters and the middle score in between five and 15 meters.

Covered area of suggested objects

The total amount of suggested objects can be combined into an area by creating a convex hull around them. By doing this, the covered area of the objects is deter-

mined. This area defines how close the suggested objects lie in reference to each other. In case there is only one object suggested the covered area is zero and in the case of two suggested objects the linear distance in between the objects is used for this criteria. The covered area is preferred to be as small as possible, and therefore is the highest score an area of less than $200m^2$. The middle score is in between 200 and $500m^2$ and the lowest is an area bigger than $500m^2$.

Completion time of description

The time it takes the user to complete the description is measured in this criteria. A timer can be implemented and will start once the type of object has been selected and stops once the user finishes the process. The total amount of time that has passed is measured, including the time it takes for the user to fill in the information and the time it takes for the process to run. A shorter completion time means that it does not take much time for the user to provide the needed description and the processing time of the information is short. The most ultimate, and quick, completion time is less than 20 seconds. A middle score is 20 to 45 seconds and the lowest score is more than 45 seconds.

The method that has been developed based on the theory can be tested upon these six criteria. Depending on the application case, it can be considered a successful method or not. Based on the results of the test elements can also be adjusted and improved.

4

IMPLEMENTATION AND RESULTS

This chapter presents the implementation and tests of the elements in [Chapter 3](#) in the context of the Fixi case. [Section 4.1](#) presents the implementation of the five main elements: *data, preprocess, input user, process and output*. For the process element three different versions have been developed.

[Section 4.2](#) presents the results of the tests that have been executed upon the developed method. The test upon the elements and upon the versions of the method are executed.

4.1 IMPLEMENTATION FOR THE FIXI CASE

This thesis research is based on the case of Fixi, an application in which a citizen can make a notification of an issue in public space to the municipality. The methodology presented in [Chapter 3](#) is implemented and tested in the context of the Fixi case.

4.1.1 Data

For each of the types of [Lynch \[1960\]](#), elements have been selected which are of great interest for Fixi. These are elements that can be reported by the app or structural elements which are present and of which the position is available. An overview of which elements are used based on the five elements of [Lynch \[1960\]](#) can be found in [Table 4.1](#).

The area in which this case is applied is scoped down to the municipality of Westervoort. Since their datasets on public space is considered far developed and the municipality of Westervoort is a customer of Decos and therefore easy to get in touch with if there are questions about the datasets. The elements in [Table 4.1](#) are available, with their position, in the open source datasets of the municipality of Westervoort, Amsterdam and Joure. The following map layers of datasets have been used.

- [BGT](#)
 - Road ('Weg')
 - Railroad ('Spoor')

Type	Element
Path	Street
Edge	Railroad
District	Neighbourhood and roadtype
Node	Crossing of two streets
Landmark	Sign, bin and street furniture

Table 4.1: Types of Lynch and their elements

- Bin ('Bak')
- Pole ('Paal')
- Sign ('Bord')
- Street furniture ('Straatmeubilair')
- Nationaal Wegen Bestand (NWB)
 - Roads ('Wegen')
- Centraal Bureau Statistiek (CBS)
 - Districts and neighbourhoods 2017 ('Wijk & Buurtkaart 2017')
- Basisregistratie Kadaster (BRK)
 - Municipality ('Gemeenten')
- Basisregistratie Topografie (BRT)
 - Backgroundmap ('Achtergrondkaart')

The BGT is a detailed map of the Netherlands in which buildings, roads, water, railways and green areas are mapped. This dataset is mandatory to collect for municipalities and is published by the PDOK, a centralised organisation. The IMGeo is an extension to the BGT and enables more type of objects to be mapped within the standardised model. These additional types are called the 'plus objects' which are optional to collect and maintain for the municipalities but can be very useful. Examples of these plus objects are: bridges, lamp posts, bus stops, road signs, stairs, flag pole, etc.

The NWB is a database of all road managers of the Netherlands. It has a standardised map layer of all roads and waterways, including the streets and their names on municipality level. These streets and their names can be used to describe and identify the street on which an object is positioned.

From the CBS, the districts and neighbourhoods of the municipalities Westervoort, Amsterdam and Joure can be extracted. The CBS is an authority that collects, analyses and publishes statistics for the purpose of the government, science and business.

In order to spatially scope down the thesis research, the boundary of the municipalities Westervoort, Amsterdam and Joure has been retrieved from the BRK. The BRK provides information about cadastral boundaries from the Netherlands.

As a background map, the BRT data is used as a reference for the user. The BRT backgroundmap is a topographical map on different scales. The backgroundmap is part of the TOP10NL layer of the BRT in combination with the Basisregistraties Adressen en Gebouwen (BAG) for the street names. The BRT backgroundmap is available in different colour-themes: standard, grey, pastel and water. For this thesis research the standard theme is used.

All of these datasets, besides the CBS data, can be accessed through PDOK by a viewer, download and web services. For the BGT the web services are, at the moment of writing this thesis research, still in Bèta version and preprocessing is needed for multiple data sources. Therefore, will the datasets be downloaded from the PDOK website and loaded after the application has started in QGIS. If the web services would be developed in a further stage, then most of the preprocessing can be done in the process as well. Although this would take more time and slow down the process, but it would also provide an optimal up-to-date dataset that can be used.

As an alternative, other elements can be included in the method to represent the five types of Lynch [1960]. The elements that are available in the method are chosen based on their relevance for the case and how many of those elements are available in the layers of the datasets of the municipalities Westervoort, Amsterdam

Element	Before preprocessing	After preprocessing	Remaining percentage
Sign	2511	2120	84%
Pole	2372	2184	92%
Bin	173	161	93%
Roadtype	5364	4349	81%

Table 4.2: Amount of elements before and after preprocessing (Westervoort)

and Joure. After these elements have been tested on how discriminant they are and other alternatives have been tested as well, other elements might be considered as a better alternatives.

Besides the datasets mentioned previously, other datasets are available as well that provide the position and other information about the elements. One of these datasets is [OSM](#), which is a open source map that covers the entire world. It is built by volunteers around the world that can freely edit and contribute to the map. The content of the dataset is dependant on which elements are provided by the volunteers. To reduce the amount of feature types that are mapped, 32 types are available for the user to map. Since [OSM](#) is completely built and maintained by volunteers, the map is frequently updated which provides up-to-date data. The disadvantage is that official mapping parties are not included in the process.

Different from the [BGT](#), this dataset is not accessible through [PDOK](#). [OSM](#) has its own website on which the dataset can be viewed by a web viewer, downloaded and requested upon web services. The high update frequency of the data is very beneficial for the method that will be developed in this thesis research, but the fact that no official mapping parties are involved by the collection of the data is a disadvantage.

4.1.2 Preprocess data

Before the data can be used, some of the the datasets are preprocessed. To begin with, all layers are spatially limited to the boundary of each municipality. This is done in two different ways and is dependant on the available information. The first option is applied to the streets and the neighbourhoods, these have been filtered by the attribute which contains the name of the municipality. The [BGT](#) dataset has been clipped in QGIS using the municipal boundaries.

Furthermore, for each of the [BGT](#) layers all elements which do not exist anymore have been removed from the layer. This means all elements that have an end-date ('eindRegist') attribute have been removed. How many of these elements have been removed for the municipality of Westervoort can be seen in [Table 4.2](#).

4.1.3 Input of the user

In [Section 1.2](#) is the type of input scoped and defined to be a form which is filled in by both the user and the process. This form will be presented with drop-down elements which are filled by the process based on the information that is available from the data and the user.

Spatial relationships are considered for the input provided by the user. In [Section 2.5](#), four types of spatial relationships are assessed. One of them is the [CBM](#) which provides 21 distinct combinations with an English term. The elements that are taken into account for the method are converted into an area since they demarcate a certain area which is considered as the neighbourhood of the object. Accord-

Spatial relation	Count	Spatial relation	Count
Ter hoogte van	14	Aan	3
Voor	10	Achter	2
Tussen	9	Op de hoek	2
Op	8	Langs	2
Naast	7	Vanaf	1
Bij	5	Op de kruising	1
Tegenover	5	Nabij	1
In	5	Random	1
Langs	5	Rond	1

Table 4.3: Spatial relationships in Fixi notifications (in Dutch)

Element	Version 1	Version 2	Version 3
Spatial relationship	Dropdown	Dropdown	Not available
Distance indicator	Line edit	Range	Line edit
Minimal buffer distance	Minimal distance	Based on range	Small minimal distance

Table 4.4: Overview three different versions of the developed method

ing to the [CBM](#) three relations are possible for the combination of a point and area element: *touch*, *in*, and *disjoint* (as can be seen in [Table 2.1](#)).

Besides the technical methods to describe spatial relationships, 75 notifications of Fixi have been assessed and the spatial relationships of those have been extracted and counted how often they occur. The result of the assessment can be found in [Table 4.3](#). Since Fixi is in Dutch the spatial relations are presented in Dutch. The main issue for spatial relations is that they are open for interpretation for the user and interpreter. Besides this interpretation issue, is the position of the user not known and will not be known because the position can variate and the position of the object has to be retrieved, not the position of the user.

Because the position of the user is not known, a different way of defining the spatial relationships is applied. The applied spatial relationships are mainly based on the spatial analysis which can be executed in QGIS without information of the position of the user. It overlaps with the three possible combinations of the [CBM](#) and combines it with the spatial relationships of [Table 4.3](#). The spatial relationships are in Dutch and provide the ability for each element that is applied to have a spatial relationship to the object. The applied spatial relationships are: *langs*, *in de buurt*, *aanwezig binnen straal*, *niet aanwezig binnen straal*, *op*. Which means the relationship is either overlapping, within a certain distance, or no relationship (not present within a certain distance).

For the development of the method three different versions of input are explored: (1) with spatial relationships and distances indicated by the user, (2) with spatial relationships and (3) with distances indicated by the user. An overview of the similarities and differences of these three versions can be found in [Table 4.4](#). By testing each of the three options, the difference between the versions can be compared according to the criteria. The outcomes of these tests can be found in [Section 4.2](#).

The dialog box contains the following fields and options:

- Stap 1: Selecteer gemeente**: A dropdown menu with 'Westervoort-Broeklanden' selected and a 'Selecteren' button.
- Stap 2: Wat wilt u melden?**: A dropdown menu with 'Langs' selected and a 'Selecteren' button.
- Stap 3: Wat is er in de omgeving?**:
 - A checkbox for 'Geen buurt bekend' (unchecked).
 - A dropdown menu with 'Brullenweide' selected and a 'Selecteren' button.
 - A dropdown menu with 'Tweede straat onbekend' selected, a dropdown menu with 'Selecteer een tweede straat' selected, and an input field with '20' and a 'Selecteren' button.
 - A dropdown menu with 'afvalbak' selected, the word 'is', a dropdown menu with 'Aanwezig binnen straal' selected, an input field with '10', and a 'Selecteren' button.
 - A dropdown menu with 'verkeersbord' selected, the word 'is', a dropdown menu with 'Aanwezig binnen straal' selected, an input field with '17', and a 'Selecteren' button.
 - A dropdown menu with 'Spoor:' selected, a dropdown menu with 'Niet aanwezig binnen straal' selected, an input field with '100', and a 'Selecteren' button.
 - A dropdown menu with 'Op wegtype' selected, a dropdown menu with 'tegels' selected, an input field with 'Afstand (m)', and a 'Selecteren' button.

At the bottom, there is a 'Clear all' button, a label 'Voorgestelde objecten: 1', and 'OK' and 'Cancel' buttons.

Figure 4.1: Form for version 1: spatial relationships and distance

Version 1: Spatial relationships and distance

The first option that will be tested presents as an option both the spatial relationships between the object and the element and the distance between the object and the element. The user interface of this form presents three columns: one for the spatial relationship, one for the element and one for the distance (see [Figure 4.1](#)). The element combo boxes are filled based on the information of the data and the user. The following spatial relationships are available for the elements:

- Street
 - Along ('Langs')
 - In the neighbourhood ('In de buurt')
 - Street unknown ('Straat onbekend')
- Objects (signs, bins and street furniture)
 - Present within radius ('Aanwezig binnen straal')
 - Not present within radius ('Niet aanwezig binnen straal')
 - Unknown ('Onbekend')
- Railroad
 - Along the railroad ('Langs het spoor')
 - Close to the railroad ('In de buurt van het spoor')
 - Not present within radius ('Niet aanwezig binnen straal')
 - Unknown ('Onbekend')
- Roadtype
 - On roadtype ('Op wegtype')
 - Close to roadtype ('In de buurt van wegtype')
 - Unknown ('Onbekend')

Version 2: Spatial relationships

In this option it is not possible for the user to provide exact information on the distance between the object and the elements. The spatial relationships have an indication in distance presented by a range. By providing the spatial relationships the user automatically indicates a distance and this distance is applied in the process. This version has two columns, one for the spatial relationship and one for

The dialog box is titled "Dialog" and contains three steps for selection:

- Stap 1: Selecteer gemeente
- Stap 2: Wat wilt u melden?
- Stap 3: Wat is er in de omgeving?

Below the steps, there are several selection options:

- Geen buurt bekend
- Westervoort-Broeklanden (dropdown) [Selecteren]
- In de buurt van (15 - 40 m) (dropdown) [Selecteren]
- Brullenweide (dropdown) [Selecteren]
- Tweede straat onbekend (dropdown) [Selecteer een tweede straat] (dropdown) [Selecteren]
- afvalbak (dropdown) is Dicht in de buurt (<10 m) (dropdown) [Selecteren]
- verkeersbord (dropdown) is In de buurt (10 - 25 m) (dropdown) [Selecteren]
- Spoor: Niet aanwezig binnen straal (30 m) (dropdown) [Selecteren]
- Op wegtype (dropdown) tegels (dropdown) [Selecteren]

At the bottom, there is a "Clear all" button and "OK" and "Cancel" buttons.

Figure 4.2: Form for version 2: spatial relationships

the element (see [Figure 4.2](#)). The following spatial relationships and distances are available:

- Street
 - Along (<15 m) ('Langs')
 - In the neighbourhood (15 - 40 m) ('In de buurt')
 - Street unknown ('Straat onbekend')
- Objects (signs, bins and street furniture)
 - Very close by (<10 m) ('Dicht in de buurt')
 - Close by (10 - 25 m) ('In de buurt')
 - Not within 25 m ('Niet binnen straal van 25 m')
 - Unknown ('Onbekend')
- Railroad
 - Along the railroad (<15 m) ('Langs het spoor')
 - Close to the railroad (15 - 30 m) ('In de buurt van het spoor')
 - Not present within 30 m ('Niet aanwezig binnen straal')
 - Unknown ('Onbekend')
- Roadtype
 - On roadtype ('Op wegtype')
 - Close to roadtype (<5 m) ('In de buurt van wegtype')
 - Unknown ('Onbekend')

The distances that are mentioned with the spatial relationships are defined by indication. An assessment has been done on the public space of the municipality of Westervoort. Distances between the centre of a road and objects is measured and the distance between elements and the objects. From these values are the distances which are mentioned above defined.

Version 3: Distance

In the last version the distance between the object and element can be provided by

Figure 4.3: Form for version 3: distance indicated by the user

the user, from this distance the relationship can be concluded. If the distance is 0 meter, then the two items overlap. If the distance is not filled in then the element is not in the neighbourhood. And for any other value, this value can be applied as the distance between the object and the element. The user interface of the form provides two columns as can be seen in [Figure 4.3](#), the first column is for the type of element and the second for the distance between the object and that element.

4.1.4 Process

The input of the user processed in QGIS, in which pre-defined functions are available for spatial analysis. These functions are used to combine the information provided by the user and the available information from the data. Then, some information is presented to the user from where the user can continue. A general overview of the process can be found in [Figure 4.4](#), what exactly is done in each one of the seven selection elements is described in the following paragraphs. Each flow of the following paragraphs is a sequel of the previous and all of them together represent the entire process flow. For the description, the version with both the spatial relationship and the indicated distance for the user is explained in a more detailed manner.

The other two alternatives do not differ a lot from the described version, but have significant differences in the input part and therefore processing part. For each selection element in the following paragraphs, the difference between version 1 and version 2 and 3 is addressed shortly at the end of each paragraph in grey text. All figures in this section are based on version 1 of the process.

1. Object to identify

All elements which are the type of object that is selected by the user are extracted from the layer which contains all poles. This is the first version of the suggested objects layer from which the amount of features will decrease during the process.

For each of the three versions is the first selection procedure, based on the object that will be identified similar.

2. Neighbourhood (For a schematic overview, see [Figure 4.5](#))

If the neighbourhood is known by the user, the selected neighbourhood is extracted

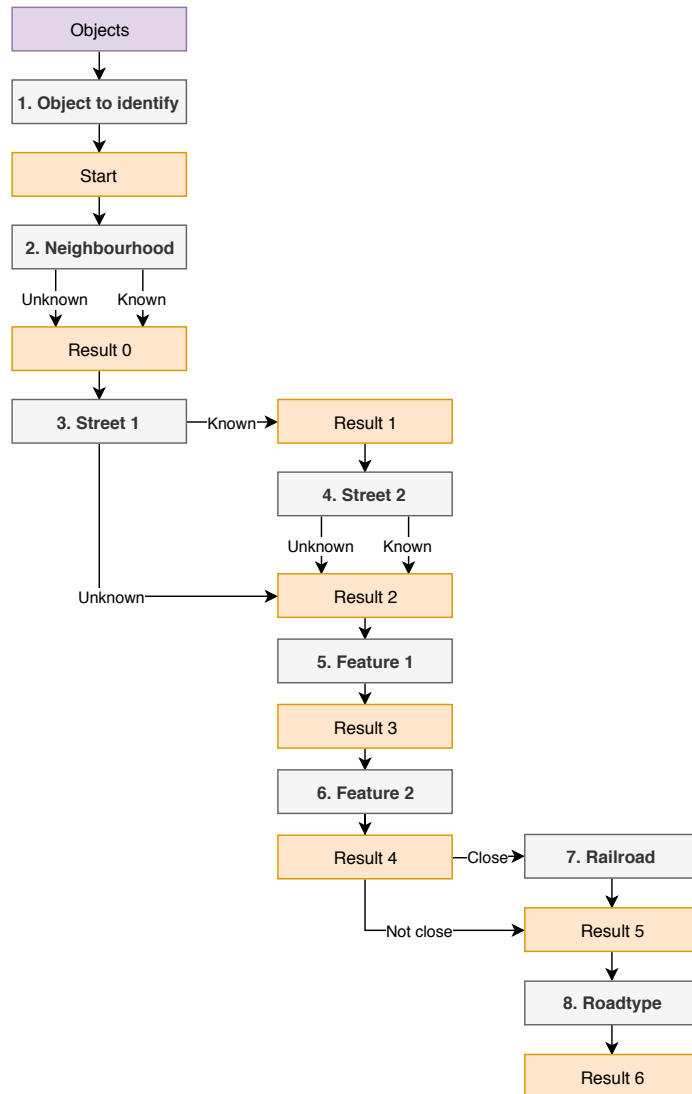


Figure 4.4: General overview of the selection process, grey is a process and orange a result which is the input of the next process

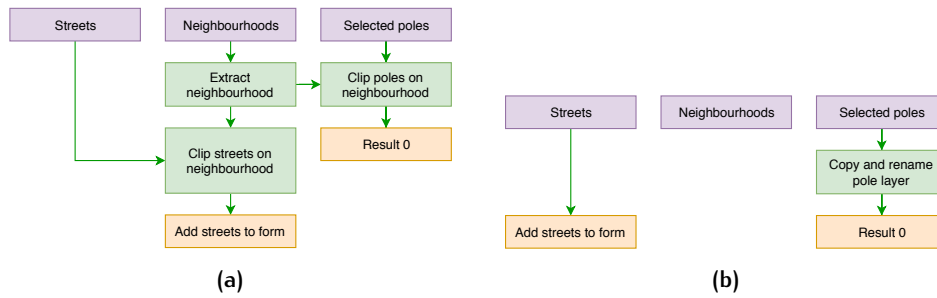


Figure 4.5: Process for selection neighbourhood: (a) neighbourhood is known by the user and (b) neighbourhood is not known by the user

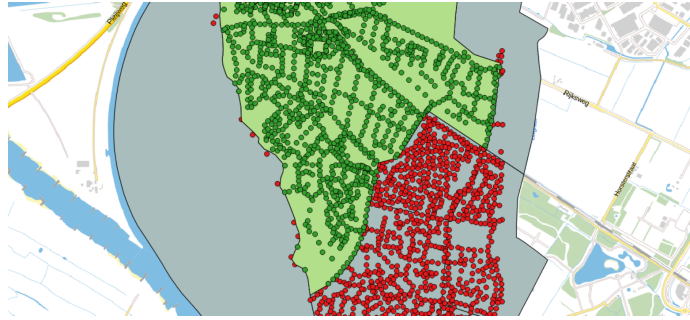


Figure 4.6: Process neighbourhood - selection of poles in the 'Westervoort' neighbourhood

from the neighbourhood layer. Then the layer of the object that has to be reported is clipped upon this neighbourhood, see Figure 4.6. All objects which lie within the boundary of the neighbourhood are extracted and added to a new layer. This layer is called *Result 0* and will be used in the next step. After the objects have been clipped, the elements from the street layer will also be clipped upon the neighbourhood so only the street names within that neighbourhood will be presented to the user in the form. If the neighbourhood is not known, the layer with the objects of the type that will be reported will be copied and renamed so it can be presented as *Result 0*. And all streets in the municipality will be extracted and presented to the user in the form.

While selecting a neighbourhood, no option of a spatial relationship or distance indicator is available. Therefore are all the three versions of the process similar for this selection element.

3. Street 1 (For a schematic overview, see Figure 4.7)

In this option there are three spatial relationships possible for the user to provide: *'langs'* (along), *'in de buurt'* (in the neighbourhood) and *'onbekend'* (unknown). For each of the three spatial relationships a different type of process is executed. For the *'langs'* and *'in de buurt van'* relationship, an example of the process is visualised in Figure 4.8.

If the spatial relationship is described as *'langs'* a street, the selected street is buffered by the distance which is provided by the user, with a minimal distance of 10 meter. The *Result 0* output with the suggested objects of the previous step is clipped upon this area. The output of this clipping function is *Result 1* which contains all objects within the provided distance of that street.

For the *'in de buurt'* relationship two buffers are created, the first one with a buffer distance of five meter and the second buffer with the distance which is provided by the user. The difference of these two buffers is taken and results in a sort of doughnut shape and on this area the *Result 0* is clipped. The output of this clipping

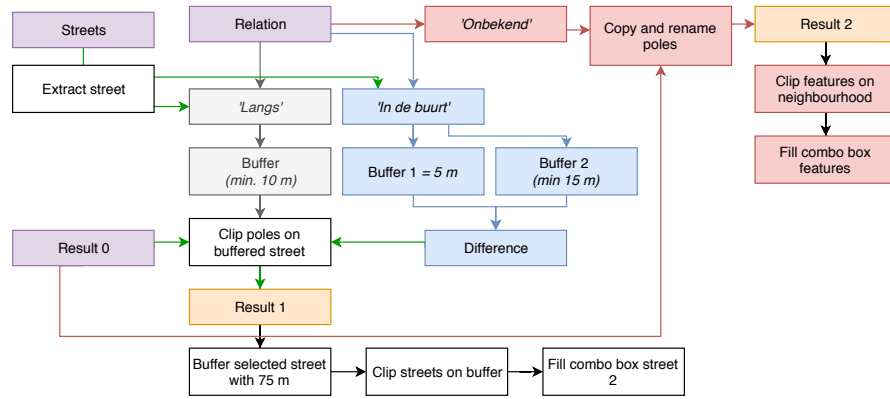


Figure 4.7: Process for selection first street

function is *Result 1* and contains all objects within the provided distance of that street and further than five meter from that street.

If the street is unknown to the user and the *'onbekend'* relation is selected, the *Result 0* layer is copied and renamed to *Result 2*. *Result 1* is skipped because this layer is used for the second street selection in the next paragraph. The second street selection is skipped if the first street is not known.

For the first two spatial relationships (along or in the neighbourhood) a street is pointed out by the user. Based on this street the combo box of the second street is filled by buffering the named street with 75 meter and providing the names of all the streets which lie in that buffer. This results in the streets which can be considered in the next description.

If the last spatial relation is selected (unknown) then no street name is available for the user and therefore no second street can be filled in. The bin and sign elements are then clipped upon the neighbourhood which was mentioned by the user and the combo box for elements is then filled with these type of features.

Version 2 of the process presents the same three spatial relationships as version 1, but with indicated distances along with it. The distance that comes along with the spatial relationship is used as the buffer in the process as presented above. How these spatial relationships and distances are matched can be found in [Section 4.1.3](#).

Version 3 of the process does not have the spatial relationships and only the indicated distances can be filled in by the user. This provided distance is applied in the buffer. The street buffer has a minimal value of 5 meter since the data is provided in lines. The user also has an option to select the option that the street is unknown and then is, like for version 1 and 2, the second street skipped.

4. Street 2 (For a schematic overview, see [Figure 4.9](#))

The process for the second street is similar to the first street, three spatial relationship options are available for the user: *'langs'* (along), *'in de buurt'* (in the neighbourhood) and *'onbekend'* (unknown). For the areas that are created by the buffers an overlap is found with the first street and these objects are then presented as the result as can be seen in [Figure 4.10](#). After this, for all three spatial relationships, the combo box for the elements is filled either based on the two selected streets or on the first selected street.

Processing the second street is similar to the first street. This is also true for version 2 and 3, and therefore the same differences are present for this selection element as in the first street selection element.

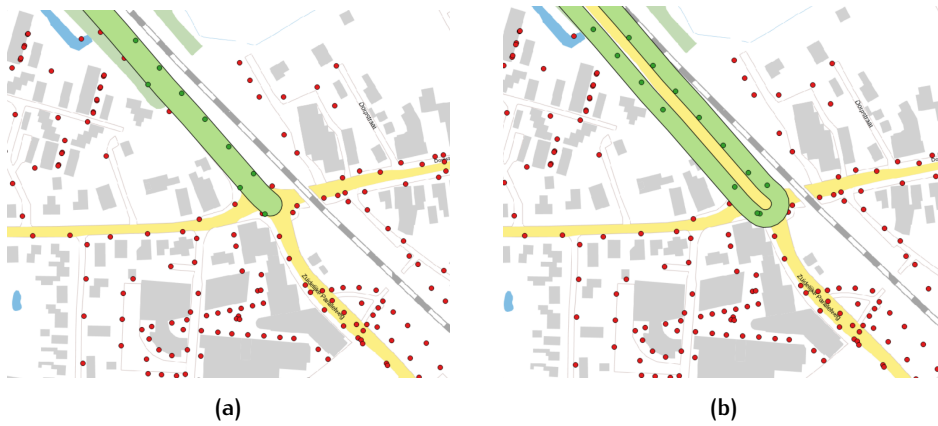


Figure 4.8: Street 1 - (a) selection of 'langs' a street and (b) selection of 'in de buurt' of a street

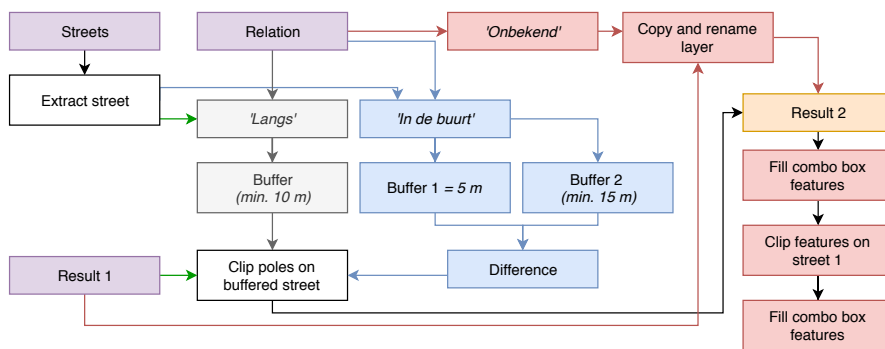


Figure 4.9: Process for selection second street

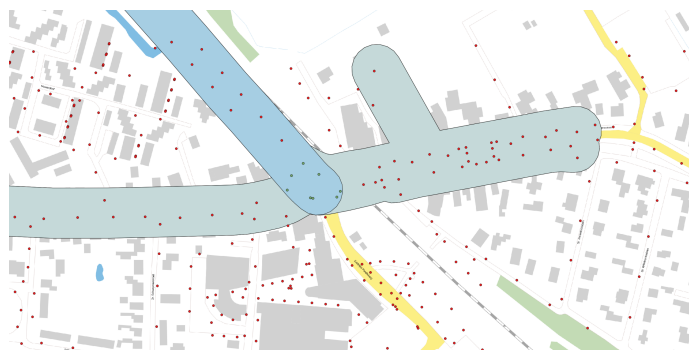


Figure 4.10: Street 2 - selection for the second street

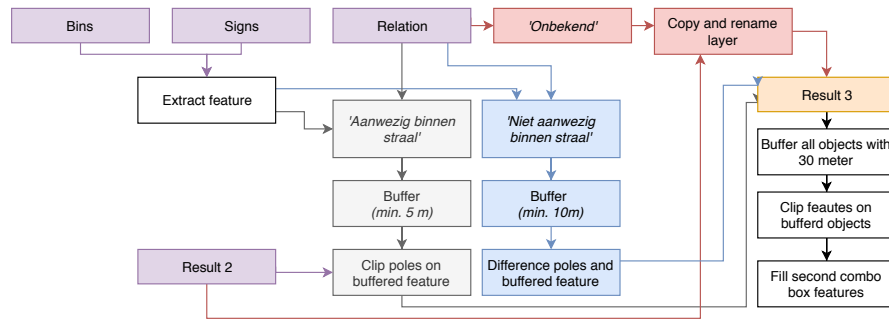


Figure 4.11: Process for selection first feature

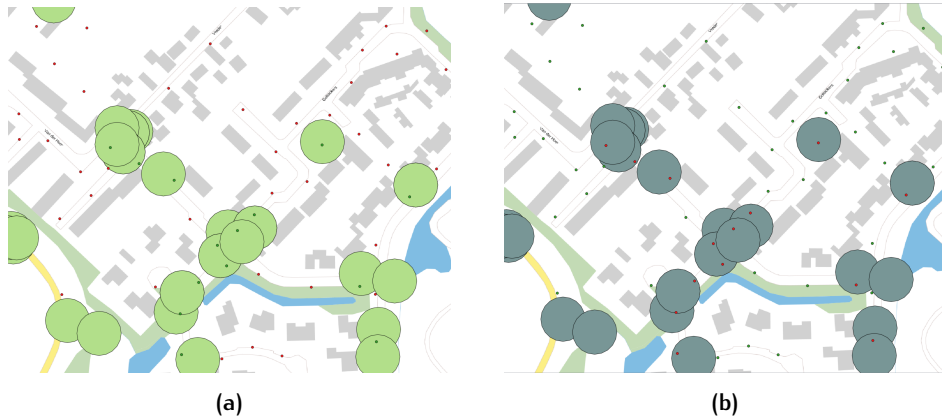


Figure 4.12: Feature 1 - (a) object is present within radius and (b) objects is not present within radius

5. Feature 1 (For a schematic overview, see Figure 4.11)

The user has the option to select three spatial relationships between the object and one of the suggested features: *'aanwezig binnen straal'* (present within radius), *'niet aanwezig binnen straal'* (not present within radius) and *'onbekend'* (unknown).

If the user selects the *'aanwezig binnen straal'*, the selected feature is buffered with the indicated distance provided by the user, with a minimum distance of 5 meter. Then the *Result 2* is clipped upon these areas to result in *Result 3* which contains all objects that are within the selected radius of the selected feature.

The *'niet aanwezig binnen straal'* option is applicable if there is none of such features in the neighbourhood of the object. This means that the selected feature is buffered with the indicated distance and all objects that fall out of these areas are used to be presented as *Result 3*.

At last the *'onbekend'* relationship takes the entire *Result 2* object layer and copies it into the *Result 3* layer.

For the next selection option the combo box is filled by taking the *Result 3* objects and buffering them with 30 meters. The other features that fall within those areas are presented in the combo box.

Version 2 of the method provides the same spatial relationships as version 1, but with predefined distances between the object and the feature. These distances are implemented for the buffer in the process.

Version 3 does not have any spatial relationships, but the distance between the object and feature can be filled in. This distance is implemented as the buffer distance with a minimal value of 5 meter. The user is also able to select the option that no feature is known.

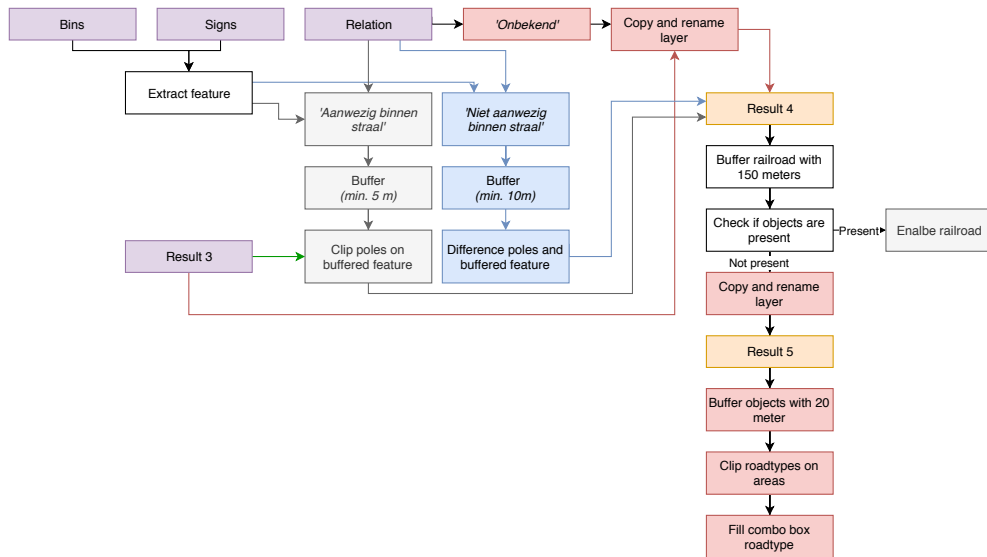


Figure 4.13: Process for selection second feature

6. Feature 2 (For a schematic overview, see Figure 4.13)

The process of processing the second feature is similar to the first feature. But the main difference is that after the *Result 4* has been created a check is done to see if there are suggested objects within a range of 150 meters of the railroad. If there are objects present within 150 meters, the option of selecting the railroad is enabled and if this is not true the combo box for the roadtype is filled. This is done by creating *Result 5*, and buffering the elements in this layer with 20 meters. The different types of railroad are clipped on those areas and these types are presented into the combo box.

Selecting a second feature is done similarly to the first feature in each version. Therefore are the differences between version 1 and version 2 and 3 similar to the ones described in the previous paragraph.

7. Railroad (For a schematic overview, see Figure 4.14)

If the railroad option is enabled, there are four options available for the user: *'langs het spoor'* (along the railroad), *'in de buurt van het spoor'* (in the neighbourhood of the railroad), *'niet aanwezig binnen straal'* (not present within radius) and *'onbekend'* (unknown).

If the object is described as *'langs het spoor'*, the railroad is buffered with the indicated distance of the user (with a minimum of 10 meter) and then *Result 4* is clipped upon this area to be *Result 5*.

In the scenario of which the object is *'in de buurt van het spoor'*, the railroad is first buffered with five meters and then with the indicated distance. The difference of these two buffers is the area on which *Result 4* is clipped upon and this layer is then *Result 5*.

The objects can also be considered *'niet aanwezig binnen straal'* and in this case the railroad is buffered with the indicated distance of the user and the difference between *Result 4* and this area is taken and called to be *Result 5*.

At last it is also possible for the user to select *'onbekend'*. In this case the *Result 4* layer is copied and renamed as *Result 5*.

For the next selection phase, the combo box of the roadtype is filled. This is done by buffering the objects of *Result 5* with 20 meter and providing all roadtypes which are present in this area.

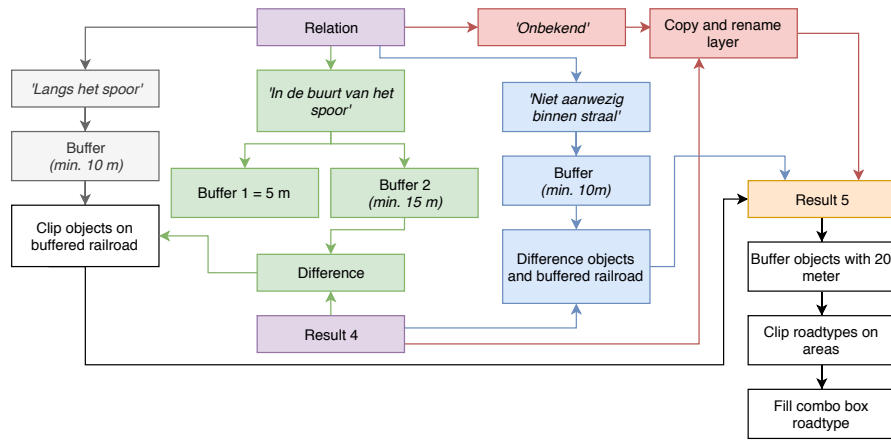


Figure 4.14: Process for selection railroad

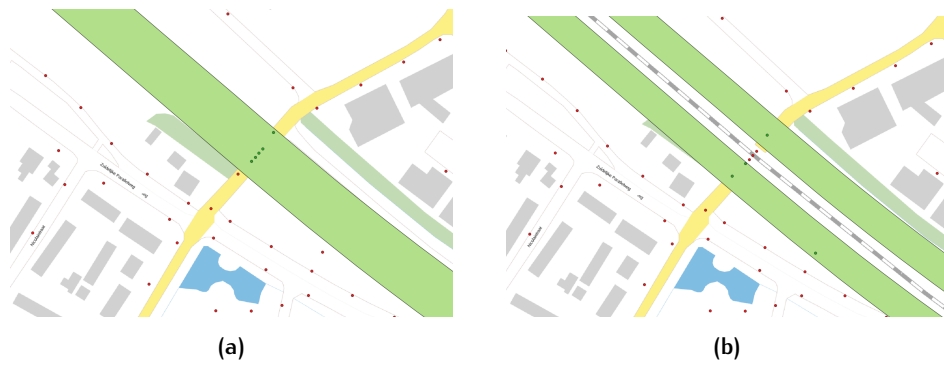


Figure 4.15: Railroad - (a) object is 'langs' the railroad and (b) object is 'in de buurt van' the railroad

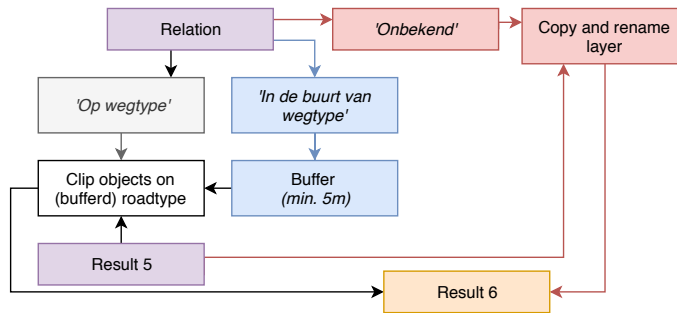


Figure 4.16: Process for selection roadtype



Figure 4.17: Roadtype - (a) object is on roadtype and (b) object is close to roadtype

Alike to the previous selection elements, version 2 of the method has the same spatial relations as version 1 but with the distances implied in the spatial relationship. Version 3 only uses the indicated distances as a value for the buffer and the spatial relations from it with a minimal distance of 10 meter.

8. Roadtype (For a schematic overview, see Figure 4.16)

Selecting a roadtype can be done based on three different spatial relationships: *'op wegtype'* (on roadtype), *'In de buurt van wegtype'* (in the neighbourhood of roadtype) and *'onbekend'* (unknown). The first two are visualised in Figure 4.17.

If the object is considered *'op wegtype'*, the objects of *Result 5* are clipped upon the selected roadtype and result in *Result 6*.

An alternative to this is *'in de buurt van wegtype'* which first buffers the roadtype before the objects of *Result 5* are clipped upon this area and resulted in *Result 6*.

At last the option *'onbekend'* is possible which takes all objects of the *Result 5* layer and copies them into the *Result 6* layer.

Processing the roadtype in version 2 is similar to the other selection processes described previously. The spatial relationships in version 2 imply the distance for the buffer.

Version 3 has three different options, either the roadtype is not known, or the distance to roadtype is 0 (which means the object is located on the selected roadtype) or the distance is applied to the buffer with a minimal value of 5 meter.

4.1.5 Output

During the process, the objects that are suggested by the method are presented on the BRT background map and the number of suggested objects are presented in the

Order	Westervoort	Amsterdam	Joure
1	Street (4%)	Street (1%)	Street (12%)
2	Roadtype (31%)	Neighbourhood (3%)	Two streets (24%)
3	Two streets (35%)	Two streets (30%)	Feature 1 (32%)
4	Railroad (41%)	Feature 1 (44%)	Roadtype (38%)
5	Neighbourhood (47%)	Roadtype (47%)	Neighbourhood (42%)
6	Feature 2 (50%)	Railroad (90%)	Feature 2 (69%)
7	Feature 1 (52%)	Feature 2 (92%)	Railroad (100%)

Table 4.5: Selectivity order of elements per municipality (with average remaining percentage)

dialog. During the process, it is possible for the user to terminate the process, close the dialog and present only the suggested object(s) on the map.

4.2 RESULTS OF TESTS

For this implementation of the method, two tests are executed: (1) the elements that have been implemented are tested and (2) the method itself is tested. This is done based on ten scenarios for each municipality: ten objects that can be reported by the method which have been selected at random by QGIS and can be seen in [Appendix A](#). The thirty objects are known in forehand and descriptions of the thirty objects is based on the available data and can be found in [Appendix B](#). All scenarios have been filled in and the tests have been executed by the author of this thesis research.

4.2.1 Test of elements

The seven elements which are applied to the method as described in [Section 4.1](#) are tested upon how discriminate they are. For each of the the ten test scenarios, a selection is made upon the total amount of objects based on each of the seven elements. This means that 70 distinct selections are made for each municipality and the amount of objects which remain after the selection are expressed in [Figure 4.18](#) as a percentage of the original amount of objects.

For each municipality is the degree of selectivity for each element different. For all three municipalities is the street the most selective element. For the municipality of Joure is the railroad not selective at all since there is no railroad presence in this municipality and in Amsterdam are almost none of the objects in the scenarios close to the railroad at all. If the average is taken from all ten scenarios for each municipality the order of selectivity is according to [Table 4.5](#).

4.2.2 Test three versions of method

[Section 4.1.4](#) presents three versions of the method implemented in the Fixi case: (1) with spatial relationships and distance, (2) with spatial relationships and (3) with distances. The three versions are tested upon the criteria described in [Section 3.6.2](#) of which the outcomes are presented and compared in the following paragraphs.

	Before	Neighbourhood	Street	Railroad	Roadtype	2 streets	Feature 1	Feature 2
Scenario 1	2066	57,8%	1,2%	2,3%	6,2%	100,0%	58,7%	15,6%
Scenario 2	24	100,0%	8,3%	70,8%	62,5%	25,0%	66,7%	12,5%
Scenario 3	2066	57,8%	0,2%	0,5%	49,5%	0,2%	12,4%	60,8%
Scenario 4	2108	17,6%	0,1%	52,2%	29,7%	0,0%	55,9%	11,6%
Scenario 5	2066	57,8%	2,2%	7,5%	0,1%	1,1%	29,1%	100,0%
Scenario 6	75	32,0%	25,3%	100,0%	65,3%	18,7%	80,0%	45,3%
Scenario 7	2066	57,8%	0,5%	41,1%	27,0%	0,1%	60,8%	20,2%
Scenario 8	158	56,3%	1,9%	34,2%	17,7%	100,0%	32,3%	36,7%
Scenario 9	2108	17,6%	0,1%	16,1%	25,8%	100,0%	35,6%	100,0%
Scenario 10	2108	10,4%	2,0%	85,5%	25,7%	0,1%	85,8%	100,0%

(a) Westervoort

	Before	Neighbourhood	Street	Railroad	Roadtype	2 streets	Feature 1	Feature 2
Scenario 1	23269	1,2%	0,0%	100,0%	55,6%	0,0%	57,6%	100,0%
Scenario 2	1090	2,7%	0,1%	100,0%	25,7%	0,1%	23,6%	100,0%
Scenario 3	23269	1,8%	0,1%	100,0%	12,7%	100,0%	100,0%	100,0%
Scenario 4	23269	1,5%	0,1%	100,0%	38,9%	100,0%	35,6%	100,0%
Scenario 5	270	3,7%	1,1%	100,0%	77,0%	0,7%	30,7%	23,7%
Scenario 6	23269	3,0%	0,3%	100,0%	64,5%	0,1%	4,7%	100,0%
Scenario 7	36	2,8%	2,8%	100,0%	80,6%	2,8%	50,0%	100,0%
Scenario 8	23269	3,0%	0,0%	100,0%	94,5%	0,0%	100,0%	100,0%
Scenario 9	148	12,2%	4,1%	100,0%	12,8%	100,0%	6,8%	100,0%
Scenario 10	23269	0,8%	0,0%	3,3%	9,9%	0,0%	26,1%	100,0%

(b) Amsterdam

	Before	Neighbourhood	Street	Railroad	Roadtype	2 streets	Feature 1	Feature 2
Scenario 1	127	18,9%	21,3%	100,00%	33,1%	100,0%	11,0%	100,0%
Scenario 2	119	18,5%	8,4%	100,00%	51,3%	8,4%	46,2%	100,0%
Scenario 3	127	18,9%	5,5%	100,00%	14,2%	100,0%	18,1%	100,0%
Scenario 4	18	83,3%	16,7%	100,00%	33,3%	16,7%	44,4%	5,6%
Scenario 5	127	54,3%	6,3%	100,00%	78,7%	3,9%	34,6%	100,0%
Scenario 6	127	11,0%	0,8%	100,00%	26,0%	0,8%	0,8%	100,0%
Scenario 7	9	33,3%	11,1%	100,00%	66,7%	11,1%	88,9%	22,2%
Scenario 8	127	54,3%	1,6%	100,00%	14,2%	1,6%	4,7%	100,0%
Scenario 9	119	30,3%	10,9%	100,00%	22,7%	4,2%	5,0%	5,9%
Scenario 10	53	100,0%	37,7%	100,00%	47,2%	1,9%	67,9%	60,4%

(c) Joure

Figure 4.18: Remaining percentage of objects after first selection

Version 1: Spatial relationships and distance

Figure 4.19 presents how the first version of the method scores on the six criteria in ten different scenarios for each municipality.

1. *Number of questions*
 Westervoort - In general low scores: eight low scores, two middle scores.
 Amsterdam - More low scores: six low scores, two middle, two high.
 Joure - Middle scores: three low scores, five middle, two high.
 General - Low: scored 17 out of 30 scores low.
2. *Is the object present*
 In all scenarios for each municipality is the expected object present in the suggested objects.
3. *Amount of suggested objects*
 Westervoort - In general high scores: two middle scores, eight high.
 Amsterdam - In general high scores: three middle scores, seven high.
 Joure - In general high scores: two middle scores, eight high.
 General - High: scored 22 out of 30 scores high.
4. *Average distance to elements*
 Westervoort - Half low and half middle: five low scores, five middle.
 Amsterdam - Most low and middle: five low scores, four middle, one high.
 Joure - Most low scores: six low scores, four middle.
 General - Low to middle: scored 16 out of 30 scores low and 13 out of 30 middle.
5. *Covered area of suggested objects*
 Westervoort - In general high scores: one low score, nine high scores.
 Amsterdam - In general high scores: two low scores, eight high scores.
 Joure - In general high scores: one low score, nine high scores.
 General - High: scored 26 out of 30 scores high.
6. *Completion time of description*
 Westervoort - In general low scores: nine low scores, one middle score.
 Amsterdam - More low scores: six low scores, three middle, one high.
 Joure - Middle scores: four low scores, six middle.
 General - Low: scored 19 out of 30 scores low.

Version 2: Spatial relationships

Figure 4.20 provides an overview with the results of the test of the second version for the three municipalities.

1. *Number of questions*
 Westervoort - In general low scores: nine low scores, one middle score.
 Amsterdam - In general low scores: eight low scores, two high.
 Joure - In general low scores: five low scores, four middle, one high.
 General - Low: scored 22 out of 30 scores low.
2. *Is the object present*
 In all scenarios for each municipality is the expected object present in the suggested objects.
3. *Amount of suggested objects*
 Westervoort - In general middle scores: eight middle scores, two high.
 Amsterdam - Mainly high scores: two low scores, three middle, five high.
 Joure - Half middle and half high: five middle scores, five high.
 General - Middle to high: scored 16 out of 30 scores middle and 12 out of 30 high.

Westervoort						
Version 1	1. Quest.	2. Present?	3. Tot object	4. Avg. dist	5. Area	6. Time
Both						
1	7	Yes	1	19	0	61
2	6	Yes	2	7	15	55
3	7	Yes	2	12	4	76
4	5	Yes	1	11	0	54
5	7	Yes	2	23	8	90
6	6	Yes	7	24	16	72
7	6	Yes	2	16	19	82
8	6	Yes	3	7	75702	57
9	7	Yes	2	33	80	65
10	3	Yes	1	15	0	30

(a) Westervoort

Amsterdam						
Version 1	1. Quest.	2. Present?	3. Tot object	4. Avg. dist	5. Area	6. Time
Both						
1	6	Yes	2	59	13	51
2	3	Yes	1	22	0	38
3	6	Yes	3	26	102	63
4	6	Yes	11	28	2868	56
5	2	Yes	1	9	0	21
6	6	Yes	14	24	4446	85
7	1	Yes	1	0	0	6
8	3	Yes	1	5	0	34
9	6	Yes	1	10	0	60
10	7	Yes	1	13	0	61

(b) Amsterdam

Joure						
Version 1	1. Quest.	2. Present?	3. Tot object	4. Avg. dist	5. Area	6. Time
Both						
1	5	Yes	1	107	0	59
2	6	Yes	5	10	3417	41
3	6	Yes	5	64	50	56
4	5	Yes	1	25	0	50
5	3	Yes	1	21	0	43
6	2	Yes	1	7	0	30
7	2	Yes	1	23	0	24
8	4	Yes	1	13	0	41
9	6	Yes	4	15	11	58
10	3	Yes	1	16	0	36

(c) Joure

Figure 4.19: Outcomes test version 1 (green: high, orange: middle, red: low score)

4. *Average distance to elements*

Westervoort - Most low scores: eight low scores, two middle scores.

Amsterdam - Most low and middle: five low scores, four middle, one high.

Joure - Most low scores: eight low scores, two middle.

General - Low: scored 21 out of 30 scores low.

5. *Covered area of suggested objects*

Westervoort - In general high scores: three low scores, one middle, six high.

Amsterdam - In general high scores: three low scores, one middle, six high.

Joure - In general high scores: two low scores, eight high scores.

General - High: scored 20 out of 30 scores high.

6. *Completion time of description*

Westervoort - In general low scores: eight low scores, two middle scores.

Amsterdam - More low scores: five low scores, three middle, two high.

Joure - Middle scores: three low scores, seven middle.

General - Low to middle: scored 12 out of 30 scores middle and 16 out of 30 low.

Version 3: Distances

The results of the test upon the third version are presented in [Figure 4.21](#).

1. *Number of questions*

Westervoort - In general low scores: eight low scores, two middle scores.

Amsterdam - More low scores: five low scores, one middle, four high.

Joure - More low scores: five low scores, three middle, two high.

General - Low: scored 18 out of 30 scores low.

2. *Is the object present*

In all scenarios for each municipality is the expected object present in the suggested objects.

3. *Amount of suggested objects*

Westervoort - More high scores: four middle scores, six high.

Amsterdam - In general high scores: three middle scores, seven high.

Joure - In general high scores: one low score, three middle, six high.

General - High: scored 19 out of 30 scores high.

Westervoort						
Version 2 Relation	1. Quest.	2. Present?	3. Tot object	4. Avg. dist	5. Area	6. Time
1	7	Yes	4	23	142	81
2	6	Yes	8	16	251	42
3	7	Yes	2	20	4	84
4	6	Yes	3	19	6	57
5	7	Yes	3	10	34	63
6	6	Yes	9	23	5	85
7	4	Yes	1	26	0	82
8	6	Yes	6	16	90242	94
9	7	Yes	10	12	9371	44
10	6	Yes	8	21	771	58

(a) Westervoort

Amsterdam						
Version 2 Relation	1. Quest.	2. Present?	3. Tot object	4. Avg. dist	5. Area	6. Time
1	6	Yes	4	21	287	33
2	6	Yes	2	21	3	58
3	6	Yes	8	21	2185	49
4	6	Yes	27	15	28741	52
5	2	Yes	1	15	0	17
6	6	Yes	69	21	35413	51
7	1	Yes	1	0	0	7
8	6	Yes	2	15	17	43
9	6	Yes	11	12	169	45
10	7	Yes	1	22	0	60

(b) Amsterdam

Joure						
Version 2 Relation	1. Quest.	2. Present?	3. Tot object	4. Avg. dist	5. Area	6. Time
1	5	Yes	10	18	3417	41
2	6	Yes	10	26	1	59
3	6	Yes	7	25	2532	40
4	6	Yes	2	20	4	49
5	4	Yes	1	32	0	41
6	2	Yes	1	15	0	26
7	5	Yes	1	30	0	38
8	3	Yes	1	27	0	33
9	6	Yes	8	10	56	43
10	6	Yes	11	22	37	47

(c) Joure

Figure 4.20: Outcomes test version 2 (green: high, orange: middle, red: low score)

4. Average distance to elements

Westervoort - More middle scores: three low scores, six middle, one high.

Amsterdam - More middle scores: two low scores, six middle, two high.

Joure - Half middle and half low: five low scores, five middle.

General - Middle: scored 17 out of 30 scores low.

5. Covered area of suggested objects

Westervoort - In general high scores: three low scores, seven high scores.

Amsterdam - More high scores: two low scores, one middle, seven high.

Joure - More high scores: two low scores, eight high scores.

General - High: scored 22 out of 30 scores high.

6. Completion time of description

Westervoort - In general low scores: seven low scores, three middle.

Amsterdam - Divided scores: four low scores, three middle, three high.

Joure - In general middle scores: four low scores, five middle, one high.

General - Low to middle: scored 15 out of 30 scores low and 11 out of 30 scores middle.

Comparing the three versions

If the results of the three versions are compared to each other there are some remarkable differences for the outcomes of several criteria. By comparing the results of the six criteria of the three versions the following conclusions can be drawn upon the six criteria. An overview of how the three different versions scored upon the six criteria can be found in [Figure 4.22](#).

1. *Number of questions* - Version two has the most low scores and the least high scores for the amount of questions. Version one and three have about the same amount of low scores, but version three has less middle and more high scores.
2. *Is the object present?* - All of the versions provided the expected object as one of the suggestions in the output.
3. *Amount of suggested objects* - Version one has the most high scores on the total number of questions and the least low and middle scores. Version three scored better than version two.

Westervoort						
Version 3 Distance	1. Quest.	2. Present?	3. Tot object	4. Avg. dist	5. Area	6. Time
1	7	Yes	2	15	11	54
2	6	Yes	2	5	15	62
3	7	Yes	2	12	4	61
4	3	Yes	1	8	0	27
5	7	Yes	10	24	610	73
6	6	Yes	7	24	16	49
7	5	Yes	1	21	0	45
8	6	Yes	3	5	75702	64
9	7	Yes	5	3	6861	41
10	6	Yes	2	11	23	48

Amsterdam						
Version 3 Distance	1. Quest.	2. Present?	3. Tot object	4. Avg. dist	5. Area	6. Time
1	2	Yes	1	2	0	14
2	2	Yes	1	8	0	23
3	6	Yes	4	10	488	42
4	6	Yes	11	18	2868	48
5	2	Yes	1	9	0	18
6	6	Yes	12	16	4574	55
7	1	Yes	1	0	0	6
8	3	Yes	1	5	0	30
9	6	Yes	1	10	0	48
10	7	Yes	1	13	0	57

(a) Westervoort

(b) Amsterdam

Joure						
Version 3 Distance	1. Quest.	2. Present?	3. Tot object	4. Avg. dist	5. Area	6. Time
1	6	Yes	18	101	3990	61
2	6	Yes	5	8	20	55
3	6	Yes	5	38	1219	41
4	5	Yes	1	25	0	43
5	6	Yes	2	14	32	53
6	2	Yes	1	15	0	26
7	2	Yes	1	23	0	16
8	4	Yes	1	13	0	34
9	6	Yes	3	15	2	46
10	3	Yes	1	16	0	23

(c) Joure

Figure 4.21: Outcomes test version 3 (green: high, orange: middle, red: low score)



Figure 4.22: Overview six criteria (green: high, orange: middle, red: low score)

Version	Low score	Middle score	High score
Version 1	56	40	84
Version 2	69	43	68
Version 3	51	45	84

Table 4.6: Count of scores per version

4. *Average distance to elements* - All versions scored very bad for average distance. Version two had the most low scores and version one and three scored slightly better.
5. *Covered area of suggested objects* - All versions scored high on the covered area. Version one scored the best out of three.
6. *Completion time of description* - Version three scored best on time and version one the worst.

If, for each version, all 180 scores (60 scores for three municipalities) are counted, see [Table 4.6](#), version one and three have the most high scores. Version three has five less low scores and is therefore considered that it scored slightly better than version one. From [Figure 4.22](#) it can be seen that this is due to the difference in scores in average distance and time in which version three scores better than version one.

Low scores are still present in the tests and elements like number of questions, average distance and time provide space for improvements or the criteria must be adjusted.

5 | CONCLUSIONS

The main aim of this thesis research is to research the possibility of object identification based on the description of neighbouring elements. In this chapter an overview of this thesis research is given and the research will be concluded. The research questions presented in [Chapter 1](#) will be answered, a reflection and discussion on this thesis research will be presented, and at last, recommendations and future work are discussed.

5.1 ANSWERS TO RESEARCH QUESTIONS

In [Chapter 1](#) the main research question of this thesis research is presented:

“Can an object identification method be established based on the description of neighbouring elements?”

From this main research question five sub-questions are formulated which are discussed in the following paragraphs. After that the main research question is answered.

5.1.1 Sub-questions

RQ1 - What type of surrounding elements can be considered for the description of an object?

For the description of an object, multiple elements are available in the neighbourhood of the object. For the method is the most important condition that the position of that element is known, which is taken into account in the next research question. According to the research of [Lynch \[1960\]](#) there are in general five different types of elements that can be found in a city: path, edge, district, node and landmark. In this thesis research, at least one of each element is implemented in the method and tests are ran to determine how discriminate these elements are. The elements that are applied are: street (path), railroad (edge), neighbourhood and roadtype (district), crossing of two roads (node), sign and bin (landmark). These elements have been selected because they are of great interest for the application of Fixi. The test concludes that the street is an important source of information which can reduce the number of suggested object drastically. Then, the type of road on which the object is situated is also very selective in comparison to the other elements. After that, the combination of the presence or absence of the elements can create a distinct combination of the elements which can be used as a fingerprint for the object.

RQ2 - Which datasets are available that provide the position of those elements?

As presented in the previous paragraph, the position of the surrounding elements is of critical need for this method. The position needs to be known in order to be used as a reference point for both the user and the processing. Official datasets like [BGT](#), [NWB](#), [CBS](#), [BRK](#) and [BRT](#) are used in this thesis research. These are datasets available from [PDOK](#), which is the official data portal of the Netherlands. The [PDOK](#) portal provides official data about the elements, their position and other metadata.

RQ3 - What kind of spatial relationships can be used as an input?

Different spatial relation techniques have been developed in the past. Examples like 4-IM, 9-IM and DEM are not considered detailed enough to describe all possible spatial combinations (Clementini and Di Felice [1995]). Therefore is the CBM introduced which can describe all spatial possible combinations and can be applied in both a linguistic manner but also a technical manner. The CBM defines five different relationships: touch, in, cross, overlap and disjoint.

By assessing 75 Fixi notifications a list of most occurring spatial relationships is established, with some of them being directional. The position of the user is not known and therefore are directional spatial relationships not possible to process. The information will be processed in QGIS and therefore are the possible spatial analysis in QGIS combined with the spatial relationships of the Fixi notifications and the CBM. Five spatial relationships are defined which are applied in the method (and freely translated in English):

1. Langs (- *along*)
2. In de buurt (- *close by*)
3. Aanwezig binnen straal (- *present within radius*)
4. Niet aanwezig binnen straal (- *absent within radius*)
5. Op (- *on*)

Three versions of input of the user (description) are tested in this thesis research, (1) with spatial relationships and distances, (2) with spatial relationships and (3) with distances indicated by the user. For these three methods, the way how the spatial relationship is implemented and the process differ and determine the outcomes of the tests.

In general, scored version 3 of the implementation the biggest amount of high criteria and least amount of low criteria. Version 3 does not specifically include the spatial relationships for the object and elements but the distances between the object and elements can be provided as an input. By providing the distances the spatial relationship is implied, but it is not possible to select that the element is not present within a certain distance. Excluding an element within a range is only possible in version 1 and 2 which adds valuable information in certain scenarios.

RQ4 - What method can be used to process the input?

For this thesis research a vector approach is applied because of the high level of detail which is present in the dataset and can be kept in a vector approach. Because of this, an object with its exact position can be retrieved ultimately instead of an area in which the object could be present. By using the spatial relationships and/or distances to the surrounding elements, spatial analysis can be conducted upon the different data layers. During this spatial analysis buffers are created and the items which fall in (or out of) these buffers are considered as suggested objects for the user.

RQ5 - To what extent does the developed method meet certain requirements?

A test has been developed to test the developed method and asses it. Six criteria have been set on which the method can score *high* (best score), *middle* (middle score) or *low* (least desired). The six criteria are:

1. Number of questions
2. Is the object present?
3. Amount of suggested objects
4. Average distance to elements

5. Covered area of suggested objects
6. Completion time of description

Each of the six criteria is evaluated by processing several (randomly selected) scenarios of which the description and the object is known. The three versions which have been developed in this thesis research have also been tested upon the six criteria. For each test that has been ran, the expected object was part of the output of suggested objects. In general scored version 3 best on the six criteria, but in some specific scenarios scored either version 1 or 2 better. This is due to the minimal distance that is implemented in the system to create a safety zone and make sure the object is within the buffer area.

5.1.2 Main research question

The main research question of this thesis research is:

“Can an object identification method be established based on the description of neighbouring elements?”

In this thesis research several elements and requirements are presented for establishing object identification, based on the description of neighbouring elements. To begin with, the elements which can be described by the user must be selected thoughtfully based on their relevance for the case, role in public space, selectivity and the available data. The data must provide reliable and complete information about the elements because it is used as a reference while processing the description.

The input can be provided in several ways: image, sound or text. These type of inputs can either be structured or unstructured. For this thesis research a structured text input has been chosen and three versions of this method have been tested. Each version differs in how the spatial relationship between the object and element is provided by the user. From the tests in this thesis research it can be concluded that indicated distances between the object and element are the most valuable input for the process. By using the distances, multiple objects can be excluded by the process if they fall out of this range.

For processing the information (reference data and description of the user), a vector approach is applied in this thesis research. This approach remains the level of detail which is available in the data and is able to provide an object as an output. A raster approach could be relevant in other cases.

It can be concluded that, to a certain degree, object identification based on the description of neighbouring elements is possible. Not all criteria are met in several scenarios, which is dependant on the available data and the type of scenario which is described. The method has space for improvements in which the output and therefore the reliability can be improved. The main elements open for improvements are amount of questions, average distance and time.

5.2 CONTRIBUTION

With this thesis research, a method to identify an object by its description has been developed and tested. In the thesis case it is applicable for reporting issues in public space, but it can also be applied when calling an ambulance or roadside assistance. New insight into identification and positioning is achieved by looking at it from a different perspective: a descriptive way.

5.3 REFLECTION AND DISCUSSION

Some elements of this thesis research can be put under discussion or have relevant shortcomings. This is due to time limitations, resources which are not available or the insights came too late in the research process. The following six elements are under discussion.

Available information of elements - The datasets that have been used in this thesis research provide the most important information of the elements: the position. But these datasets lack other types of information about the elements. If the orientation, lamppost number, or other information of the elements would have been available, a more detailed selection is possible including viewshed analysis or the appearance of certain elements.

Raster method to combine information - The vector approach has been chosen as best approach based on theory. The implementation of the vector approach has not been compared in practice to the raster approach. Comparing the developed vector approach with a raster approach will provide practical insights for a choice between a vector and raster approach for this method. Due to time limitations this has not been implemented in this thesis research.

Reconsider made choices - Some elements of the method have been defined in the beginning of the thesis research and are not reconsidered in a later stage. An example of this are the elements which are implemented. The elements have been selected in the beginning, before they were tested upon but based on a theory. In a later stage of the thesis research these elements have been tested and based upon the results no changes are made.

Efficiency of the code - Since the main aim of the thesis research is to research the possibility of object identification based on the description of neighbouring elements, is the efficiency of the code not taken into account in the thesis research. Even though the efficiency of the code has influence on one of the criteria on which the method is tested: '*Completion time of description*'. Making the code as efficient as possible can influence the results of the tests.

Test scenarios - Ten randomly selected scenarios have been chosen from three municipalities, which means that in total 30 scenarios have been tested upon the three methods. It could be possible if more and/or other scenarios are tested that different results are found.

The five main elements of the city - The five elements of a city as described by Lynch [1960] can be discussed like van Nes [2002] has done. van Nes [2002] discusses the weaknesses of this method by addressing the difference in how observers perceive the city and the limitation if the city is reduced to five main elements.

Alternative models of the city can be that of CityGML or IMGeo which are discussed in Section 2.2. CityGML and IMGeo are models which describe and standardise the elements of the city in public space.

5.4 RECOMMENDATIONS AND FUTURE WORK

From the results, conclusions and discussion of this thesis research, recommendations can be made concerning the following topics:

- *Reduce buffer*: in the current implemented method is the entire area which is mentioned in between the object and element taken into account. Therefore

is the area in case of a 16 meter distance the entire buffer from 0 to 16 meter. Considering only the area from a buffer between 15 and 17 meter could change the results of the tests.

- *Order of the elements*: after testing the selectivity of the elements, the type of element and their order has not changed. By taking into account the results of the tests, a more selective method might be developed that can score better on the tests.
- *User experience of process*: for implementation into Fixi, research has to be done on the most convenient way of implementing the method in Fixi. At this moment, some flows of the method are not how a user would expect it or make it as easy as possible for the user to identify an object, future research should be able to improve this including logical orders and error messages.
- *Visibility analysis*: taking into account the Digital Surface Model ([DSM](#)) or other layers which provide obstructions, a visibility analysis can be executed and the combinations can be assessed based on the visibility of the elements from the position of the object.
- *Compare vector and raster approach*: the developed vector approach can be compared to a raster approach to see which of the two approaches score better on the criteria given in the tests.

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A

SELECTED OBJECTS FOR TESTING



Figure A.1: Selection of 10 objects in Westervoort

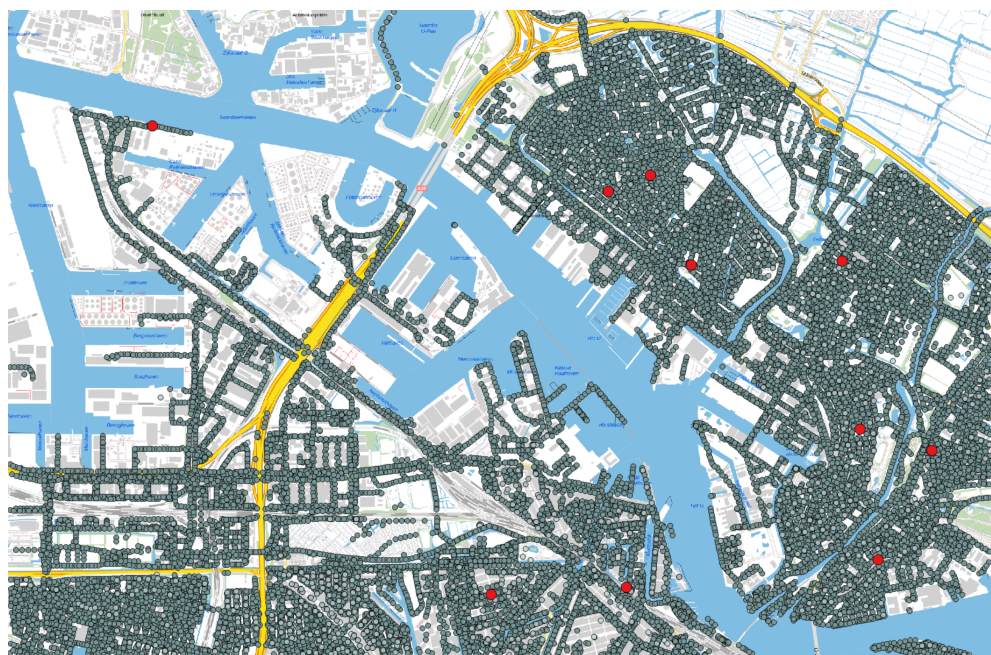


Figure A.2: Selection of 10 objects in Amsterdam



Figure A.3: Selection of 10 objects in Joure

B

OBJECT DESCRIPTIONS FOR TESTING

Westervoort

1 - Object ID: bf72e5d49-de45-11e7-951f-610a7ca84980

Object type: lichtmast

Neighbourhood: Westervoort

Street: 7m Noordelijke Parallelweg

Street 2: x

Object 1: 23m verkeersbord

Object 2: 24m afvalbak

Railroad: 23m

Roadtype: on gebakken klinkers

2 - Object ID: bf481ef60-e3d3-11e7-8ec4-89be260623ee

Object type: verkeersregelinstallatiepaal

Neighbourhood: Westervoort

Street: 1m Hamersestraat

Street 2: 9m Brouwerslaan

Object 1: 8m drukknoppaal

Object 2: 11m portaal

Railroad: 226m

Roadtype: on gebakken klinkers

3 - Object ID: bf732a3a2-de45-11e7-951f-610a7ca84980

Object type: lichtmast

Neighbourhood: Westervoort

Street: 1m Liemersallee

Street 2: 24m Noordelijke Parallelweg

Object 1: 20m afvalbak

Object 2: 24m verkeersbord

Railroad: 2m

Roadtype: 1m tegels

4 - Object ID: bdc1357ee-e330-11e7-951f-610a7ca84980

Object type: verkeersbord

Neighbourhood: Westervoort-Broeklanden

Street: 1m Liemersallee

Street 2: 16m Broeklanden

Object 1: 10m lichtmast

Object 2: 18m afvalbak

Railroad: 435m

Roadtype: 1m betonstraatstenen

5 - Object ID: bf726bc22-de45-11e7-951f-610a7ca84980

Object type: lichtmast

Neighbourhood: Westervoort

Street: 5m Zuidelijke Parallelweg

Street 2: 49m Dorpsplein

Object 1: 10m verkeersbord

Object 2: xx

Railroad: 55m
Roadtype: 1m cementbeton

6- Object ID: b3038b7cf-4e9f-11e8-951f-610a7ca84980
Object type: afsluitpaal
Neighbourhood: Westervoort-Lange Maat en Hoogeind
Street: 31m Duckers Boulant
Street 2: 51m Lange Maat
Object 1: 15m lichtmast
Object 2: 24m afvalbak
Railroad: 850m
Roadtype: 1m betonstraatstenen

7- Object ID: bf7369ac1-de45-11e7-951f-610a7ca84980
Object type: lichtmast
Neighbourhood: Westervoort
Street: 10m Kloosterdreef
Street 2: 21m Schoonoord
Object 1: 24m verkeersbord
Object 2: 30m afvalbak
Railroad: 320m
Roadtype: 1m betonstraatstenen

8 - Object ID: bd4a33be1-de40-11e7-8ec4-89be260623ee
Object type: afvalbak
Neighbourhood: Westervoort
Street: 5m Klapstraat
Street 2: xx
Object 1: 6m lichtmast
Object 2: 12m verkeersbord
Railroad: 389m
Roadtype: on tegels

9 - Object ID: bc2abdc18-de42-11e7-8ec4-89be260623ee
Object type: verkeersbord
Neighbourhood: Westervoort-Broeklanden
Street: 2m Looyenland
Street 2: xx
Object 1: 7m lichtmast
Object 2: xx
Railroad: 135m
Roadtype: on tegels

10 - Object ID: bc2dd24bf-de42-11e7-8ec4-89be260623ee
Object type: verkeersbord
Neighbourhood: Leigraaf-De Steenderens
Street: 6m Heilweg
Street 2: 24m Vicarije
Object 1: 15m lichtmast
Object 2: xx
Railroad: 906m
Roadtype: 1m asfalt

Amsterdam

1 - Object ID: b5d3e2c26-dc66-11e7-951f-610a7ca84980
Object type: lichtmast

Neighbourhood: Blauwe Zand
 Street: 2m Leeuwarderweg
 Street 2: 47m Vlielandstraat
 Object 1: 128m afval apart plaats
 Object 2: xx
 Railroad: 2,28 km
 Roadtype: 49m waardeOnbekend

2 - Object ID: b46257dd1-dc61-11e7-951f-610a7ca84980
 Object type: afval apart plaats
 Neighbourhood: Vogelbuurt Zuid
 Street: 8m Sijjesstraat
 Street 2: 36m Leeuwerikstraat
 Object 1: 6m lichtmast
 Object 2: xx
 Railroad: 1,33 km
 Roadtype: 12m waardeOnbekend

3 - Object ID: b52389ae6-dafa-11e7-951f-610a7ca84980
 Object type: lichtmast
 Neighbourhood: Bloemenbuurt Zuid
 Street: 13m Azaleastraat
 Street 2: xx
 Object 1: xx
 Object 2: xx
 Railroad: 2,1 km
 Roadtype: 7m waardeOnbekend

4 - Object ID: b24f6f137-d551-11e7-951f-610a7ca84980
 Object type: lichtmast
 Neighbourhood: Petroleumhaven
 Street: 7m Ankerweg
 Street 2: xx
 Object 1: 221m kunstobject
 Object 2: xx
 Railroad: 411m
 Roadtype: 30m waardeOnbekend

5- Object ID: bf2d285b7-dbo2-11e7-951f-610a7ca84980
 Object type: abri
 Neighbourhood: Banne Zuidoost
 Street: 9m Banne Buikslootlaan
 Street 2: 53m Statenjachtstraat
 Object 1: 7m lichtmast
 Object 2: 41m afval apart plaats
 Railroad: 3,185 km
 Roadtype: 59m waardeOnbekend

6- Object ID: b3fe3764c-dafa-11e7-951f-610a7ca84980
 Object type: lichtmast
 Neighbourhood: Tuindorp Oostzaan Oost
 Street: 5m Meteorenweg
 Street 2: 44m Plejadenplein
 Object 1: 108m afval apart plaats
 Object 2: xx
 Railroad: 1,56 km

Roadtype: 61m betonstraatstenen

7 - Object ID: b1b342227-d554-11e7-8ec4-89be260623ee
 Object type: reclamezuil
 Neighbourhood: Westerstaatsman
 Street: 4m Bentinckstraat
 Street 2: 59m Cliffordstraat
 Object 1: 11m lichtmast
 Object 2: xx
 Railroad: 568m
 Roadtype: 64m waardeOnbekend

8 - Object ID: b47083a2b-dafa-11e7-8ec4-89be260623ee
 Object type: lichtmast
 Neighbourhood: Tuindorp Oostzaan Oost
 Street: 5m Planetenplein
 Street 2: 6m Planetenstraat
 Object 1: xx
 Object 2: xx
 Railroad: 1,931km
 Roadtype: 166m waardeOnbekend

9 - Object ID: bf2c084bf-dbo2-11e7-951f-610a7ca84980
 Object type: kunstobject
 Neighbourhood: Terrasdorp
 Street: 8m Klinkerweg
 Street 2: xx
 Object 1: 6m lichtmast
 Object 2: xx
 Railroad: 2,248km
 Roadtype: 16m waardeOnbekend

10 - Object ID: b3993e380-d551-11e7-951f-610a7ca84980
 Object type: lichtmast
 Neighbourhood: Westelijke eilanden
 Street: 6m Lange Eilandsgracht
 Street 2: 22m Eilandsgracht
 Object 1: 50m afval apart plaat
 Object 2: xx
 Railroad: 22m
 Roadtype: 5m waardeOnbekend

Joure

1 - Object ID: bb3cd4bfe-2411-11e8-951f-610a7ca84980
 Object type: lichtmast
 Neighbourhood: Joure, Jonkersland
 Street: 187m Boeresingel
 Street 2: xx
 Object 1: 115m afval apart plaats
 Object 2: xx
 Roadtype: 1m betonstraatstenen

2 - Object ID: bb3cdc142-2411-11e8-951f-610a7ca84980
 Object type: afsluitpaal
 Neighbourhood: Joure, Centrum
 Street: 3m Zijl

Street 2: 17m Groene Dijk
 Object 1: 12m lichtmast
 Object 2: xx
 Roadtype: on gebakken klinkers

3 - Object ID: bb3cca4fa4-2411-11e8-951f-610a7ca84980
 Object type: lichtmast
 Neighbourhood: Joure, Jonkersland
 Street: 77m Boeresingel
 Street 2: xx
 Object 1: 53m afval apart plaats
 Object 2: xx
 Roadtype: on tegels

4 - Object ID: bd2a8c2fo-1dc8-11e8-a5a2-73a1868acdce
 Object type: bank
 Neighbourhood: Joure, Blaauwhof
 Street: 22m Wietske Tademalaan
 Street 2: 75m Prof Titus Brandsmaweg
 Object 1: 2m afvalbak
 Object 2: 2m lichtmast
 Roadtype: on betonstraatstenen

5- Object ID: b3092e92f-1e93-11e8-a5a2-73a1868acdce
 Object type: lichtmast
 Neighbourhood: Joure, Blaauwhof
 Street: 16m Midstraat
 Street 2: 27m De Merk
 Object 1: 55m bank
 Object 2: xx
 Roadtype: 1m gebakken klinkers

6- Object ID: bb3cde858-2411-11e8-951f-610a7ca84980
 Object type: lichtmast
 Neighbourhood: Joure, Centrum
 Street: 7m Kolkstraat
 Street 2: 7m Appelwyk
 Object 1: 7m bolder
 Object 2: xx
 Roadtype: on gebakken klinkers

7- Object ID: bd2a8ea08-1dc8-11e8-a5a2-73a1868acdce
 Object type: fietsenrek
 Neighbourhood: Joure, Blaauwhof
 Street: 23m Wietske Tademalaan
 Street 2: 70m Pastorielaan
 Object 1: 13m lichtmast
 Object 2: 16m bank
 Roadtype: 7m betonstraatstenen

8 - Object ID: b30931046-1e93-11e8-a5a2-73a1868acdce
 Object type: lichtmast
 Neighbourhood: Joure, Blaauwhof
 Street: 6m Jonkersbosje
 Street 2: 19m Scheen
 Object 1: 16m afsluitpaal

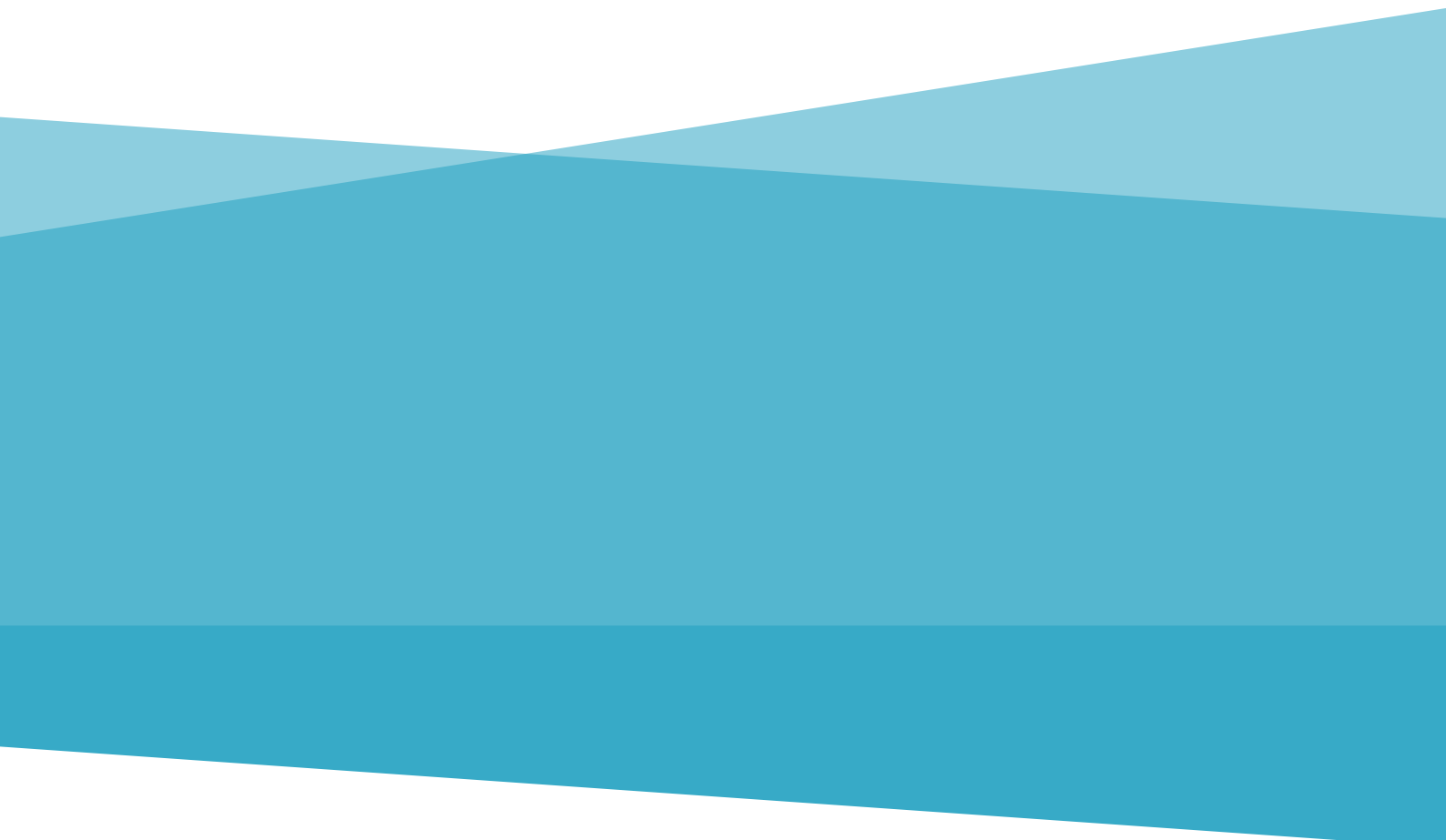
Object 2: xx
Roadtype: on tegels

9 - Object ID: bb3ccafa5-2411-11e8-951f-610a7ca84980
Object type: afsluitpaal
Neighbourhood: Joure, Jonkersland
Street: 6m Grienedyk
Street 2: 63m Slachtedyk
Object 1: 3m bank
Object 2: 4m afvalbak
Roadtype: 1m betonstraatstenen

10 - Object ID: b7d1ffe42-2412-11e8-a5a2-73a1868acdce
Object type: bolder
Neighbourhood: Joure, Centrum
Street: 15m Kolkstraat
Street 2: 17m GERBEN MARTENSSTRAAT
Object 1: 59m lichtmast
Object 2: 64m afsluitpaal
Roadtype: 1m gebakken klinkers

COLOPHON

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