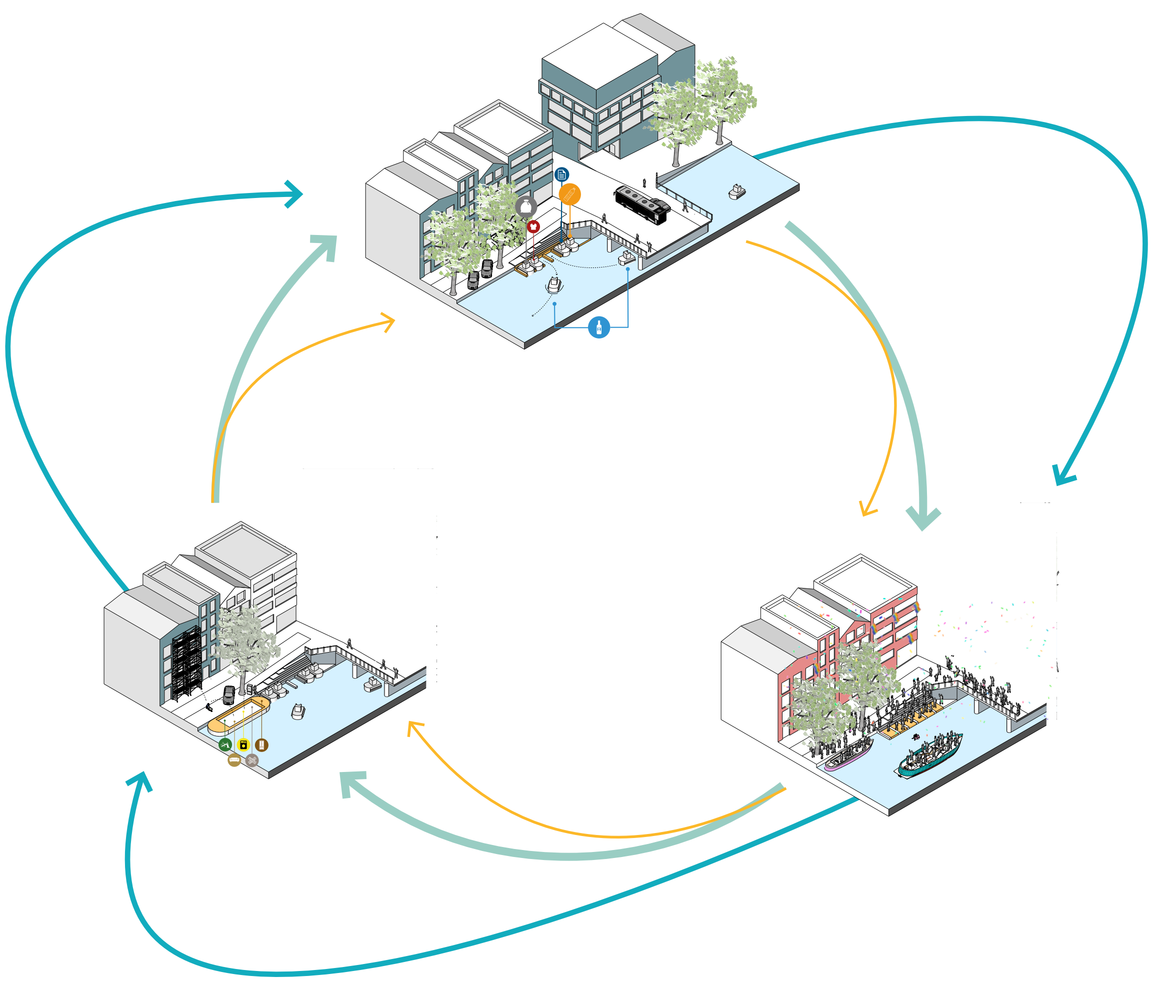
Rethinking Waste

Urban integration of waste collection and treatment systems based on circular concepts

Recommendations for Amsterdam



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P5 report

Final report MSc Urbanism thesis

T.J.L. Cortenraede

Faculty of Architecture and the Build Environment, Delft

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Final report MSc Urbanism thesis
05/04/2018

T.J.L. Cortenraede (4512588)
twancortenraede@gmail.com
MSc Urbanism
Faculty of Architecture and the Built Environment, TU Delft

Research group:
Smart Cities and Urban Metabolism

First mentor:
Dipl.-Ing. Ulf Hackauf

Second mentor:
Dipl.-Ing. Alex Wandl

Delegate board of examiners:
ir. Susanne Pietsch

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Preface

This report is the final product of my master program at TU Delft. I started with a bachelors degree in Landscape Architecture in Wageningen and continued developing knowledge on cities within the master track of Urbanism at the faculty of Architecture and the build environment in Delft. The reason for choosing urbanism was based on my drive to get a better understanding of cities, their urban systems and the relation to people. Especially future sustainable urban development became of great interest.

In 2016, my interest was sparked during an internship at the municipality of Amsterdam. At the municipality of Amsterdam I got in touch for the first time with the concept of circular economy and the ongoing transition of the city. I came in contact with different actors which were ambitious to facilitate this transition and who thought about a more sustainable society. However, it became clear that still many questions were unanswered and that spatial challenges especially are yet to be tackled. The nice working environment and the possibility to explore the concept of circular economy and the related practical questions, stimulated the will to investigate this subject further within my thesis.

At the faculty of Architecture and Build environment, the research group of Smart Cities and Urban Metabolism was the perfect environment to further develop my ideas and expertise. What started as a project focussing on the circularity of industrial cities evolved in a new focus on the city itself and circularity on a human scale. The research group was of great help to find the right scope for my research. It gave me possibilities to connect and participate in the European project of REPAiR. This involvement created more understanding of Amsterdam. It also included an interesting trip to Naples, Italy, from which different challenges European cities face became apparent. This combination of factors and influences resulted in this report where I bundle al my personal interests and gained expertise on the subject of circular economy.

Before I want to wish you pleasure reading this report, I would like to thank some people who were of great help throughout this intense year. First of all, my two mentors. Ulf Hackauf and Alex Wandl have been of great support for me throughout this whole process. My thesis was one big quest for finding the right scope and approach. Both mentors were of great help in this process, trying to guide me in the right way, still keeping room for my own creativity and perspectives. I really enjoyed the combination of critical discussions and relaxed small talks. The great atmosphere during our meetings really helped me to move forward with this project. They form a great team in which they really complement each other and always helped me in the best possible way.

This report would not have been there without the support of my friends and family. I would like to thank my parents which have been there throughout my whole study to support me. Jet and Marit, and my other fellow graduate colleagues, were always there to have critical discussions or maybe even more important, to have fun times at the faculty to make the hard work more bearable. Finally, I would like to thank my friend Lars. He probably had to suffer to most from my whining and complains. However, he always stayed positive and pushed me in the right direction.

In the end, I am satisfied with the result and happy to finalize my studies this way. Please enjoy reading this report and hopefully it will give you knowledge and wisdom!

Twan Cortenraede

Delft, april 2018

Summary

The worldwide trends of depleting natural resources and increasing generation of waste create challenges concerning the development and growth of our cities. Urban growth is enforcing these trends, resulting in growing problems and reaching limitations to the growth of our economies.

In this thesis, these worldwide trends will be challenged in the city of Amsterdam, the Netherlands. The concept of circular economy is used to improve residential waste collection and treatment to close loops and reduce environmental impact. Amsterdam is a fast growing city and has many spatial challenges related to this growth. A new more integrated system for residential waste treatment and collection is needed. In this way, the city can live up to its high circular ambitions and reach their set goals in a short time frame.

To conquer these challenges, a link between circular economy and urban design is made. Circular concepts can now be translated to urban systems, creating the possibilities for urban integration. In this way, circular economy becomes part of the city, interacts with other systems and circular economy evolves in a economic, social and environmental concepts which contributes to sustainable development of our cities in the future.

The circular proposals are integrated in Amsterdam, taking into account the great diversity in urban forms and possible connections to existing systems. This all results in a list of recommendations for the municipality on how to improve their vision and continue with their circular ambitions. The main recommendations concluded from this research are:

1. Waste treatment and collection should connect to existing urban systems, creating more support and integration within daily lives.

2. Circular economy does not have just a economic value. Circular waste treatment can contribute to the city, strengthen communities and improve living quality .

3. The value of circular waste treatment needs to experienced by the residents themselves. It will contribute the to motivation and support a change in disposal behaviour.

4. Separate waste collection should be available for all the residents of Amsterdam. It will require large investments in some parts of the city. However, by making cleaver use of existing structures, improvement can be made fast and without tremendous costs.

Content

01
Introduction

The earth's interlocking resources – the global system of nature in which we all live – probably cannot support present rates of economic and population growth much beyond the year 2100, if that long, even with advanced technology.

(Meadows et al., 1972)

Worldwide trends of urbanization, depleting natural resources and increasing generation of waste raise questions and creates challenges on how we can facilitate sustainable urban growth. In 1972, the Club of Rome, drew attention on the fact that our current economic growth and urban systems are limited. The use of non-renewable resources within our society creates limits to our growth (Meadows et al., 1972). Solutions have to be found how this consumption of natural resources can be reduced and how new types of resources, to sustain our society, can be used. This thesis addresses these topics, by investigating the use of the circular economy concept within urban environments. By seeing waste as a resource, natural resources can be substituted and the use can be reduced. To change our behaviour and improve the reuse of resources, smart solutions have to be found which can be integrated within our daily urban living environment. A connection between the conceptual circular economy and urban design needs to be made to implement new solutions for improving our collection and treatment of residential waste.

Amsterdam is a city which has to deal with these world wide trends. Challenges regarding waste and the integration of waste collection and treatment infrastructure are arising. In this thesis, proposals are made for integrative solutions which can be implemented in Amsterdam. They will help Amsterdam to live up to their circular ambitions and reach their set goals. This research is separated in 14 chapters, which show the process of creating new residential waste systems based on circular concepts and how these new systems can be integrated within the urban environment. Chapter 2 and 3 define the actual problem by looking into worldwide trends and how they affect the city of Amsterdam. Next, Chapter 4 describes the new links that need to be made between theories from a scientific perspective, contributing to the challenge of sustainable urban development. The gained knowledge form these first chapters forms the objectives of this theses, presented in chapter 5 and 6.

Chapter 7 provides a full understanding of the current situation and the functioning of the waste treatment and collection systems in Amsterdam. This knowledge is crucial to propose changes for new systems which are presented in chapter 8 and 9. These proposals can be integrated within the city of Amsterdam and give an overview of different possibilities on how urban integration may occur (chapter 10, 11 and 12). Finally, in chapter 13, conclusions are drawn where becomes clear what the real challenges are for the municipality and which steps are crucial to stay a progressive circular city. In chapter 14 a final reflection is given, by looking at the shortcomings of the executed research and designs. From this critical reflection, recommendations flow that serve other scholars and governmental bodies in future research, taking steps in turning the proposals into reality.

⟵

Rijksmuseum, Amsterdam
(I Amsterdam)

02
Problem field

Urbanization, depleting natural resources and increasing generation of waste

←
Zuidas, Amsterdam
(Twan Cortenraede)

02.1 Urbanization

The starting point of this thesis are three world-wide visible trends and their interrelations. These trends are most certain going to result in challenges concerning the development of our cities in the future. The first trend of urbanization, which is already visible for more than a decade, is going to influence the functioning of our cities. In 2007, the urban population became bigger than the rural population and it is expected that towards 2050 this difference will increase even more (United Nations, 2014). Figure 1 shows it is even expected that by 2070, 75% of the world population will live within urban environments (Bueren, 2012). It is evident that this urban growth will increase the pressure on the different urban systems which form an urban environment. This thesis addresses the effect of urbanization on two other trends. The first trend is the depletion of natural resources. The second trend is about the increasing generation of waste. This chapter explains this problem filed, where both trends will be explained and where it will become visible how the trend of urbanization enforces these trends and make them critical to address. This problem field forms eventually the base for the formulation of the problem statement for the city of Amsterdam later on.

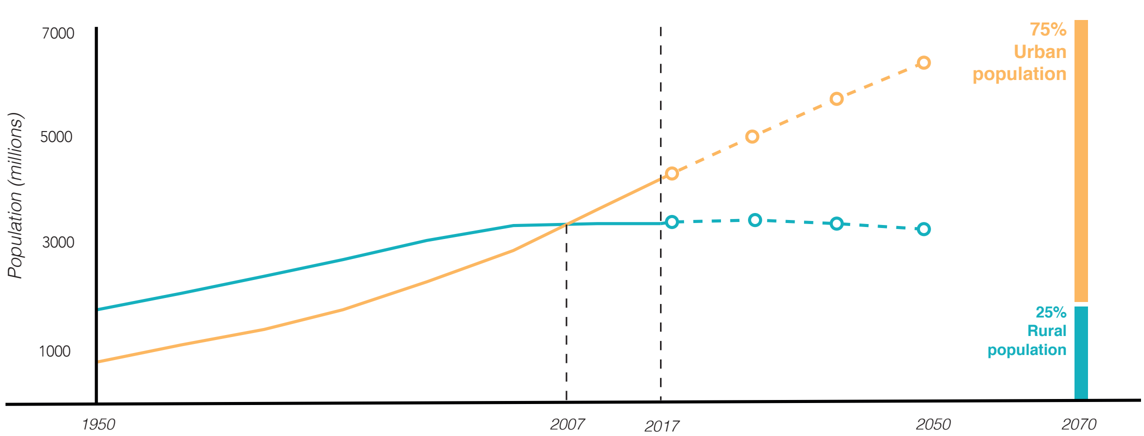

Figure 1
Expected population growth in urban and rural areas
It is expected that by the year of 2070, 75% of the world population will live in urban environments.

(Image by author, based on United Nations, 2014; Bueren, 2012)

02.2 Depleting natural resources

Nowadays we are aware of the fact that natural resources we use in our daily lives are not inexhaustible. This concern started in 1972, when awareness was created by the Club of Rome in their report ‘limits to growth’ (Meadows et al., 1972). They made us aware of the fact that a lot of natural resources are not renewable and that there are limits to our economic growth because of this. An elaboration on the problems related to this trend and the urgency to make changes are the main driving forces behind this research. This trend of depleting resources is accelerated by the fact that cities are growing and more resources are used. It will become visible that these two trends combined create a problem which is necessary to tackle in the coming future.

In 2011, an article in the guardian discussed six natural resources which are drained the most by the world population of already 7-billion people (Ruz, 2011). Camilia Ruz came to the conclusion in this article that most of the important natural resources we use, like oil, natural gas, phosphorus and coal, will deplete within the coming 50 years. Next to that, she illustrates the growing scarcity of water, of which we think we should have plenty of it. Within her article the core of the problem is presented. Resources we are using in our daily lives, which is almost common sense for us, are depleting. With ongoing growing economies, the rate of depletion goes faster, which makes it a problem we have to face now.

The BBC made in 2011 an interesting graphic, showing the depletion times of different minerals, fossil fuels and ecosystems. The graphic, based on multiple researches concerning natural resources reserves, gives a good overview in what time frame we are facing depletion of crucial resources (figure 2). For instance, the mineral antimony, which is one of the core components of batteries is expected to deplete the coming years. Especially minerals used for electronic devices are scarce and are expected to deplete within 50 years. This shows already the magnitude of this problem. With population growth and growing welfare, the demand for these products will only grow, and so the demand for these resources.

The ‘Stock check’, done by the BBC involves also three types of fossil fuel: coal, oil and gas. All three are expected to deplete within 50 years. These resources are mostly used for the production of energy. In 2012, 81,3% of all the produced energy was generated by using fossil fuels. Only 9% renewable resources were used, like hydro, wind and solar energy. Urban areas are responsible for 75% of all the energy consumption in the world. These figures show the dependency of urban areas on these fossil fuels. The coming 50 years new ways of energy supply have to be find (UN Habitat, n.d.). This problem has to be addressed in particularly, since urban areas are growing and energy demand will increase even more. Fossil fuels are not only resources for energy production. Oil is the main component of plastics and other chemical products, like paint for instance. All these products depend on a continuous flow of oil, which is apparently not that self-evident. The growing cities will affect the depletion speed of these resources because of increasing use of energy and products.

Urbanization has another effect on the use of natural resources. 40% of all the resources extracted from the planet are stored within the build environment. Cities have a big impact when it comes to resource extraction (Bueren, 2012). Constructing cities cost a lot of resources. However, looking at it from a different perspective, cities could become the mines of the future. A great amount of

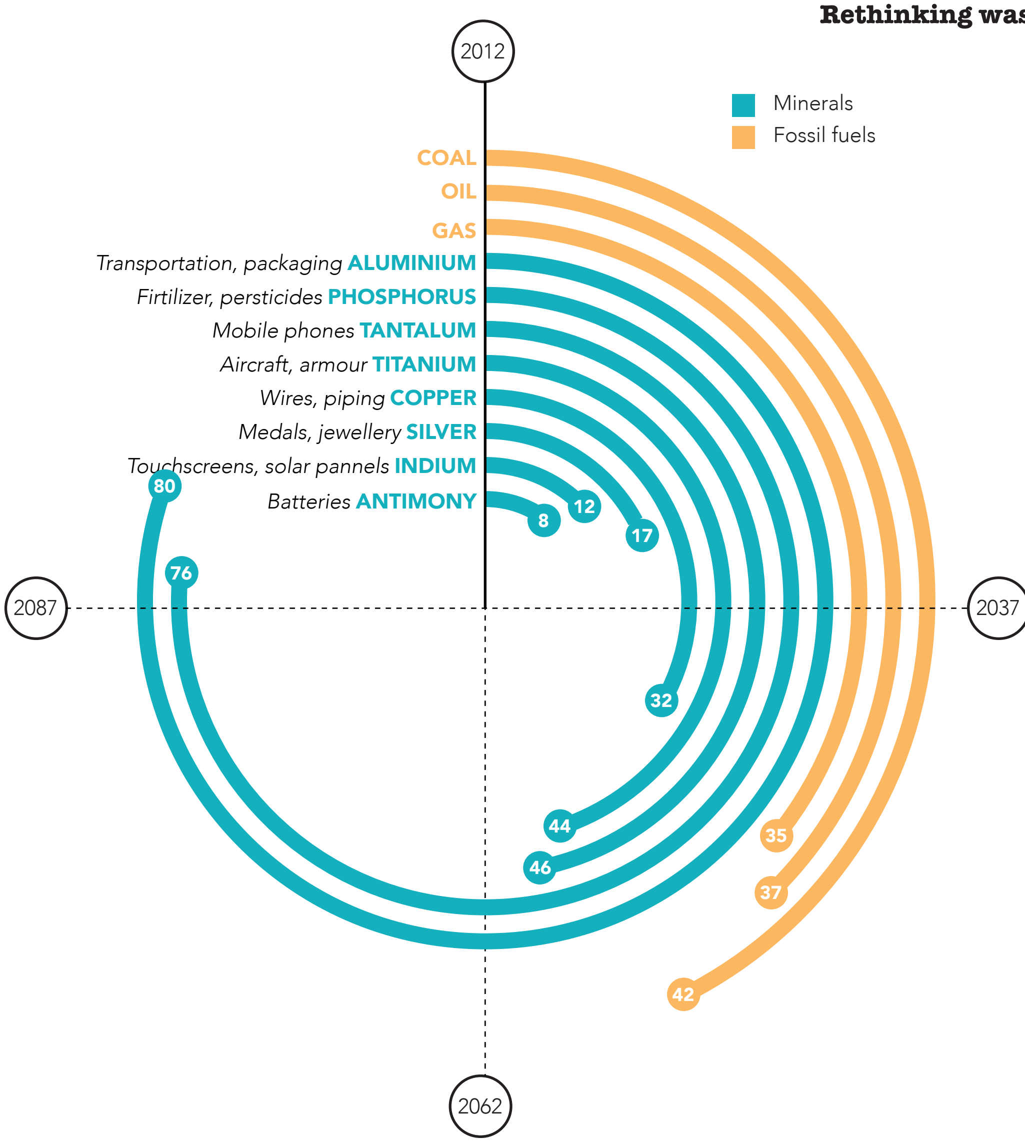

Figure 2

Estimated depletion time of different minerals and fossil fuels

The numbers at the end of the different loops represent the amount of years it is expected tot take for the natural resources to deplete completely. Especially minerals used in electronic devices are expected to deplete quickly.

(Image by author, based on BBC, 2011)

materials are now stored within buildings or are disposed as waste. Developing new techniques and seeing cities as mines could maybe lead to a new approach to resource use.

The trend of depleting natural resources is happening and the moment of full depletion of several resources is near. Some materials and resources are crucial for the functioning of our society and little alternatives are available. When the trend of urbanization will continue, this could lead to tremendous problems in the near future. The use of natural resources should be revised and new alternative resources should be discovered or better utilized. In this way, the future cities will be able to continue to grow. The 'limits to growth' should be taken seriously. New solutions have to be found to shift these limits, and to make sustainable economic and urban growth possible.

02.3 Increasing generation of waste

According to Hoornweg et al. (2013) solid waste is particularly an urban phenomenon. In rural areas less waste is being disposed since less people live there, food is less packaged, there is in general less food waste, and less manufacturing and use of other goods. Residents living in urban areas produce twice as much waste compared to a person with the same state of welfare living in rural areas. When making the assumption that citizens are generally richer, these citizens even generate four times as much waste compared to a rural citizen. When comparing growth of urban population and the estimated growth of waste generation in different areas of the world, it is visible that in the case of a higher urbanization rate, waste generation will increase according almost the same rate (figure 3). However, there are more factors which influence the growth of waste generation, for instance population growth in general which is not identical all over the world. Nevertheless, this comparison gives a strong suggestion of a positive correlation (Hoornweg & Bhada-Tata, 2012). Waste generation is as well connected to level of income. Countries classified as high income countries generate 46% of all the waste in the world (figure 4).

Hoornweg et al. (2013) tried to make future projections for the global waste production in the report *'What a Waste, A Global review of Solid Waste Management'*, commissioned by the World Bank. They made three projections, consisting of different trends and global circumstances (figure 5). In the first scenario, 90% of the world population (7-billion) will live in urban areas by the year 2100. Within this scenario, cities are developed in a more sustainable way, the consumption of fossil fuels has been reduced and the residents are more aware of negative environmental effects. The second scenario represents the 'business-as-usual' prognosis, where 80% of a global population of 9.5-billion lives in cities. The last scenario describes a world population of 13.5-billion and an urbanization rate of 70%. This scenario is characterized by a lot of countries with rapid population growth and areas with poverty and limited wealth. All three scenarios describe totally different future forecasts and it can be argued how accurate these scenarios are. However, all the scenarios describe a doubling of the global waste generation till 2050. The more developed and high income countries, as described before, have the biggest share in this waste generation. In the coming future, these countries need the focus on waste reduction or a change in waste treatment. However, in the far future, other regions in the world (lower income countries) are becoming a bigger problem.

Waste production is not a problem in itself, but it becomes a problem when efficient treatment ways are not applied. Waste which is not collected or disposed properly will have negative effects on the environment. Waste, which has been dumped or used as landfill, can effect groundwater conditions by contamination. Drinking water, which is already becoming scarce, will reduce in quality and can lead to substantial health risks. On the other hand, when waste is being incinerated, CO2 is being released within the atmosphere. This eventually contributes to the greenhouse effect and climate change. Dumping, landfill and incineration are waste disposal / treatment methods which leads to considerable negative environmental impacts. These traditional systems of production, consumption and disposal do not only have their downsides concerning negative environmental impacts. The traditional systems are as well a missed opportunity where valuable resources are disposed and are not reintegrated within the production process. The problem of waste is a problem which is strongly related to production and consumption patterns.

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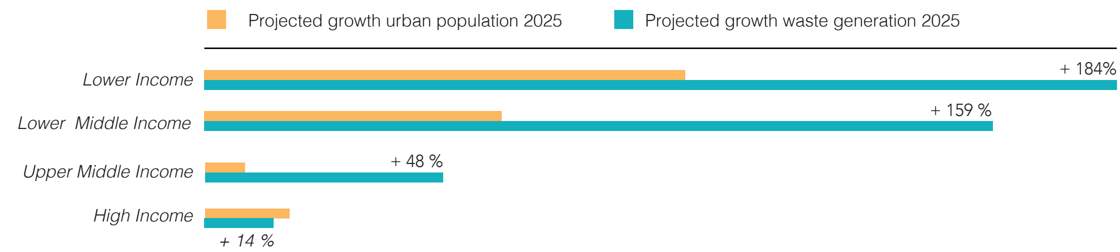

Figure 3

Urban population growth and projected growth of waste generation 2025

(Image by author, based on Hoornweg & Bhada-Tata, 2012)

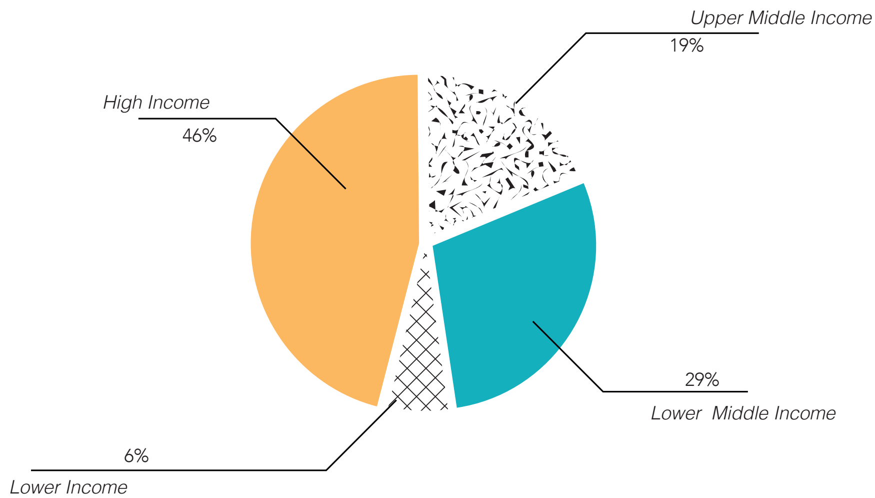

Figure 4

Generation of waste by income level country

(Image by author, based on Hoornweg et al., 2013)

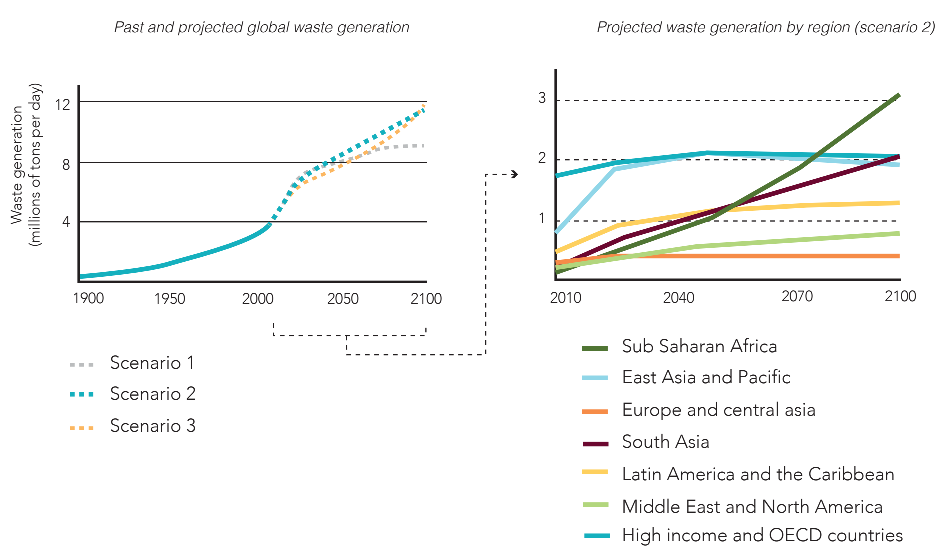

Figure 5

Projected growth of waste generation according to different scenario's

(Image by author, based on Hoornweg et al., 2013)

02
Problem field

To conclude, it is evident that we need to prepare for an increasing generation of waste. Population growth, as well as the trend of urbanization, result in a growth of waste production. Even in scenarios where we already try to develop our cities in a more sustainable way, the pile of waste will become bigger. In this sense, there is a high relevance to rethink our waste generation and treatment. This becomes even more urgent if you combine the increasing waste generation with the trend of depleting resources and our growing dependency on these resources. These two problems, enforced by urbanization, should be combined, since dealing with the waste problem, could contribute to solving the problem concerning depleting resources.

03
Problem analysis

Transition towards a circular economy and the related challenges in the context of Amsterdam

←
NDSM Werf, Amsterdam
(Twan Cortenraede)

Introduction

The two problems enforced by urbanization discussed within the previous chapter seem to be two problems of their own. However, on a conceptual level, these two problems have already been linked. Waste could be the solution to the problem of depleting natural resources by seeing waste not as an end stage, but as a resource which could be better utilized (figure 6). Within the further analysis of the real problem the concept of circular economy will be introduced. Within a circular economy waste becomes a resource which could lead to a reduction in natural resource use. This concept will be explained briefly, followed by an overview of its use within policies and visions on multiple scales. Eventually the city of Amsterdam will be discussed in more detail. By looking into the circular ambitions of the city and the faced challenges, the problem of this thesis can be stated. The problem statement eventually results in a vision which will be the aim of this thesis.

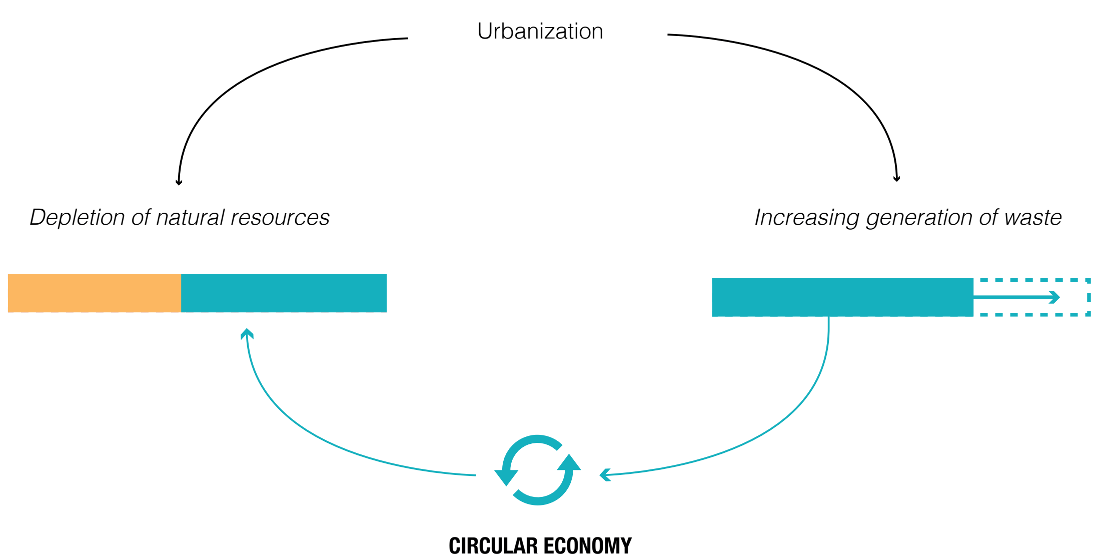

Figure 6
The concept of circular economy
Using waste as a resource to reduce the use of natural resources

(Image by author)

03
Problem analysis

03.1 Circular economy: a solution for sustainable urban development

As described on the previous page, a possible solution for the stated problem has already been found. A circular economy approaches waste in such a way that it makes it valuable and tries to avoid an end-of-life stage. In general, a circular economy is not only about the reuse of materials in a closed loop system. The Ellen Macarthur Foundation (n.d), a leading organisation if it comes to circular studies defines a circular economy as following: '*A circular economy seeks to rebuild capital, whether this is financial, manufactured, human, social or natural. This ensures enhanced flows of goods and services*". The easiest way to explain the concept of circular economy is by its linguistic meaning. Murray et al. (2017) describe circular economy as the opposite of a linear economy (figure 7). A linear economy converts natural resources into waste via production. Within this process natural capital is removed from the environment and by waste pollution the value of the natural resource is reduced. This results in a negative net effect since value has been lost. When an economy becomes circular, waste will be returned in the economy as a resource with the highest possible value. In a perfect functioning circular economy, there is no loss of value and the net effect on the environment will be zero. Less waste is being generated and a reduction of resource use will be achieved. A circular economy works according the principles of the three R's. Within the circle there should be a Reduction of resource use and a focus on Reusing products or components. When reuse is not possible the materials should be Recycled. Within this chapter only the essentials of circular economy are explained to make the real problem understandable. The theoretical framework (chapter 4) will give a more elaborated explanation of the concept of circular economy. The use of the concept becomes more clear within the chapters focusing on the analyses of this thesis. This new economic system is seen as a solution to guide urbanization in a sustainable way. It deals with the problem of increasing resource use and generation of waste. Circular economy is not just an economic system but can be interpreted in a brought sense to achieve sustainable development. Urban systems should be seen as larger organisms. By looking at nature, human systems can be made more efficient, since nature does not have end-of-life-stages (Simonds, 1862). The concept of circular economy tries to bring development from a human perspective back in sync with circular natural processes.

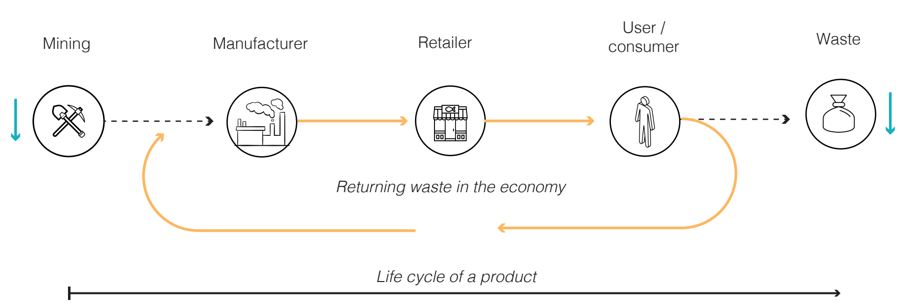

Figure 7

Reducing the use of natural resources and the avoiding the end-of life-stage of waste

(Image by author, based on Murray et al., 2017)

03.2 Circular economy: a guidance for sustainability policies and visions

The concept of circular economy has become one of the visions to reduce negative effects on the environment and deals with the global trend of climate change. The transition towards a new circular economy has become a guiding concept within governmental policies on different scales within the Netherlands. The goal of this chapter is to give inside on this transition and to show in which areas the ambitions are the highest and most progression is being made. Circular economy is a broad concept where multiple directions can be taken. At the end it will be visible what the focus points of the different regions are and which one is the most interesting to focus on.

To determine these focus points and in which face of the transition we are, multiple policy documents and strategies have been analysed. In figure 8 (on the next page), a time-line of the publications of these documents is presented. Major reports of the four biggest cities of the Netherlands have been taken into account since, overall, within these cities the urgency of this transition is the biggest and these cities have the highest ambitions.

Worldwide agreements and European visions

Climate change and other environmental concerns have been high on the agenda the last decade. Since 1990, the Intergovernmental Panel on Climate change published multiple reports on global climate change and environmental degradation (IPPC, n.d.). These reports created awareness of a worldwide problem with its corresponding consequences. Most of the discussion on a global level concern the problem of climate change. Agreements on this level are made to tackle this problem and they do not state the potentials of circular economy in particular. In December 2015, there was a big breakthrough in dealing with climate change and reversing the process of global warming. The Paris agreement, an agreement within the United Nations framework, stated clear goals to reduce CO2 emissions worldwide (United Nations, n.d.). However, the way these goals should be reached is up to the participating countries. Some say that circular economy may be a way to achieve these goals more easily (Blok et al., 2016). This agreement most certainly will contribute to increasing the speed of transitioning to this new economy.

On a European scale there is more attention on transitioning towards a circular economy to reduce waste and recognizing waste a resource. Already in 2014, the European commission addressed the circular economy on their agenda: *'Towards a Circulair Economy, A zero waste program for Europe'* (European Commission, 2014). A year later this resulted in an European action plan for speeding up the transition (European Commission, 2015). However, the actions consisted most of creating new regulations, supporting circular economy initiatives and investing in research projects (like the Horizon2020 project). Actions for implementations still need to be investigated.

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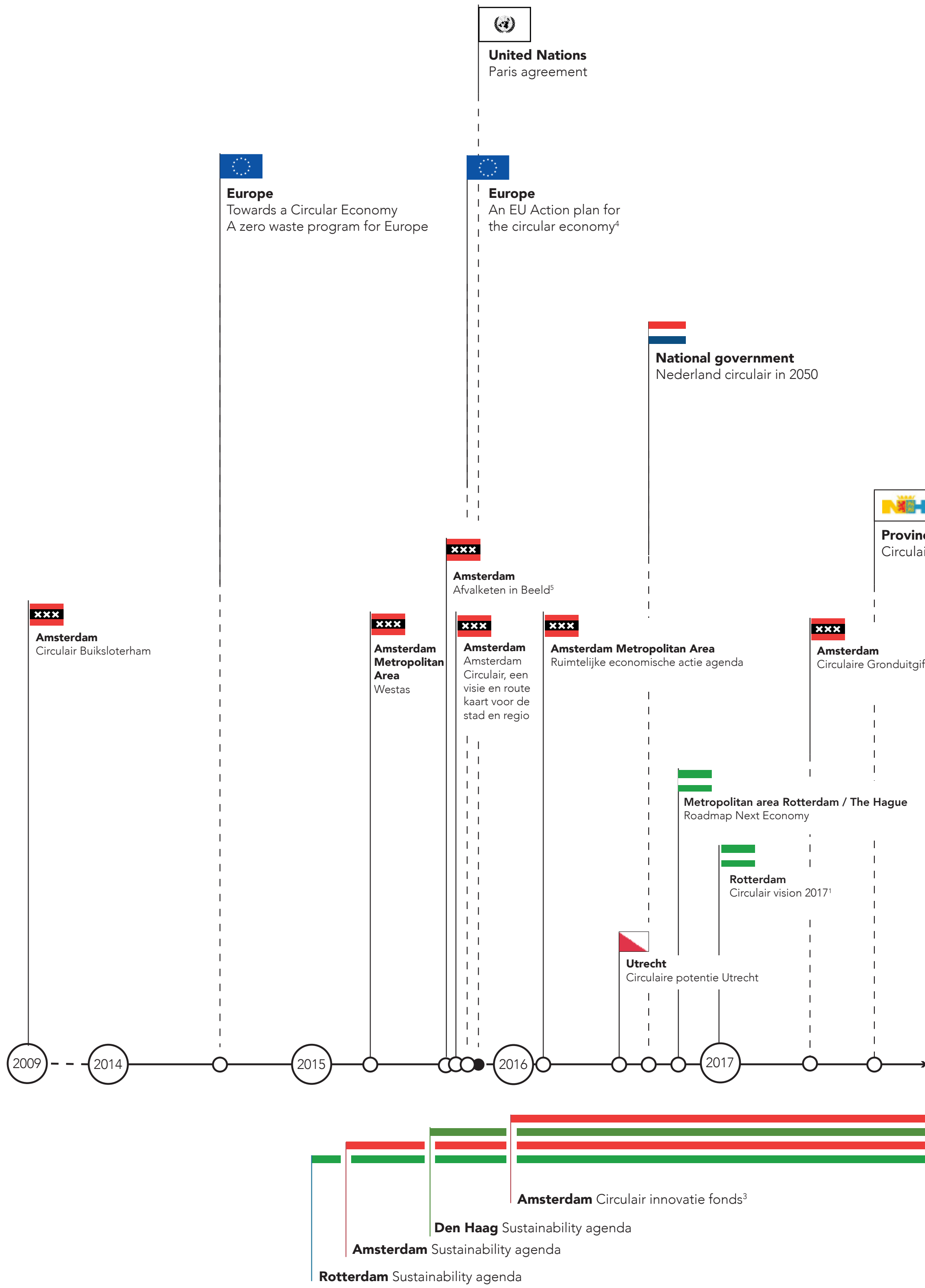

1: (Gemeente Rotterdam, 2017); 2: (Gemeente Amsterdam, 2017a); 3: (Gemeente Amsterdam, 2016a); 4: (European Commission, 2015); 5: (Gemeente Amsterdam, 2015c)

Figure 8

A time-line of published circular economy visions on different scales

(Image by author)

The Netherlands, national policy

The Dutch national government states within their report *'Nederland Circulair in 2050'* the necessity to strive for a circular economy because of three reasons: substantial growth in resource use, dependency of the Netherlands on other countries for resource supply and the relation to climate change in the form of CO2 emissions. Besides facing these problems, the national government sees within the Netherlands opportunities in transitioning to a circular economy, like economic opportunities (Rijksoverheid, 2016). The national government describes within their circular vision for 2050 five different instruments to create the right circumstances for the upcoming transition:

- Stimulation legislation
- Smart stimulants for the market
- Financing
- Knowledge and innovation
- International cooperation

With these five instruments the national government has a strong focus on financing the transition and remove legislation borders. The implementation of circular principles which will stimulate the transition should happen on smaller scales. Eventually, these implementations should be incorporated within the national policies.

Municipal visions and sustainability agenda's

Within the Netherlands, municipalities and metropolitan regions are probably the most ambitious in transitioning towards a circular economy. It is visible that these governmental bodies are experimenting the most and are eager to find possibilities to speed up the transition. However, the different regions have various approaches. A difference of focus can be seen on how to start or further develop the transition towards a circular economy.

Amsterdam

The municipality of Amsterdam has set high ambitions on this subject and wants to be one of the leading transitioning cities. The circular ambitions of Amsterdam already started in 2009 with the start of circular Buiksloterham (Metabolic, 2014). Within this new housing development area, circular concepts were used to develop a zero waste circular neighbourhood. In the years to follow, Amsterdam adopted circular economy within their 'sustainability agenda' and sees the concept as one of the biggest opportunities to facilitate sustainable growth in he future (Gemeente Amsterdam, 2015a). After including the transition within their sustainability agenda, Amsterdam presented at the end of 2015 their roadmap towards this new economy. Within their report '*Amsterdam Circulair, een visie en routekaart voor de stad en regio*', they presented their focus points and even the first proposals for implementations which would strengthen the transition (Gemeente Amsterdam, 2015b). With this report, Amsterdam also tried to make clear that the transition has spatial effects and would need spatial implementations in the form of infrastructure and new economic activities. This spatial element was especially addressed within the project Westas, where Amsterdam was one of the twelve partners who wanted to investigate the potentials and especially spatial effects of circular economy within the Amsterdam Metropolitan Area (AMA). (Westas, 2015). An example of research being done is an analyses of the spatial

▶ *Continuing page 26*

effects of transitioning towards a circular economy, and how this would affect our way of planning on a regional scale (Peters, 2017). This shows that Amsterdam and the surrounding region have a quite spatial approach to circular economy. They see the importance to investigate the spatial effects and are aware of the changes which are probably needed within our way of urban planning. Amsterdam is supported in their ambitions by the Province of Noord-Holland, which published the report *'Circulair Noord-Holland'*, and the Amsterdam Metropolitan Area, which addresses circular economy within their *'Ruimtelijke economische actie agenda '* (Metropoolregio Amsterdam, 2016; Circle Economy; 2017). With this support, this area and especially Amsterdam, becomes a place where circular projects are more likely to be realised in the coming years.

Rotterdam / The Hague

The other big economic region of the Netherlands, the metropolitan area of Rotterdam and The Hague (MRDH), is seeing the opportunities of this circular economy as well. Rotterdam and The Hague both integrated the transition within their sustainability agendas for the coming years (Gemeente Rotterdam, 2015; Gemeente Den Haag, 2015). The direction the metropolitan area wants to take within this transition becomes visible within the report *'Roadmap Next economy'*, realised by the MRDH and the Third Industrial Revolution Consulting group led by Jeremy Rifkin (Metropoolregio Rotterdam Den Haag, 2016). Within this report, circular economy becomes part of a way bigger transition towards a new economy. MRHD approaches the transition towards this new economy especially as a technical and digital revolution. By making more efficient use of available data and monitoring resource flows, a more efficient economy can be created. They mainly concluded that these new digital methods need to be investigated and that the metropolitan area should focus on becoming leader within this digital revolution. In comparison to the AMA, there is less focus on the actual flows and the related spatial challenges and opportunities. However, the vision of the MRHD is already more precise on how to enforce the transition, which makes it even more clear that especially on a municipal and metropolitan scale the ambitions are the highest.

Utrecht

The fourth biggest city of the Netherlands, Utrecht, approaches the transition in a quite different way. Utrecht does not reveal a lot of its circular goals publicly, nevertheless they are working on circular projects, and investigated the potentials in their report: *'Circulaire potentie Utrecht'* (Bastein & Rietveld, 2016). The city of Utrecht also differs a lot from Amsterdam and Rotterdam/ The Hague. Utrecht is not an industrial city and focusses a lot on a knowledge and service economy. Besides that, Utrecht does not a have a clear structure of a metropolitan area. This will probably result in a totally different approach to the transition compared to the other two regions.

Conclusion: focus on Amsterdam

The first steps in solving the problem of depleting resources and increasing generation of waste have been made. The concept of circular economy has been introduced a couple of years ago. Circular economy is becoming a common theme within visions and policies on different scales. Foremost, the metropolitan regions and municipalities are taking the lead within the transition. The municipality of Amsterdam tries and probably is one of the leading cities when it comes to enhancing this transition. They have a clear focus on the concept of circular economy and already address spatial challenges and opportunities. The making of this first link with spatial challenges and the high ambitions of the municipality, form the reason why this thesis focusses on the city of Amsterdam. The next chapter elaborates on the problem field within Amsterdam and the circular ambitions of the city. These first observations lead to the problem statement of this thesis.

03.3 Amsterdam: circular ambitions, resource use and waste

The worldwide problem described within the problem field is taking place within Amsterdam as well. Amsterdam shows a trend of urbanization and it is the fastest growing city of the Netherlands. According to forecasts published by the province of Noord-Holland It is expected that in the year of 2034 the city will reach the level of one million inhabitants (Het Parool, 2017 January 9; Meershoek, 2017, June 28). This growth will affect the functioning of urban systems and raises questions of how this growth should be facilitated in an area where space is scarce. Circular economy stands already high on the agenda within the municipality. In the following paragraphs the current status of the transition within Amsterdam will be shown by looking at the cities ambitions. Next to that, resource management within Amsterdam will be discussed and how this could be improved. This requires to look at the current situation of waste generation, treatment, and resource use within the municipality of Amsterdam. It will become clear what main challenges are most interesting to look at.

Amsterdam and its natural resource depended economy

The growth of Amsterdam results in a growth in resource use. More inhabitants and more building activities increases the consumption of the city. A higher energy demand can be expected, when the trend of urbanization continues. The problem is that still, most of the energy production runs on fossil fuels, and it is expected that in 2030 still most of the energy will be produced using these resources as energy carriers (Peters, 2017). The AMA, and so Amsterdam, has a high dependency on these fossil resources. The AMA consumes every year around 10 million tons of materials and resources. However, 60% of these resources are imported from all over the world. This shows the high dependency on other regions, which is one of the reasons the national government describes why a transition towards a circular economy is needed. 50% of this import consists of fossil fuels which are used within the production of chemical products and plastics (Gemeente Amsterdam, 2015b). It can be expected that the import of these fossil resources will continue to increase the coming years, looking at the current national import trend showing a growth in import of fossil energy carriers every year (CBS, 2016). Exact predictions on the resource use of Amsterdam are not available. However, looking at the national trends and the expectation that urbanization will lead to increasing resource use, the urgency for Amsterdam becomes clear. Something has to happen to decrease the dependency on other regions, reduce environmental impact and to find new sources for material and energy production.

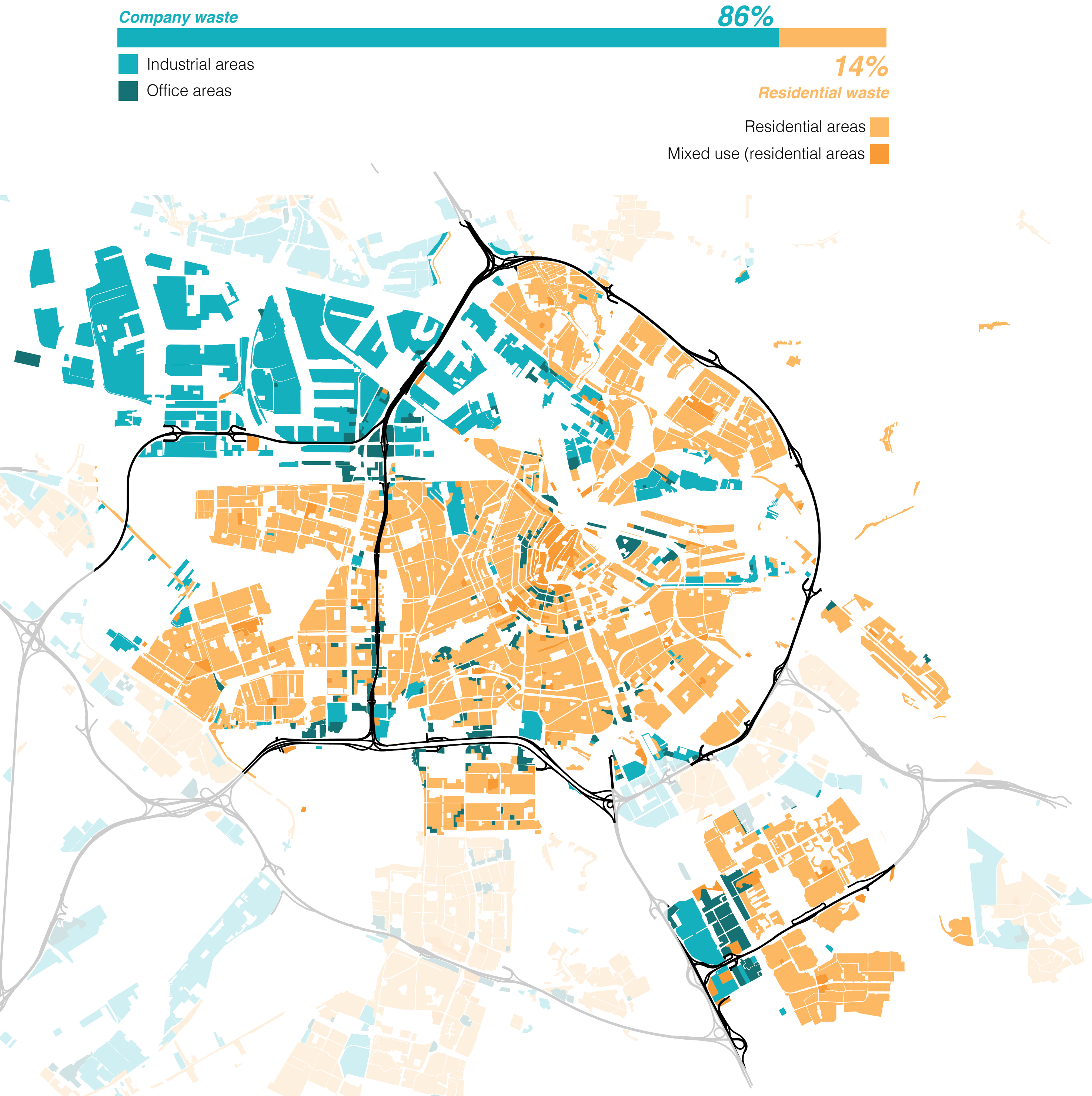

Figure 9

Ratio between company and residential waste and the locations where it is generated.

(Image by author, based on Gemeente Amsterdam 2015c and GEO data base municipality of Amsterdam)

Waste generated in Amsterdam

In 2015, the municipality executed detailed research to gain insight in the waste generation of Amsterdam (Gemeente Amsterdam, 2015c). In total, Amsterdam produces around 217 million kilograms of waste per year. There is a huge difference in quantity if you split out the waste generation in residential waste and company waste. 86% percent of the waste is originating from companies and only 14% is generated by households (figure 9). An obvious choice would be to try to focus on the biggest quantity. However, the waste produced by households is probably a bigger challenge to tackle compared to the company waste. The collection and treatment of household waste requires a system for the whole city, including collection systems and around 822.000 inhabitants to influence. This system is controlled by the municipality itself, so it is also easier to restructure this entire system. Company waste is collected by private contractors and requires more a change in business management. A more circular business management does not affect the city itself or has any spatial consequences.

For this reason, this thesis focuses on the system of residential waste within Amsterdam, since changing the system is a larger challenge compared to company waste because of the required spatial integration and implementation within the current urban structure.

Circular ambitions Amsterdam and related challenges

The city of Amsterdam is trying to facilitate the transition by experimenting with a wide variety of projects. The municipality of Amsterdam tries to learn by doing, since circular economy is a new concept and still little is known in what ways urban areas can be made more circular. The earlier mentioned project of Buiksloterham, is such a project where they try to experiment with zero waste neighbourhoods. Within the sustainability agenda they described the years 2015 and 2016 as years of experimenting to gain more knowledge on circular projects. The municipality of Amsterdam especially tries to create evidence that circular economy has advantages and that it is the way to achieve sustainable development (Gemeente Amsterdam, 2015a).

Since Amsterdam has high circular ambitions, a circular collection and treatment system for residential waste should be one of their focus points. In this way waste really can become a resource and forms a solution to the scarcity of natural resources and the environmental impact of using those. Amsterdam presented a quite detailed overview on the treatment process of residential waste within their report *'Afvalketen in beeld'* (Gemeente Amsterdam, 2015c). It can be concluded that most of the waste is being reused, however, not in the most valuable way. Most waste is recycled on a material base, which is one of the least valuable options. More value could be achieved when there would be more focus on reuse, and repair (more detailed analyses of the current treatment system can be found in chapter 7.3). The current system mainly focusses on central treatment facilities on a large scale. These treatment companies are mostly situated within the Port of Amsterdam. However, the Port of Amsterdam is under pressure because of the need for more space for housing development (Port of Amsterdam, 2017). The question is if this system of large treatment facilities is still the best and most circular treatment

▶ *Continuing page 30*

system. Not only large scale treatment facilities are under pressure by housing development plans. Waste points throughout the city, where residents can bring their waste are in conflict with new housing plans (figure 10). Even the municipality itself recognises that a new approach should be found on how these points can be reintegrated into the city (Gemeente Amsterdam, 2015c).

In sense of the circular economy transition, they have not set exact goals yet. The first goal they want to achieve is to collect 65% of the waste in separate flows by 2020, to increase the possibilities for reuse (Gemeente Amstedam, 2015c). For a circular economy to operate, it is crucial to collect waste in homogeneous flows instead of heterogeneous, since the treatment for every waste type is different and they can not be treated when they are mingled. However, with a current separation rate of around 30%, which is way lower compared to the Dutch average of 47%, this goal is still far away from being achieved. Reaching this goal will require quick action and interventions to improve the collection system (more information about the current collection system can be found in chapter 7).

03.4 Problem statement and vision

Within chapter 2 and 3 the scope and scale of this thesis has been determined. Circular economy in the context of Amsterdam is the focus of the research and design conducted within this thesis. Amsterdam has high circular ambitions and is facing challenges concerning their waste production. Separate collection rates are way to low, treatment is not optimized yet and this all happens within a growing city where space becomes scarce. Circular projects are already happening, however, still on an experimental level. The time has come for Amsterdam to implement circular solutions to improve residential waste collection and treatment. This will contribute to a sustainable growth and less dependency on natural resources which are depleting. Reaching the set goals for 2020 requires a strong vision for the future and the courage to propose city wide implementations, changing the whole system of residential waste treatment and collection.

This all results in the following problem statement:

Amsterdam is missing knowledge on how to implement circular solutions spatially, to improve the separate collection rates and treatment of waste flows. This is even a bigger challenge since space is scarce and housing development projects are putting the current system under pressure. The question is how Amsterdam can manage to improve the residential waste system within a dense urban area living up to its circular ambitions.

This thesis will tackle this challenge and this results in the following vision:

Developing a new residential waste collection and treatment system for Amsterdam living up to the circular economy ambitions of the city. There is the need for finding ways to translate circular concepts in spatial projects which can be integrated within the dense urban system. In this way, spatial challenges are confronted and Amsterdam can become an actual progressive circular city.

To better understand the given challenge, the related theoretical concepts are explained within the theoretical framework. This next chapter elaborates on the gap in knowledge concerning this challenge.

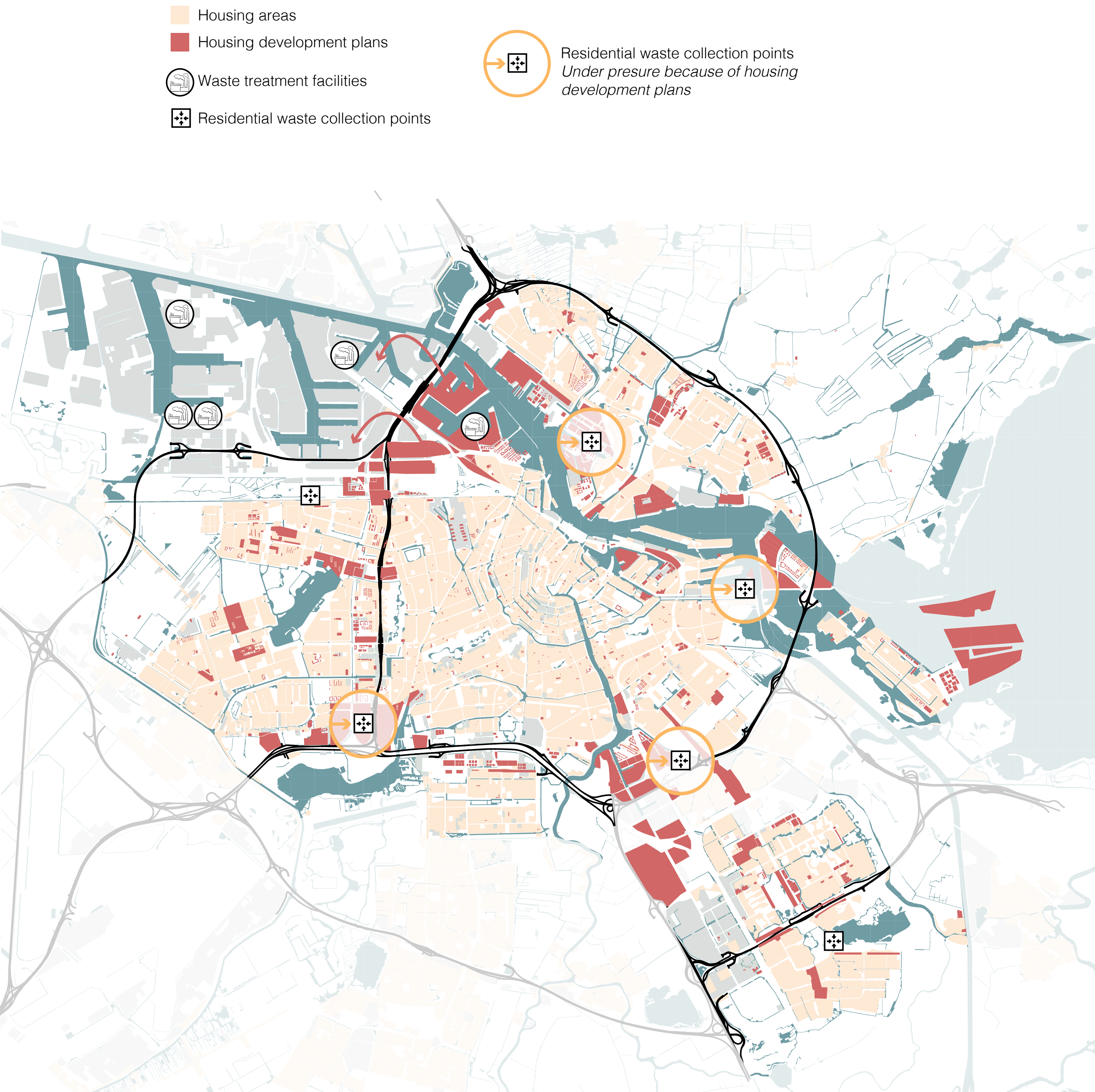

Figure 10

Waste treatment facilities and collection infrastructure under pressure by housing development plans

(Image by author, based on Gemeente Amsterdam 2015c and GEO data base municipality of Amsterdam)

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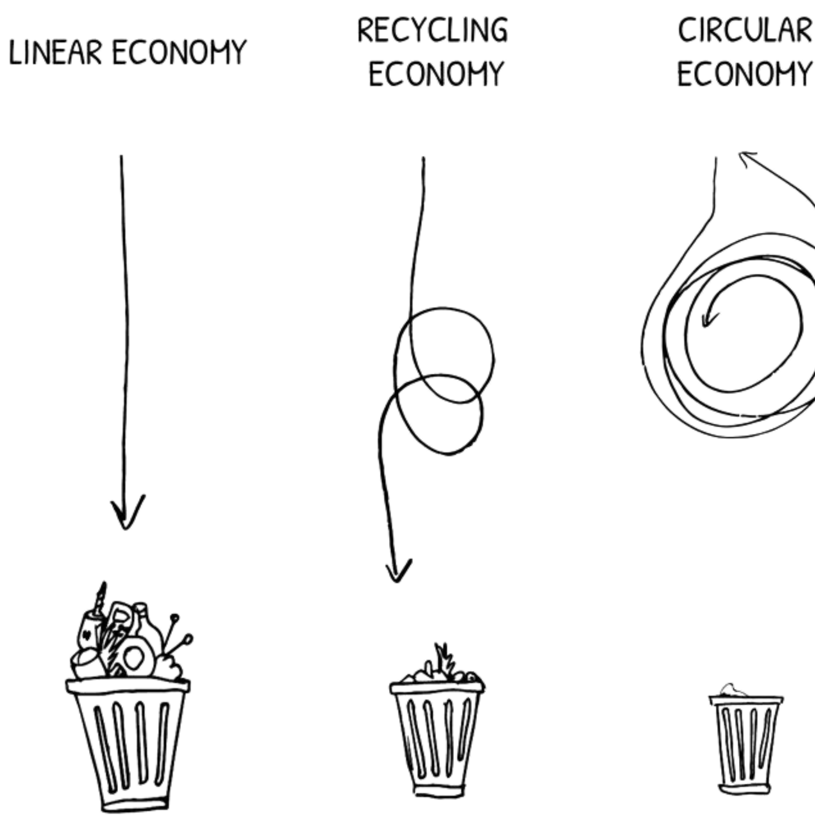
To better understand the concept of circular economy and especially the relation to urban areas three different theories are discussed. Firstly, the concept of circular economy itself, its origin and its different dimensions and current focus. Secondly, urban metabolism as method to analysis flows within urban areas. Finally, the upcoming relation between urban metabolism and urban design will be discussed. Especially how the concept of these two fields could lead to implementation of circular economy principles in urban areas.



(Plan C)

04.1 Circular economy

The easiest way to explain the concept of circular economy is by its linguistic meaning. Murray et al. (2017) describe circular economy as the opposite of a linear economy. A linear economy converts natural resources into waste via production. Within this process natural capital is removed from the environment and by pollution of waste the value of the natural resource is reduced. This results in a negative net effect since value has been lost. When an economy becomes circular, there will be no loss of value and the net effect on the environment will be zero. Within a circular economy we speak about two different kind of circles. The first on is the biological circle. This circle tries to bring the end product back to natural levels. An example of this is the composting of biowaste and the return of it in the biosphere in the form of fertilizer. In this way the circle has been closed and all the remained value has returned to nature (figure 11). The second circle is about the recycling of products, most often called the technological circle. Within this circle the focus is to recycle the product in a way the least value is lost. Within this circle the main idea is described by the three R's. Within the circle there should be a Reduction of resource use and a focus on Rusing products or components. When reuse is not possible the materials should be Recycled (figure 12). In this way, the lifespan of a product is increased and the non-valuable end-of-life stage is prevented as long as possible.

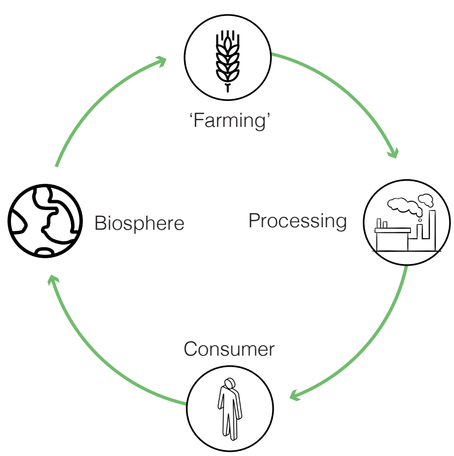


Figure 11
Retain value of biological nutrients
Within a linear economy biological waste has an end of life stage and will not return into the biosphere. In a circular economy no value is lost and every time the biological product is disposed it is brought back into the biosphere. In this way an endless self-propelling system is created where value of natural resources are retained.

(Image by author, based on Murray et al., 2017)

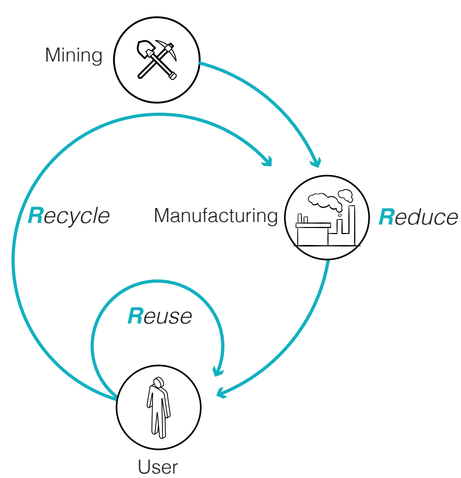


Figure 12
Retain value technological products
Technological products can have an end of life stage as well. Within a circular economy the use of resources is minimized (reduce), products are being reused, and if that is not possible the materials of the product are being recycled. In this way the lifespan of products and materials is extended and an end of life stage is prevented.

(Image by author, based on Murray et al., 2017)

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A circular economy diagram according the Ellen MacArthur foundation

The Ellen MacArthur Foundation developed a diagram illustrating circular economy based on the reattainment of value within the recycling process. Within a circular economy, as explained by Murray et al. (2017), the loss of value is minimized with the reuse or recycling of the product. These principles, which are incorporated in the circular economy vision of the Ellen MacArthur foundation, already existed for a longer time. Ad Lansink presented in 1979 the *'Ladder van Lansink'* (figure 13). The idea behind this ladder was when you want to reduce negative environmental impacts created by waste, you should climb up the ladder. The least good way of using waste is to use it as landfill. The best way would be the prevention of generating waste at all (Lansink & Vries, 2010). This theory of Lansink helps to understand the processes within the diagram.

In figure 14 the working of this circular economy diagram, by the Ellen MacArthur foundation ,is explained. This diagram is a helpful tool to understand the different options how waste can be treated and returned in multiple ways within the production chain. This representation is the base of this thesis and will be of use to understand the gaps in knowledge and perform certain circular analyses.

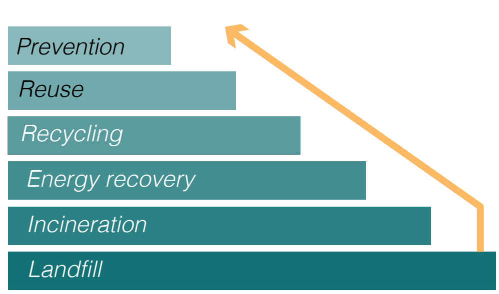

Figure 13
Ladder of Lansink
(Image by author, based on Lansink & Vries, 2010)

Origin and development of circular economy

The exact origin of the concept of circular economy is strongly debated, however, it is certain that the thinking behind circular economy already exists for a very long time. Already in 1848, Hofman, talked about the ideal factory which only produces products and no waste (Lancaster, 2002). A century later, Kenneth Boulding (1966) made the link to a circular ecological system. He states that humanity must find its place within this circle which is capable of continuous reproduction of materials and resources. In 2011, Matthews and Tan, added to the already existing definitions the term of a 'closed-loop' economy (Matthews & Tan, 2011). It is clear that over the years multiple definitions with different points of focus have been made. However, they have in common that they all talk about a 'closed-loop' economy where waste should be minimized or reused to create a self-maintaining continuous system.

China is one of the countries that has put circular economy high on its governmental agenda. Some even say that China was the place where the concept of circular economy was used first in practice (Yuan et al., 2006). In 1998 the concept of circular economy was first introduced within Chinese scholars. In China circular economy was at first an approach to facilitate sustainable urban growth while dealing with the trend of depleting resources. Feng (2004) defined three core principles of circular economy: The ''3R" principles – reduction, reuse and recycling of materials and energy. These three principles form the core of circular economy and form three approaches you can take to achieve circular goals. With these three approaches an efficient economy can be created and environmental pollution will decrease. But to achieve this the current economic system and human activities should be revised (Yuan et al. 2006). However, there is a change of perspective of the concept of circular economy. Circular economy arose from an environmental strategy

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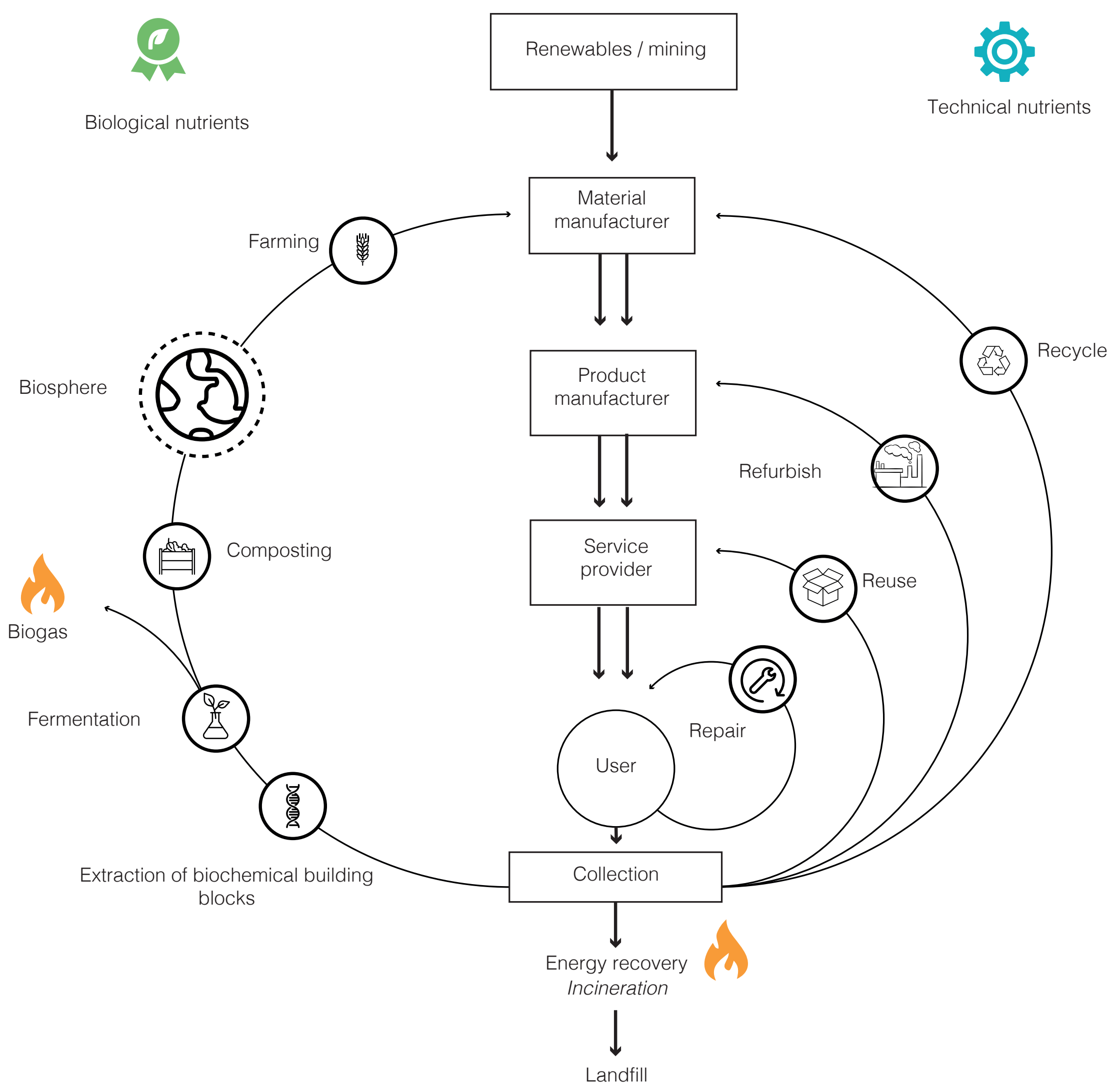

Figure 14

Circular economy diagram by the Ellen MacArthur Foundation

The circular economy scheme build by the foundation makes a difference in biological (left) and technological streams (right). At first the biological flows will be explained, secondly the technological flows.

Both schemes start at the user, which can be a company or an Amsterdam resident. The waste flow is being collected and transported to a designated treatment facility. The least good way of treatment is incineration. This way of treatment results in energy and eventually the left overs are used as landfill. The most valuable recycling method for biological flows is the retrievement of biochemical building blocks. The materials can be used within chemical or pharmaceutical industries. After this process, biogas, energy and heat can be retrieved by the process of digestion. The leftovers will be composted and brought back into the biosphere in the form of fertilizer. These steps would be the most ideal way of recycling and shows how the highest value can be obtained from biological waste flows.

According to the Ellen Macarthur foundation, technological components can be recycled or reused in four different ways. The best way is to repair the product without disposing it. When the decision is made to dispose the product, the second best way of recycling is to let other people reuse the product. The third best way is to refurbish the product. The still functioning parts are reused and new products are made of it. The final stage should be the recycling of the raw materials. Within this scheme, how smaller the circle, the most value is preserved. The biggest circle still has value, but is just a fraction of the original value of the product.

(Image by author, based on Ellen MacArthur Foundation, n.d.)

by focussing on reduction in material usage and in energy consumption. Nowadays, and also in China, circular economy becomes more an economic strategy. The focus is now more on creating a sustainable economic system and related to that a sustainable society, while at the same time trying to achieve sustainability goals and deal with the trends of climate change and depleting natural resources (Yuan et al., 2006). China already changed their perspective on circular economy in early stages. Before 2012, not much research had been done on the economic benefits of circular economy. Until then, the believe was that circular economy would become our future economic system, but prove was not there. Circular economy became interesting from an economic perspective since it concerns maintaining value and creating value by re-using (Stahel 2015). In 2012, the Ellen Macarthur Foundation (2012) published their report '*Towards the circular economy*'. They introduced the circular economy as an alternative for our current linear production which is vulnerable for the trend of depleting resources and produces a lot of waste and environmental harm. This new economy functions as an industrial system which is regenerative. Besides introducing the concept once again, they gave arguments that circular economy is not only interesting from an environmental point of view, but can generate a lot of economic value. The report stated that the concept of circular economy could save manufacturing companies in Europe US$630 billion a year by 2023. This completely changed the mind-set about circular economy and world-wide, countries and city regions became interested in this new concept that could help us towards sustainable growth in the future.

Dimensions of circular economy, its focus and related theories

The focus of the concept of circular economy changed over the years. The development of circular economy has been influenced by many different theories. To explain the current focus of circular economy some influences will be discussed. Geisendorf et al. (2017) describe these multiple influences and shows how diverse the concept of circular economy actually is. By giving this overview it becomes possible to show the current gaps in knowledge within circular economy theories. These gaps will structure the rest of this thesis.

Below some of these influencing theories will be discussed. In the next the conclusion, the missing dimensions of circular economy will be discussed.

Cradle to cradle

The cradle-to-cradle concept developed by McDounough & Braungart (2002) focusses on the development of products which are designed in a way they could be reused completely in a later stadium. This includes products, as well ass it applies to buildings and architectural design. It takes in to account the total lifespan of a product or building and thinks in the beginning of the design phase already about the reuse or recycling options. This concept applies a lot on the manufacturing and design industries, since they need to start developing different products or buildings which can facilitate a closed-loop system.

Laws of Ecology

Barry Commonor (1971) contributed with his 'Four Laws of Ecology' to the development of the general concept of circular economy. His four laws describe that everything is linked to each other and everything must go somewhere and never disappears. It created the realization that we live in one big system, where nature and humanity both have influences. His main message was that nature knows it best. So natural processes are more efficient and environmental friendly compared to processes forced by human interventions.

Looped and performance economy
A performance economy, presented by Walter Stahel (2010), goes even a step further compared to a circular economy. Within a performance economy not only resources are being exchanged, but next to that, services related to goods are being sold through rent and lease constructions. In this way the manufacturer stays the owner of the product and responsible for the whole life-cycle of the product. In this way, the theory of Stahel has a strong focus on increasing efficiency and a reduction in resource use. Stahel proposes in this way a complete new way of looking towards ownerships and business models.

Regenerative design
John Lyle (1994) contributed with his work on regenerative design on the development of circular economy in general. Lyle integrates nature thinking within the design process. Using nature as a metaphor or as a guideline, more sustainable designs could be made since natural process have a minimum of negative environmental effects.

Industrial Ecology
Industrial ecology focuses on the integration of circular processes between industrial activities. Industrial ecology uses non-human, natural ecosystems as a model for industrial activities. Those natural systems are the inspiration for achieving high efficiency in recycling materials and energy use (Ayres & Ayres, 2002). One way of implementing industrial ecology is by designing eco-industrial parks. In such an industrial park, energy should be produced by using renewable energy, systems should be integrated within the natural ecosystem and waste or by-products are being used by other companies as resource (Bueren, 2012). However, Conticelli and Tondelli (2014) argue that industrial ecology in the form of eco-industrial parks has been mainly focused or limited to industrial processes. The focus is mainly focused on energy efficiency and resources and waste exchange. The spatial component of implementing industrial ecology and the related spatial issues are less addressed.

Blue economy
The blue economy provides a business model where scarcity is turned into abundance (Pauli, 2010). The book shows connections between environmental problems and local solutions are proposed to these problems. All to reduce environmental negative effects and finding new ways of making profit. This makes the blue economy another theory which addresses especially the economic side of circular economy and the local circular thinking as a whole.

Conclusion: Missing dimensions within circular economy theories

Circular economy has multiple dimensions and perspectives on closing the loop. Different theories focus on reduce, reuse or recycle, and some describe the whole circular system as a new economic system. With these different focus points the theories are focusing as well on different levels of scale. Cradle to cradle for instance has a focus on the design processes of products or buildings. Industrial ecology on the other hand mostly looks at industrial processes and symbioses. Within eco-industrial parks waste and resources are exchanged between industries to diminish waste and reuse waste (Bueren, 2012).

However, it is argued that some dimensions are still missing within circular economy theory and that there is too much focus on the economic perspective of the system. Smol et al. (2017) state that there are already

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some examples of circular economy in countries like, China, Japan and EU. However, they are still some limitations. Existing circular economy theories have a strong focus on reducing resource use by increasing the efficiency of production. This focus can be found in for instance the theory of industrial ecology or cradle to cradle.

To show the missing dimensions of circular economy, the comparison with theories of sustainability can be made. Geissendoerfer et al. (2017) describe the motives of sustainability as following: '*The motives behind sustainability are based on past trajectories, are diffused and diverse, and often embrace reflexivity and adaptivity to different contexts.'* However, circular economy seems to have just a main focus on resource use reduction and making better use of waste stream. Sustainability tries to benefit the environment, the economy and society at large. Circular economy appears to create mostly economic benefits for the actors which start implementing the concept within their business strategies. Eventually it will probably lead to better environmental circumstances, however, the economic motive maintains the main motive. Murray et al. (2017) also make the comparison with the more brought theory of sustainability. The three main pillars of sustainability; economic, environment and social, should be addressed according the sustainability theory. When addressing all three pillars, real sustainability could be achieved. Murray et al. (2017) state that *'Only if societal needs are defined and included in the basic formulation, can we hope to build on all three pillars of sustainability. This needs urgent attention in the Circular Economy conceptual framework.'*

This thesis especially focusses on the non economic and more human dimensions of circular economy which are still under addressed. The bottom part of the diagram, the role of the users and the collection are crucial elements of a circular economy and are happening in complex urban environments. More knowledge is needed on the effect of these flows and circular treatment ways on existing urban systems and fabrics. This highlights another aspect of circular economy which is little discussed. The spatial impact of transitioning to a circular economy is not much knowledge about. There is knowledge about creating new circular systems, but how to implement them and integrate them within urban environments is an unaddressed topic.

The theoretical framework continues with two research fields which are already working on these urban waste flows and spatial integration (figure 14).

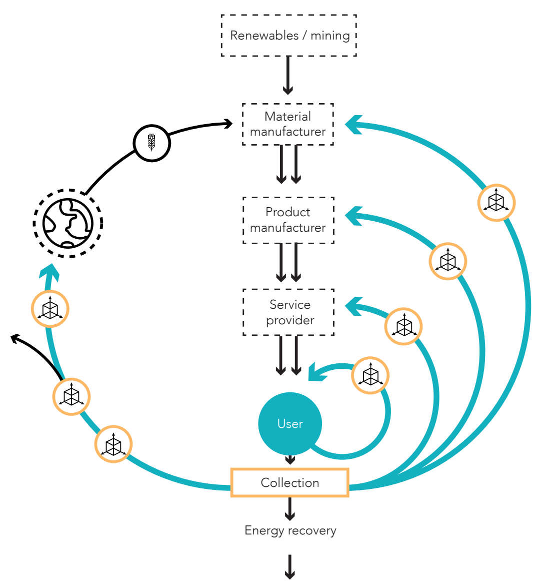

Figure 14
Focus of this thesis
Waste flows within urban areas on a low scale related to users. Focusing on the spatial impact of these flows, the collection and the different forms of circular treatment.

(Image by author)

04.2 Urban Metabolism

To get a better understanding of resource use and waste generation, the theory of urban metabolism is discussed. When looking at cities as a part of the natural system it is more easy to understand the relation with and impact on other ecosystems. Urban metabolism is used to examine the environmental impact and performance of a city. Environmental problems are growing since the input of energy and resources is growing, as well the output in the form of waste. By examining the city as a system, the flows of energy, resources and even pollutions can be traced. This information can help to manage these flows, reintegrate the flows with natural processes, increasing recycling rates, achieving higher efficiency in resources usage and production of renewable energy (Newman, 1999).

Tjallingi (1995) describes in its book ‘Ecopolis’ the starting point of urban metabolism and the metaphors we use to describe urban flows of materials and resources. We should see nature as the system of all the resources and living processes. In this case, humanity is part of this whole, so there is not a difference between natural processes and man-made processes. Urban metabolism looks at urban systems from an ecological perspective. The study of ecosystems, derived from biological sciences, is the object of research. The urban ecosystem is a system that is always open and where resources, flows of energy and materials can enter an environment and eventually, after a transformation can depart again. The city can be seen as a complex ecosystem, just as it is seen as a social, economic or spatial system.

Urban Metabolism has broadened its scope over time. Kennedy et al. (2007) describes urban metabolism as the sum of all the technical and socioeconomic processes that occur in cities. These processes result in growth, the use of more natural resources, the need of producing renewable energy and eliminating waste. In this definition the relation is being made with other systems within the urban system, like the social system and the economic system. So all systems interact with each other and do not operate separately.

Evolution of the urban metabolism framework

Over the last fifty years, the concept of urban metabolism developed itself, by especially trying to understand the complexity of urban systems. Zhang (2013) explains within here paper *‘Urban metabolism: A review of Research Methodologies’* this evolution (figure 15). Already in 1965,

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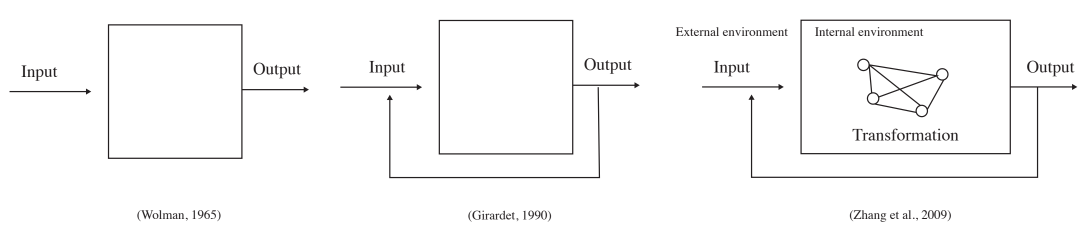

Figure 15
Evolution of the urban metabolism framework
(Zhang 2013))

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Abel Wolman, discusses the metabolic requirements of cities in his book 'The Metabolism of cities'. He described these requirements as all the materials and resources that are needed to sustain an urban system, including its residents, work and leisure. This metabolic cycle is completed when all the materials have been used and residual waste has been disposed with a minimum amount of environmental impact. Wolman described his concerns about our waste production and the shortage of resources like water and energy. This model was still a linear model where inputs and outputs where measured, which were transformed within a black box. Girardet (1990) came as first with the concept of circular metabolism. He stated that the output of a system should be used as input for the system. Waste should be regarded as an asset and recycling should be fully integrated within the functioning of the city. But still, within in this concept, the system itself (for instance a city) was displayed as a black box. However, here is visible that the first link with circular economy is made. Zhang et al. (2009) tried to further develop this circular metabolism model by focussing on this unknown black box. They created a model to understand the components of the urban metabolic system. According to Zhang et al., the urban metabolic systems consists of a domestic sector, an agricultural sector and an industrial sector. The three sectors operate within an urban system and form the basis of the network of flows. Since cities cannot be sustained with resources and flows from inside the city boundaries, resources have to be imported from outside the city, which is called the external environment. These resources are processed and transformed in the urban area, called the internal environment. Within this model, scales are not presented as set boundaries as neighbourhood, city, and region. The external environment can be any region that supports the urban system. So it is possible that urban systems have links with areas on the other side of the world. Here the link has been made with the broader definition of urban metabolism by Kennedy (2007).

The use of urban metabolism for circular economy implementation

As explained, urban metabolism analysis flows of all kinds through especially urban environments. By making for instance a Material Flow Analyses (MFA) of a city, the level of performance of the city in sense of resource use can be analysed (Ayres & Ayres, 2002). With these methods it becomes possible to analyse very precise the trajectory, amounts and networks of waste flows through cities. This can be valuable information for finding circular solutions and find flows which are performing not well. An example of such a MFA is given in figure 16, where the in and output of the Amsterdam Metropolitan Area is visualized. However, urban metabolism itself is an analysing method to understand processes within cities. It does not provide methods to improve the system or implement new processes. The implementation part will has to come from a combination with another research field which will be explained in the next part of the theoretical framework.

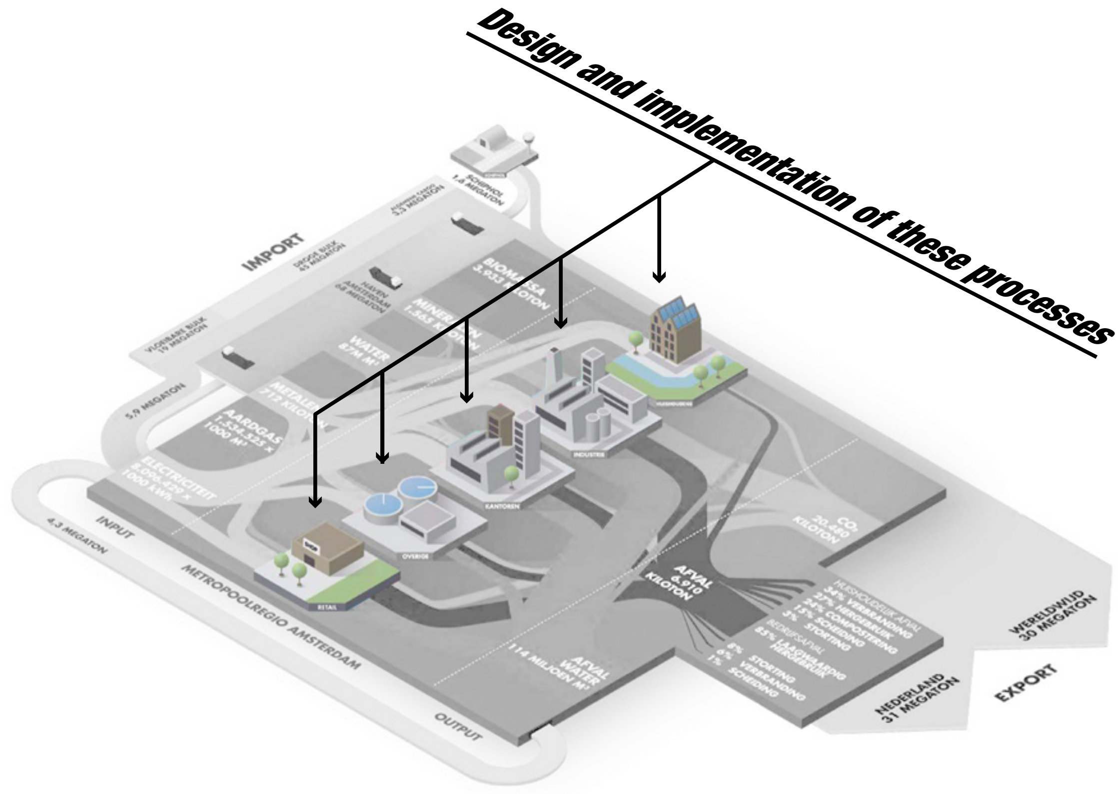


Figure 16

MFA of the Amsterdam Metropolitan Area

Material flow analyses gives great inside in the performance of an area. However, urban metabolism describes the processes within the urban system which influence the flows, it does not provide solutions for implementing and designing new processes

(Image by author, edited from Gemeente Amsterdam, 2015b))

04.3 Urban Metabolism and Urban design

Urban metabolism is mostly seen as a tool to analyse the performance of an urban area. This kind of research is useful to determine the sustainability of the urban system. It helps to quantify the challenges and supports measures that have to be taken. However, according to Kennedy et al. (2010), urban metabolism could be more. Urban metabolism should be more established within the profession of urban design. Combining the different professions could be the base for sustainable urban development. Urban metabolism may be seen as a research theme that combines different research fields.

Nevertheless, there is still a lot of effort needed to get urban metabolism established within the profession of urban design. However, there is a development going on in the right direction. Barles (2010) explained that most urban metabolism research happened so far within the profession of industrial ecology and industrial areas, but they are now including social and urban metabolism within their research.

Zhang et al. (2015) confirm that, so far, urban metabolism is mostly a research method to quantify and understand

▶ *Continuing page 42*

the interaction between the natural and human system. The multiple analysis methods performed within urban metabolism can be used to support policies and interventions which will contribute to more sustainable urban environment. However, they argue that there is little research and knowledge on integrating urban metabolism within the professions of urban design and planning. Within their paper '*Urban Metabolism: A review of current knowledge and directions for future study*', attempts for combing the different professions are explained.

One of the first attempts is the Netzstadt method developed by Oswald et al. (2003). Within this approach, concerning the city as a network, flows of goods, people and information are taking into consideration. These flows flow through the city and concentrate at certain nodes within the city. The understanding of these flows and nodes form the base for redeveloping the city of Luzern, which they use as a city to test their developed method.

Janneke van der Leer (2016), a former graduate student within the research group of Urban Metabolism and Smart Cities at TU Delft, tried to integrate urban metabolism analysis and urban design within her master thesis. She used material flow analysis to assess the impact of waste in the neighbourhood of Buiksloterham (Amsterdam) and proposed spatial interventions to transform the neighbourhood into a zero-waste neighbourhood. She showed how changes in the current waste system could be integrated within the urban fabric and urban social processes. This project was a good experiment on a neighbourhood scale, however, what she mentions as a recommendation for further research, the implementation on a city scale should be analysed further.

04.4 Conclusion: linking urban design to circular economy concepts

Circular economy has been explained and other related theories (summary in figure 17). It becomes clear that circular economy is a brought concept with multiple angles. An unaddressed perspective is the human perspective and the relation between circular economy and urban design. Urban metabolism can provide important information about our current urban systems and can even point out which processes can be improved. The biggest challenge is to integrate these processes within the urban environment and create valuable links to other urban systems. This link, between urban metabolism and urban design, has already been made. However, still can still be discovered on how these flows can change our urban environment and how integrated solutions can be created. A valuable link needs to be created between the conceptual thinking of circular economy and the contextual urban design profession. When this link is being made, the spatial effects of new circular concepts can be determined and integration options can be found. Circular economy is a concept of itself. Nevertheless, how Geisendof et al. (2017) and Murray et al. (2017) describe, only true sustainability can be achieved when social, economic and environmental systems are combined and synergies are created. Urban design can play a crucial role in this process and find true valuable circular solutions.

This new link is the core of this thesis and will be further described in the next chapter, discussing the different objectives of this thesis.

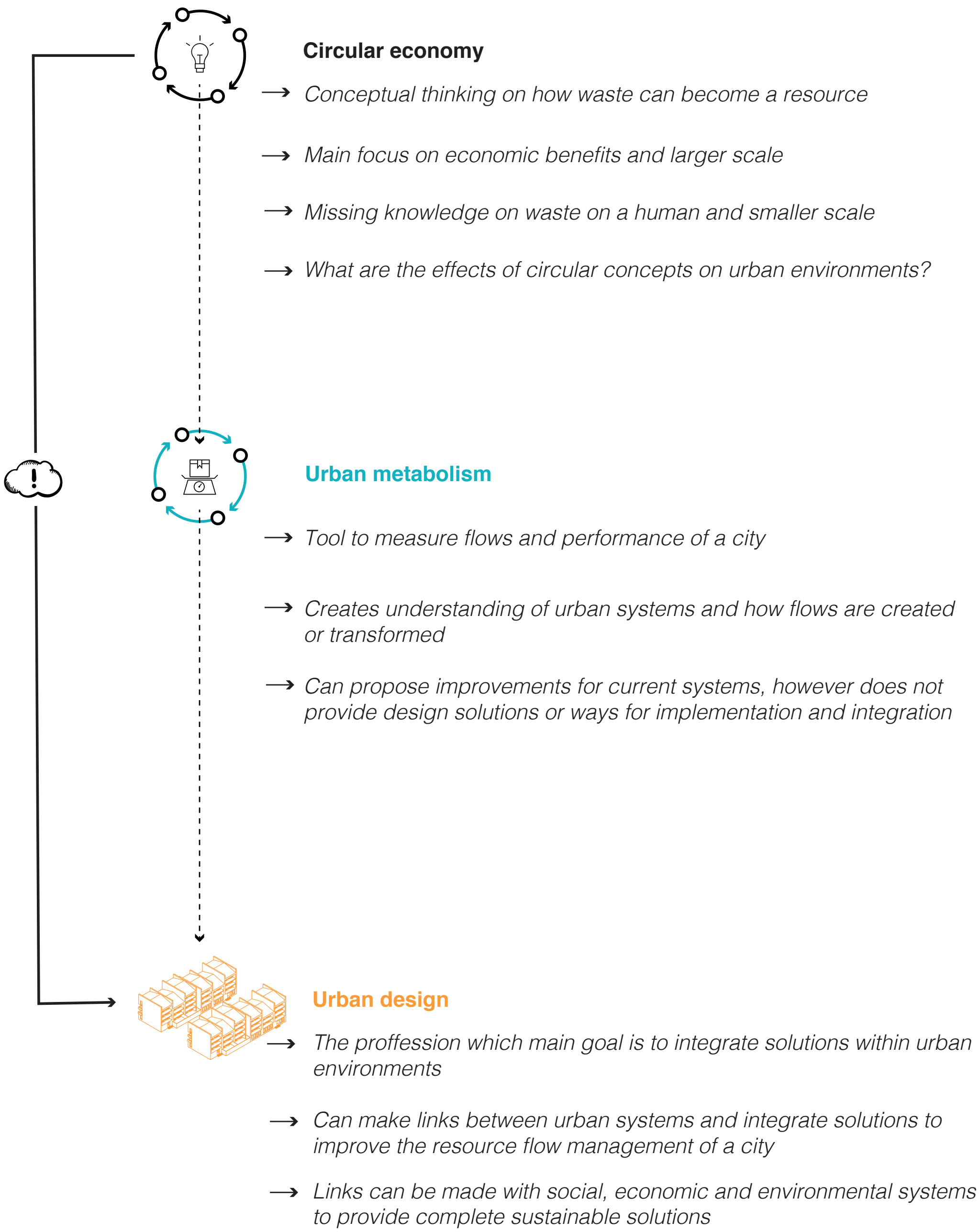


Figure 17

A summary of the described theories and creating new links between circular economy and urban design

(Image by author)

05

Objectives and research question

Now the problem within Amsterdam has been stated and a gap in knowledge is noticed, the objectives for this thesis can be given. The stated problem vision in chapter three, resulted in a vision to improve the residential waste system for Amsterdam. Chapter 5 discusses the objectives from a research perspective and design perspective, which are related to the challenges in Amsterdam. The relevance of these objectives will be explained at the same time. When the objectives are clear, the related main research question and sub questions can be stated. These questions form the outline of this thesis and are structured within a methodological framework (chapter 6).

Problem statement

Amsterdam is missing knowledge on how to implement circular solutions spatially to improve the separate collection rates and treatment of waste flows. This is even a bigger challenge since space is scarce and housing development projects are putting the current system under pressure. The question is how Amsterdam can manage to improve the residential waste system within a dense urban area living up to its circular ambitions.

Future vision

A new residential waste collection and treatment system for Amsterdam living up to the circular economy ambitions of the city. Finding ways to translate circular concepts in spatial projects which can be integrated within the dense urban system. Confronting the spatial challenges and let Amsterdam become a real progressive circular city.

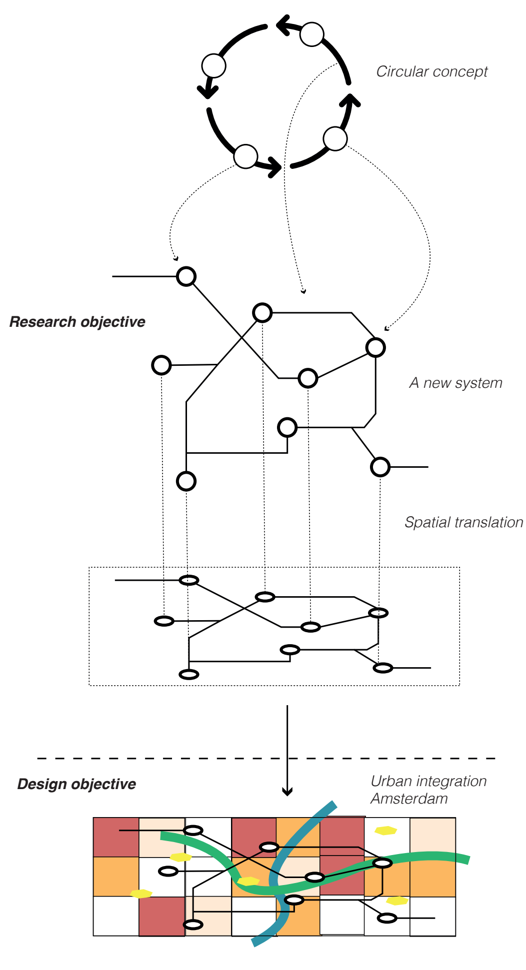


Figure 18
Research and design objective
(Image by author)

Main research question

How can circular concepts be translated into an integrated urban system to improve the treatment and collection of residential waste in Amsterdam?

Research objective and its scientific relevance

The objective of this thesis is to develop a method which translates circular concepts into urban systems, which can be spatially implemented within urban environments (figure 18). With such a method, the spatial effects of circular concepts can be shown. The understanding of spatial consequences of these new systems can help urban designers to modify old and implement new systems. It will become more easy to see where synergies can be made with other urban systems and how integration in the existing urban fabrics is possible.

This research will contribute to the ongoing discussion on how systemic designs and concepts can be translated to spatial designs. A link is being made between the conceptual circular economy and practical profession of urban design. It will make integration of circular systems more easy within the urban environment.

Design objective and societal relevance

The design goal is to implement the developed circular systems as a part of the research objective. Proposals will be made on how new circular waste collection and treatment principles can be integrated within the urban environment of Amsterdam. Here the real link with urban design will be made, to show how synergies can be created with other urban systems and how the new developed waste system can be adjusted to the spatial characteristics of the city.

This proposal for a new system will contribute to the circular ambitions of the city of Amsterdam. The city has set high goals concerning residential waste treatment, and these implementation options will provide suggestions to reach these goals. With this design step, it becomes more clear how these goals can be reached and what kind of interventions are needed. A more circular and valuable residential waste treatment has benefits for the residents itself. Less waste and better recycling methods will help to reduce the negative environmental impacts. This reduction will improve life quality within the city and makes it possible to develop our cities in a sustainable way. By linking the waste system to other urban systems, it will become possible to create more added value for the residents and show residents how they can help to reduce the ecological food-print of the city and contribute to a progressive, innovate circular city.

06

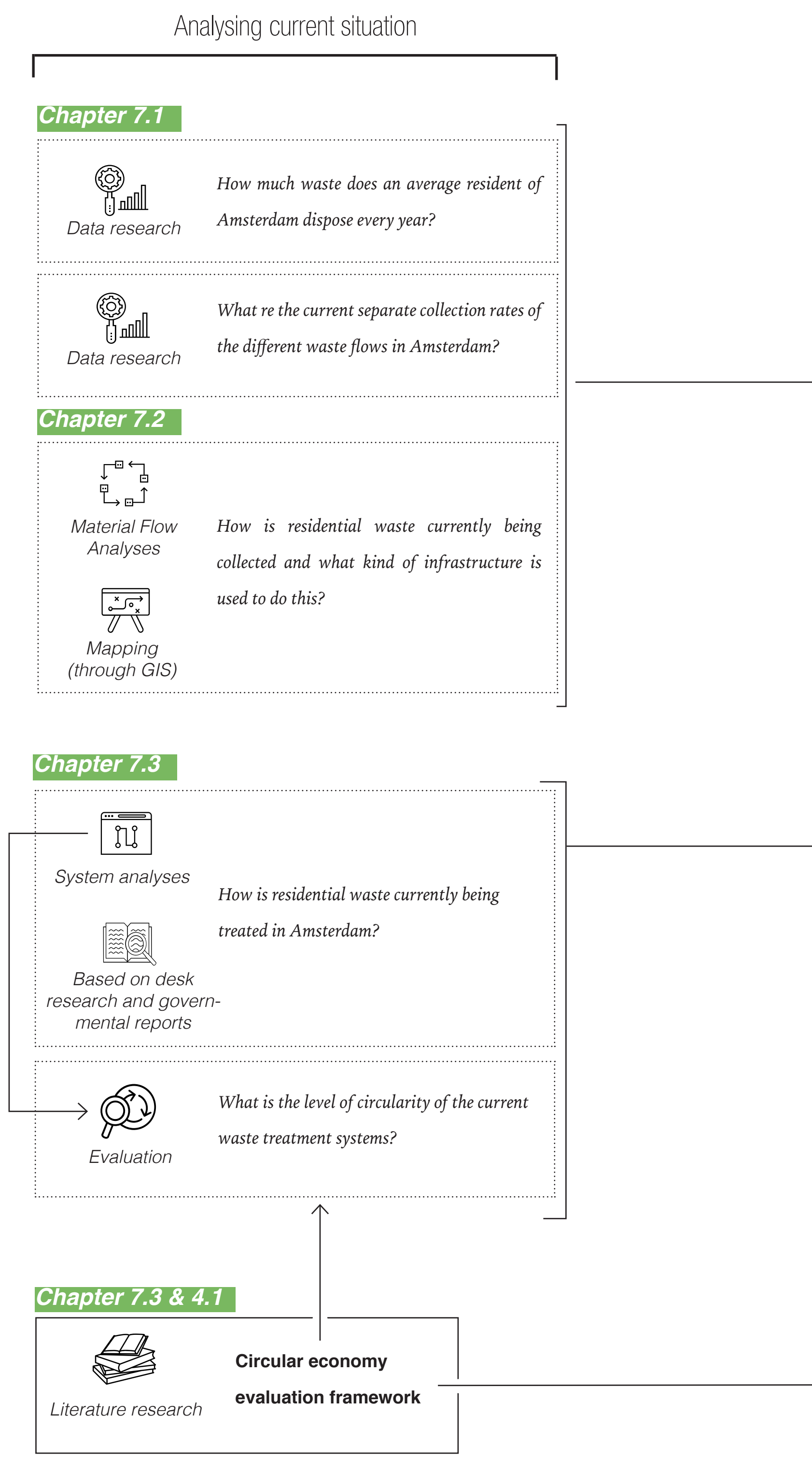
Methodology

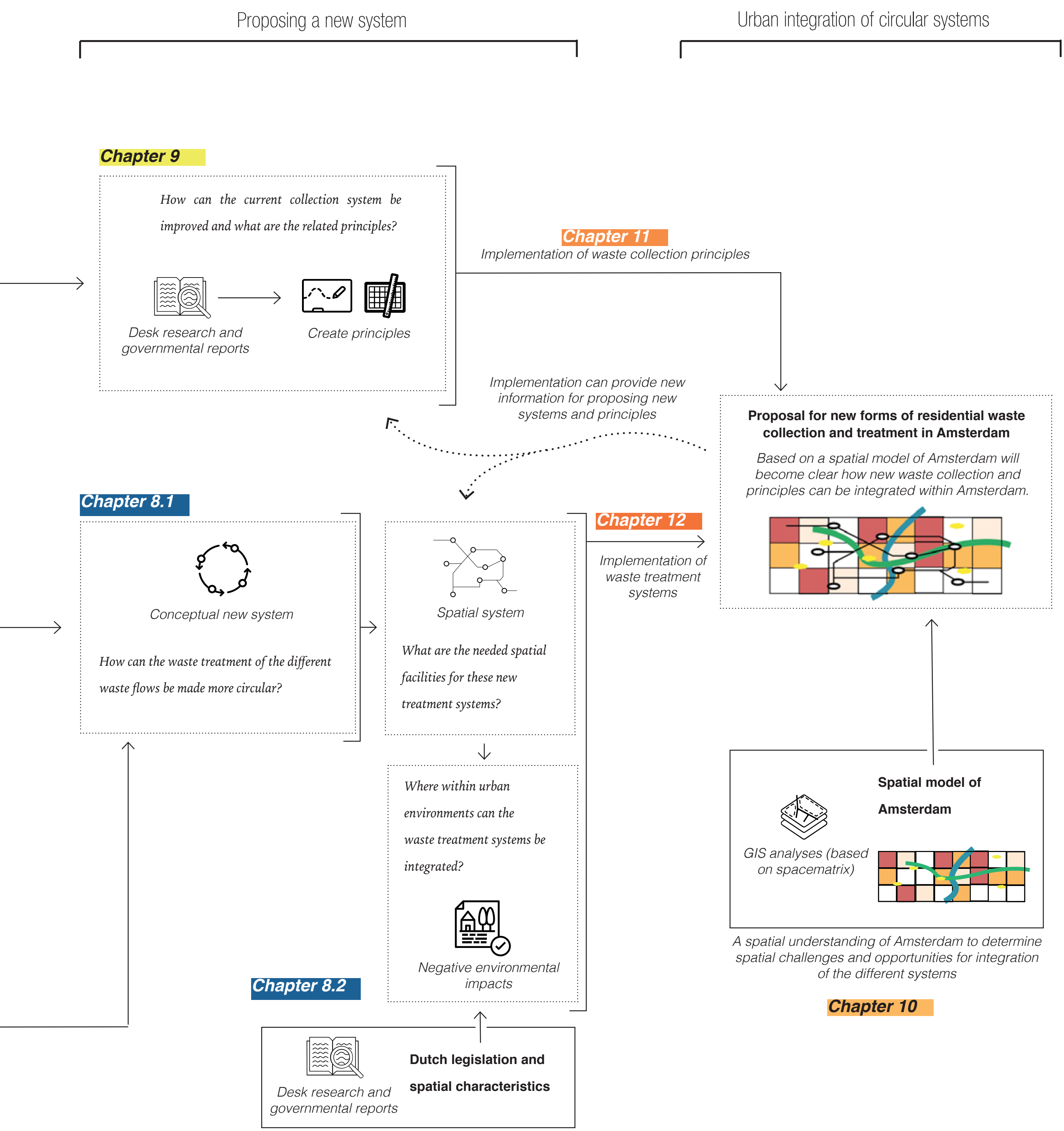
The main research question is decomposed in multiple sub research questions which will form the outline of the research and design. On the right, the methodological framework is visualized which shows how this thesis is structured and how the main research question will be answered.

To know what to improve, the current system with its problems and values have to be known. Since collection and treatment are strongly related, both systems will be analysed. The collection system will be analysed on quantities, volumes and separation rates. The treatment system will be evaluated on its circular value. The evaluation will be based on the circular economy framework developed by the Ellen MacArthur foundation (2012).

In the second part a new systems will be proposed. Circular improvements for the treatment systems will be translated into spatial systems. By describing the spatial characteristics and negative environmental effects of these system, it becomes possible to determine which systems are suitable for urban integration. Principles will be created as well for the collection system, which describe how more waste can be collected separately.

The new systems will be implemented and integrated within Amsterdam. To better understand the possibilities for urban integration, an overview of Amsterdam is made, explaining the different urban typologies of the city. With this information, proposals can be made how the new collection principles could be integrated within the city. Both new systems will eventually lead to a proposal for a new waste collection and treatment system for Amsterdam. However, connections between the collection and treatment system should already be made. Both are interrelated and effect each other. At the same time, knowledge gained from implementing the systems should be input again for the systems on a conceptual level.




Proposing a new system
Urban integration of circular systems
Chapter 9
How can the current collection system be improved and what are the related principles?
Desk research and governmental reports
Create principles
Chapter 11
Implementation of waste collection principles
Implementation can provide new information for proposing new systems and principles
Proposal for new forms of residential waste collection and treatment in Amsterdam
Based on a spatial model of Amsterdam will become clear how new waste collection and principles can be integrated within Amsterdam.
Chapter 8.1
Conceptual new system
How can the waste treatment of the different waste flows be made more circular?
Spatial system
What are the needed spatial facilities for these new treatment systems?
Chapter 12
Implementation of waste treatment systems
Where within urban environments can the waste treatment systems be integrated?
Negative environmental impacts
Chapter 8.2
Desk research and governmental reports
Dutch legislation and spatial characteristics
Spatial model of Amsterdam
GIS analyses (based on spacematrix)
A spatial understanding of Amsterdam to determine spatial challenges and opportunities for integration of the different systems
Chapter 10

→

Residual waste treatment

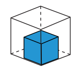
(Oliver Sved)

Analysing current situation

Amsterdam residential waste collection and treatment system

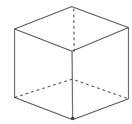
07 Analysis

Packaging glass



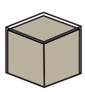
Total 31,8 kg / 0,09 m³ **58%** Separate 18,4 kg / 0,05 m³

Fruit and vegetables



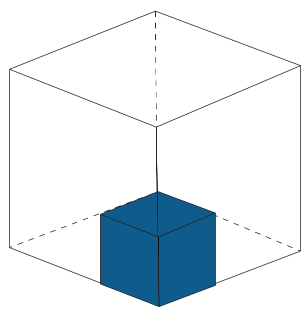
Total 79,4 kg / 0,2 m³ **2%** Separate 1,85 kg / 0,004 m³

Wood



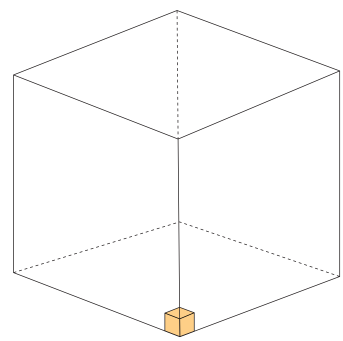
Total 20,2 kg / 0,1 m³ **96%** Separate 19,4 kg / 0,1 m³

Paper / cardboard



Total 64,6 kg / 0,45 m³ **38%** Separate 24,8 kg / 0,17 m³

Packaging plastics



Total 23,4 kg / 0,49 m³ **8%** Separate 1,8 kg / 0,04 m³

Electronic appliances

Total 2,2 kg / 0,012 m³ **63%** Separate 1,4 kg / 0,008 m³

Wooden furniture

Total 1,1 kg / 0,07 m³ **43%** Separate 0,5 kg / 0,03 m³

Furniture

Total 5,2 kg / 0,03 m³ **18%** Separate 0,9 kg / 0,01 m³

Metal

Total 10,5 kg / 0,022 m³ **80%** Separate 8,4 kg / 0,017 m³

Garden waste

Total 20,8 kg / 0,04 m³ **22%** Separate 4,6 kg / 0,01 m³

Textile

Total 17,3 kg / 0,06 m³ **18%** Separate 3,2 kg / 0,01 m³

Amsterdam residential waste collection and treatment system

In order to propose changes to the current treatment and collection system of residential waste in Amsterdam, the current situation should be analysed. In this chapter an overview is given on the waste production of an average resident of Amsterdam. This analyses will give information about the volumes and fractions which are currently collected separately. Following, the current collection system and its related infrastructure is analysed to understand its relation to the city. The third part of this chapter analyses the circularity of the current waste treatment system of Amsterdam. By analysing the treatment of different waste flows, it becomes clear what the current value of the treatment methods is and if the way of treating could be made more circular.

07.1 Waste quantities, volumes and separate collection rates

To evaluate the performance of the current collection system of residential waste, it is necessary to know what quantities we are talking about, and especially the current separation rates. By looking into quantities and translating them into volumes the spatial impact of different types of waste becomes visible. The spatial impact of waste can be determined in this way, which is valuable information when finding solutions for urban integration. In figure 19, the eleven largest and most dominant waste flows are analysed according to their quantity, volume and current separation rates. The visual representation of the volumes provides the possibility to see the substantial differences in volume between the different types of waste.

The calculations are based on a research done by the municipality of Amsterdam called *'Afvalketen in Beeld, Grondstoffen uit Amsterdam'* (Gemeente Amsterdam, 2015c). The research provides precise calculations on the average waste generation of an inhabitant of Amsterdam. It became possible to give the estimated figures presented in figure 19. In 2015, an inhabitant of Amsterdam generated 370 kg of waste. The different waste flows can be categorized in two different types. Figure 19 shows the homogeneous waste flows which are collected separately. The waste flows consist of one dominant type of waste which can be treated in the same way. The second type of waste flow is the heterogeneous waste flow. This is a mix of different types of waste. This waste flow is called residual waste. The quantities were calculated in kilograms, however, by using a transformation table it was possible to give an estimation of the volume in cubic meters. Eventually the separation rates are calculated by looking into the total waste production per waste flow and the part which is collected separately. It is important to

← Figure 19

Quantities, volumes and separation rates of eleven waste flows in Amsterdam

The figures represent the generation of one inhabitant of Amsterdam per year. The cubes visualize the total volume of waste (white cube) and the volume of the current separate collected faction (coloured cube).

(Image by author, based on Gemeente Amsterdam, 2015c)

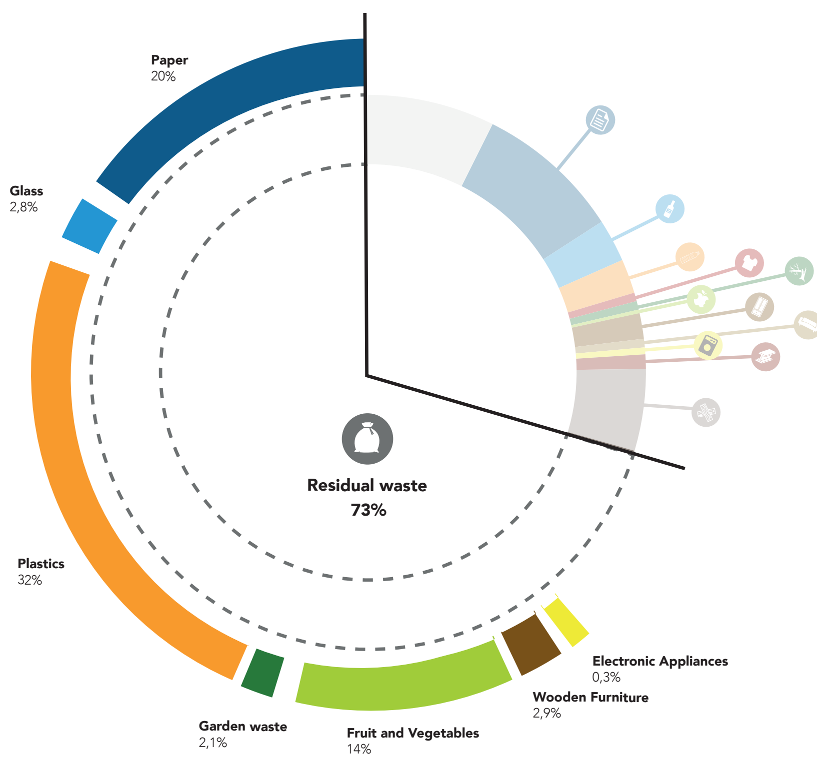
▶ *Continuing page 52*

know that in this case we talk about the source separation. This does not include the separation which is done after collection within waste treatment companies.

This study shows that between waste flows there can be a huge difference in both volumes and separation rates. Most of the waste flows do not reach the 65% separation goal set by the municipality of Amsterdam. Besides that, there is a difference in volume, which should be taken into account when designing with waste. Every waste flow has different characteristics and uses different amount of space within the city. Residual waste takes up 73% of the total waste production and represents the biggest volume. It has to be kept in mind that when separation rates will increase, the amount of residual waste will shrink. Figure 20 shows how much waste of the analysed homogeneous waste flows is now within the residual waste flow. When more waste is collected separately, the amount of residual waste will decline, and the volume of the homogeneous waste flows will grow. This will have a big impact on the city since most of the collection infrastructure is now focusses on the collection of residual waste. After this analyses, there may be concluded that the waste flows of metal and wood are already reaching the 65% goal. The same accounts almost for electronic appliances. The conclusion for all the other waste flows is that improvement has to be made quickly. New methods should be discovered to increase these separate collection rates within Amsterdam.

Figure 20
Residual waste and its consistency
73% of the total waste production is still the heterogeneous waste flow residual waste. However, it is important to know that residual waste consists of a variety of homogeneous waste flows. For instance, 20% of residual waste is paper. When increasing the separation rates, the amount of residual waste will decline and the volume of the separated homogeneous waste flows will increase.

(Image by author, based on Gemeente Amsterdam, 2015c)



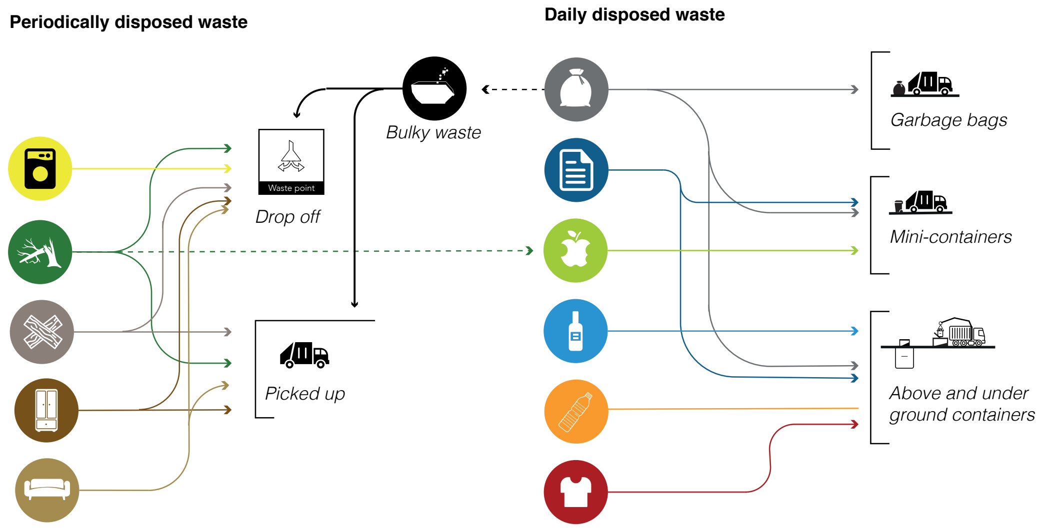


Figure 21

Residential waste collection methods

Most off the daily disposed waste flows are collected via street-containers. In some parts of Amsterdam, mini-containers are provided at home. Residual waste has the most collection methods, including as well the option to place garbage bags in front of the house. The periodically disposed waste flows are collected or dropped of at six waste points throughout the city. Residual waste in this category is called bulky waste. Garden waste could be collected together with fruit and vegetable waste in mini-containers at home.

(Image by author, based on Gemeente Amsterdam, 2015c)

07.2 Current waste collection methods and related infrastructure

To understand how the current collection system works, an overview of the collection methods will be given. After knowing how the system works, it can be evaluated and proposals for change can be made.

The current collection methods can be divided in two different types (figure 21). The different collection methods for daily disposed waste flows and periodically disposed waste flows could be derived from the report '*Afvalketen in beeld*', written by the municipality of Amsterdam (Gemeente Amsterdam 2015c).

Residual waste is collected via under or above ground containers, individual mini-containers at home, or garbage bags can be placed on the streets. Most of the homogeneous daily waste flows, like paper, plastic and glass are being collected via under and above ground containers. In some areas a mini-container at home is provided to collect these waste flows. Fruit and vegetable waste, which is also a daily disposal is almost not collected separately. Only some neighbourhoods have separate mini-containers for this waste flow.

The second type of waste, the waste flows which are not disposed daily and most of the time have a larger volume (because it are products or larger chunks) are collected in a different way. In Amsterdam there is the possibility to bring these types of waste to a waste point at the border of the city. Amsterdam has six of these municipal waste points where all residents can bring their waste. Another option, especially for residents without a car, is to let your waste be picked up. In half of the city an appointment

▶ *Continuing page 54*

has to be made, and a waste truck will pick up the waste which has been dropped on the street by the resident. In the city districts further away from the city centre, designated areas are marked at the streets where these waste flows can be placed weekly or every two weeks. They will be collected automatically.

Figure 21 shows an overview of these different collection methods which form the whole collection system. Included within this overview is the related infrastructures needed for the system to function. Only containers and waste points are physical forms of infrastructure which need to be integrated within the urban environment Throughout the city, there is a big difference in used method and also availability of infrastructure. Figure 22 shows these infrastructures throughout Amsterdam.

The mapping of the infrastructures shows a strong dominance of residual waste containers. The areas where the containers are not available are the areas where the waste is collected via mini-containers and garbage bags on the streets. The other homogeneous waste flows are represented by 75% less containers. Especially textile and plastics are not well represented. The main reason for this is the fact that glass and paper is already collected for a way longer time compared to packaging plastics. Mini-containers can be found in some neighbourhoods, however, most of them are for residual waste. In the case of the daily disposed waste flows, it may be concluded that the low separated collection rates are partly related to the fact that there is a dominance in residual waste disposal options. In some areas it is even not possible to separate your waste. Besides that, it seems that there is no clear system which applies for the whole city. There are large differences between neighbourhoods. The differences probably relate to the differences in available public space to integrate the waste collection containers. In the dense city centre almost no options are available to dispose your waste separately. In the suburbs of Amsterdam, more space is available for waste collection infrastructure. To make separate waste collection available for all the residents of Amsterdam, solutions for integrating waste collection infrastructure for every neighbourhood type should be found.

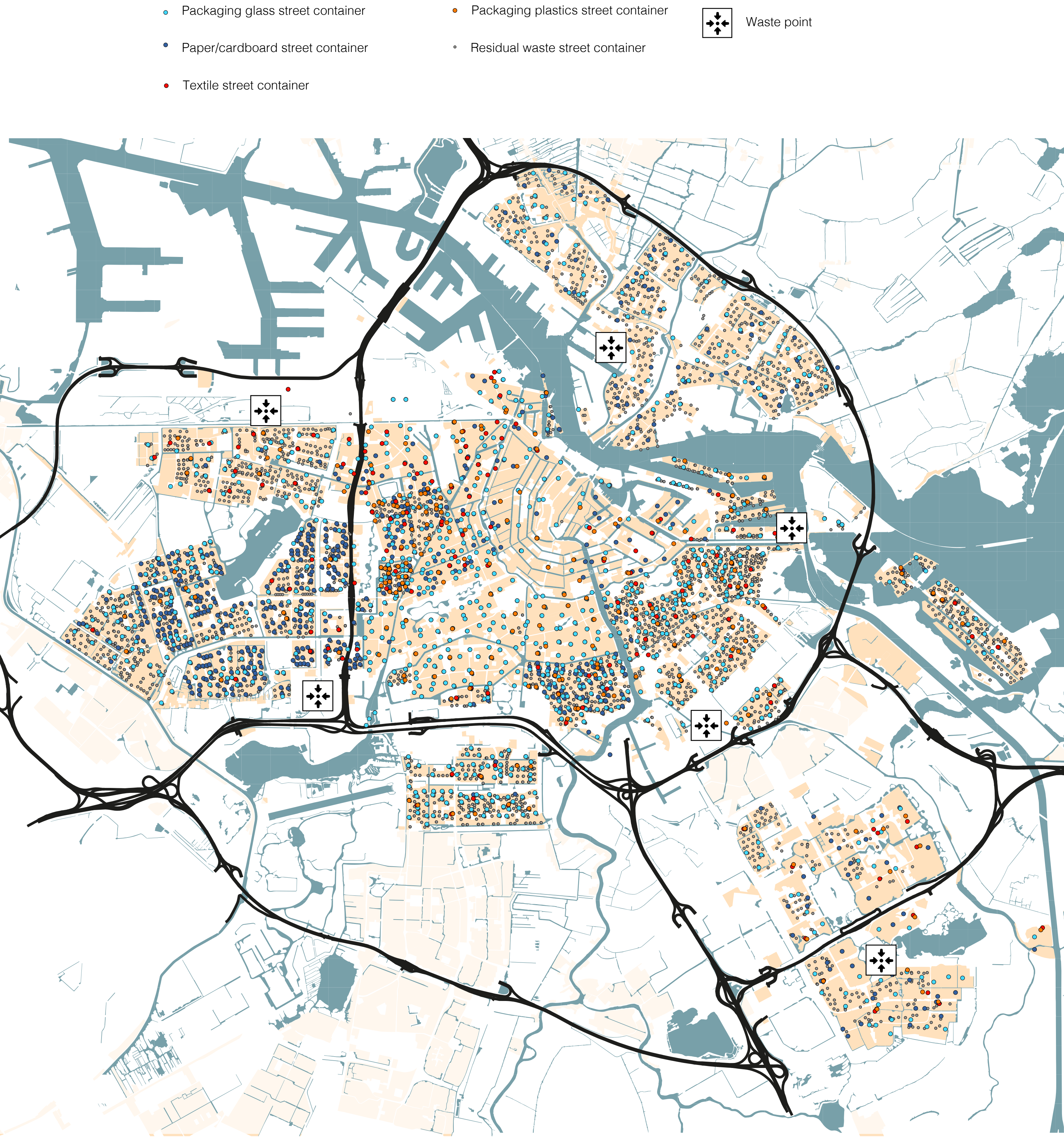
For the non daily disposed waste flows, there are only 6 points in Amsterdam where residents can dispose the waste themselves. As already mentioned before in the problem analysis are some of these waste points located at possible housing development locations. Besides that, there are not enough of these waste points to serve all the residents of Amsterdam. Dutch municipalities use the rule that for every 60.000 inhabitants, one waste point is needed. For Amsterdam there is only 1 waste point per every 140.000 inhabitants. In an ideal situation, the number of waste points should be at least doubled (Gemeente Amsterdam 2015c).

Figure 21 ⟶
Residential waste collection infrastructure
This map shows the physical infrastructure of street containers and waste points in Amsterdam. A strong difference becomes visible between different city districts.

Waste collection infrastructure is not available in all parts of Amsterdam. The option to dispose waste separately should be there for all the residents. It will require solutions for every part of Amsterdam, taking the different urban forms of Amsterdam into account.

Missing data on textile and packaging plastics containers in Amsterdam North. The data includes all the containers in 2015. Currently already more containers have been placed throughout the neighbourhoods. For this thesis the data from 2015 is used as a starting point and object of analysis.

(Image by author, based on GEO data municipality of Amsterdam)


Packaging glass street container
Packaging plastics street container
Waste point
Paper/cardboard street container
Residual waste street container
Textile street container

07.3 Circularity of current treatment systems

Amsterdam has set its circular goals; however, the question is if circular principles can already be found in the treatment of residential waste. The current system of treatment is the starting point of this thesis. It is the goal to find room for improvement to achieve more valuable recycling and reuse. Within this chapter the current waste treatment systems of multiple residential waste flows are evaluated according to circular principles.

The analyses of the all the different treatment systems can be found on the following pages (figure 22- 31). In figure 22, the treatment system of paper is illustrated. In this analyses it becomes clear where and how waste is being treated. This information will be used when the level of circularity is determined for this system.

For the circular evaluation, the diagram created by the Ellen Macarthur Foundation will be used. An explanation about this diagram and how it works can be found in chapter 4.1. The described system and way of treatment will be visualized within the diagram. In the case of paper and cardboard, the treatment consists of the recycling of the materials. This material reuse is represented in the diagram with the biggest circle. When the different treatment methods are visualized, conclusions can be drawn on the value of the current treatment system. This analyses forms the base for chapter 8 where new goals for waste treatment are set, which will make the treatment system more circular.

The conceptual model of the Ellen MacArthur Foundation forms a good base to evaluate the current treatment. Within this chapter the treatment of all major residential waste flows are analysed and translated to this scheme of circular economy. The information is obtained from the research *'Afvalketen in Beeld, Grondstoffen uit Amsterdam'* commissioned by the municipality of Amsterdam (2015c) and information from waste treatment company van Gansenwinkel (n.d).

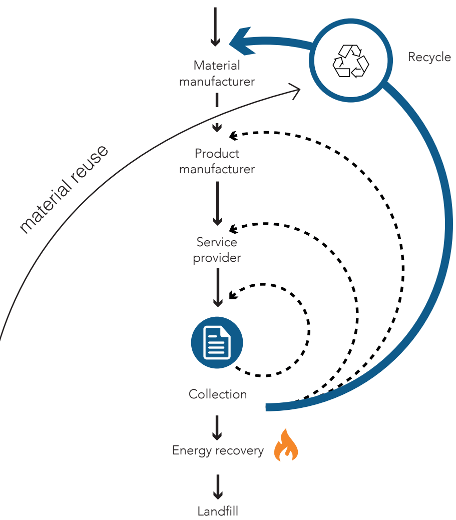
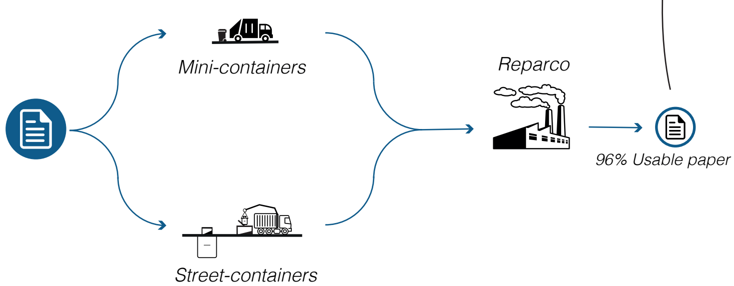


Figure 22

Treatment of paper/cardboard and its circular evaluation

Paper and cardboard are not treated within Amsterdam. This waste flow is collected via containers and transported to Renkum in the east of the Netherlands. Reparco sorts the paper and transforms 96% of the paper waste into new paper. This shows that paper can be recycled very effectively. Since paper is not a product which can be repaired or refurbished, the treatment is already fully optimised and works according the circular principles. The main task if it comes to paper is to increase the separated fraction. In this way more paper can be reused and less natural resources have to be used.

(Image by author, based on Gemeente Amsterdam, 2015c)



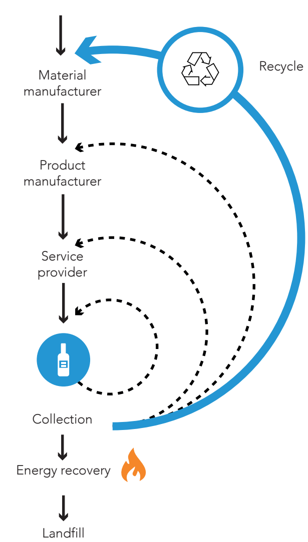


Figure 23

Treatment of packaging glass and its circular evaluation

Glass has the same characteristics as paper. It is almost fully reusable. The treatment is done by Maltha, a treatment facility nearby Rotterdam. Within this facility the glass is sorted and cleaned. 96% of the collected glass can be molten into new glass. For glass we can conclude the same as for paper. The treatment is already optimized to an acceptable and desirable level. The focus should be on increasing the separated fraction to reduce even more the use of natural resources.

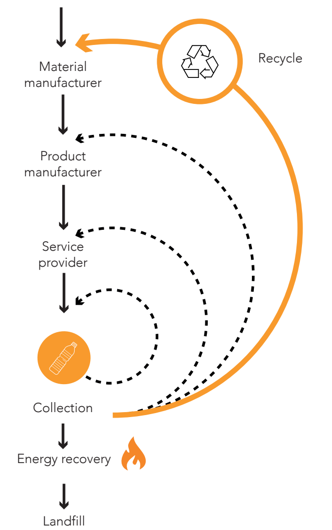
(Image by author, based on Gemeente Amsterdam, 2015c)

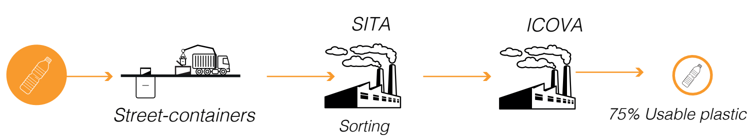
Figure 24

Treatment of packaging plastics and its circular evaluation

Plastics forms a substantial part of our waste production (see volume analysis chapter 7.1). There is a growing trend visible in the separate collection of this waste flow over the past couple of years. However, plastics are available in a lot of different forms, which makes it hard to fully reuse. 75% of the plastics is currently granulated for material reuse in the facility of ICOVA, situated in the harbour of Amsterdam. 25% still ends up in incineration plants. A recent research, done by the Centraal planbureau (2017), stated that current policies are focusing on increasing the separated collection. However, there should be more focus on sorting according to quality. When this happens, a higher percentage of the plastic waste can be recycled and more environmental profit can be realised.

(Image by author, based on Gemeente Amsterdam, 2015c)





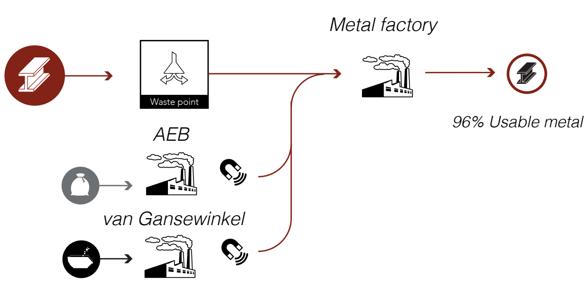
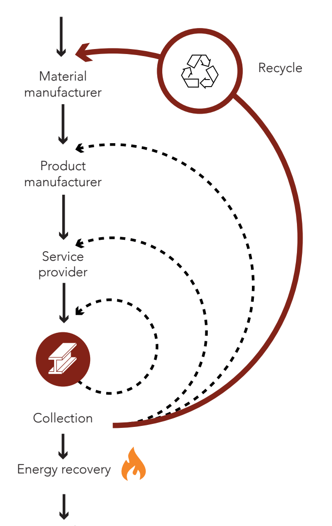


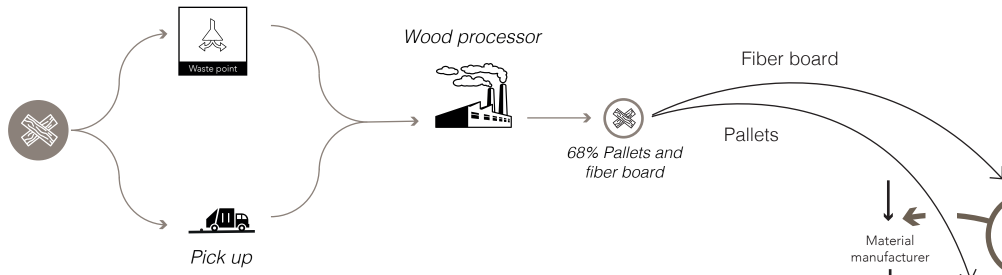
Figure 25

Treatment of metal and its circular evaluation

The metal waste flow is a quite unique waste flow. Metal is very easily separated from other waste flows by using magnets, which results in a high separation rate, also visible in the previous analyses about the waste collection (chapter 7.1). Besides the easy separation, metal is a material which can be reused my melting it and transforming it again in metal products. 96% of all the metal is being recycled and reused. These two findings, about the separation rate and the treatment, shows that there is no improvement needed within this waste stream. According to the circular principles a valuable way of recycling has already been reached.

(Image by author, based on Gemeente Amsterdam, 2015c)





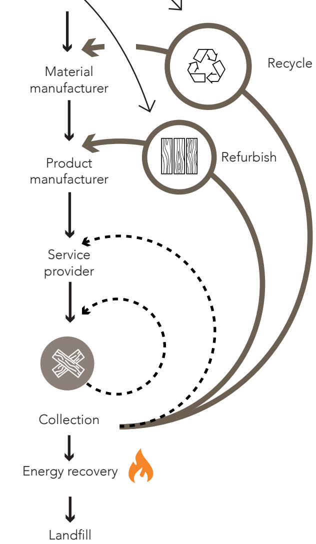


Figure 26

Treatment of wood and its circular evaluation

One of the best separate collected waste flows in Amsterdam is Wood. 96% is collected separately. Most of the wood is reused in the form of fabricating pallets or it is shred and used as a resource for fibre board. The use of wood within pallets can be seen as a kind of refurbishment, since the usable wooden planks are being used by maintaining their current form. The shredding and transformation into wooden fibre boards is a less valuable reuse method, since it downgrades the original material. However, the question is if wooden pallets are the most valuable option to reuse wood. Their might be more valuable products in which recycled wood can be used.

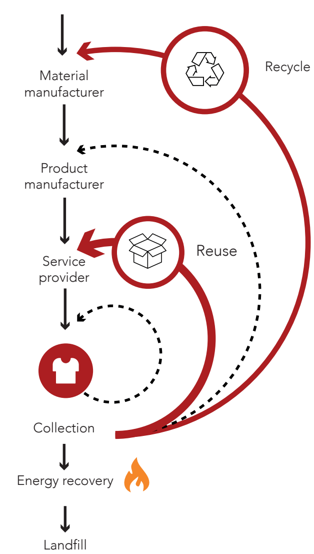
(Image by author, based on Gemeente Amsterdam, 2015c)

Figure 27

Treatment of textile and its circular evaluation

Sympany is the company which collects and sorts clothes and textile within Amsterdam. Textile can be handed in through containers throughout the city. Besides the containers, people bring their clothes to thrift shops or sell their clothes online. More than 50% of the clothes collected by Sympany are reused, for instance in third world countries. Most of the rest is decomposed and the raw materials can be used again in textile production. Only 8% ends up in the incinerator. The way of treatment does already follow the circular principles. However, there could be more focus on the reuse of clothes. A lot of clothes are thrown away which are still in a good condition. There is an opportunity to reuse and repair these clothes within Amsterdam instead of shipping them around the world.

(Image by author, based on Gemeente Amsterdam, 2015c)



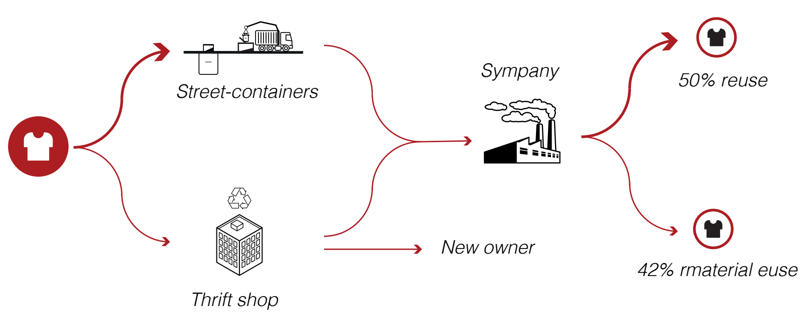
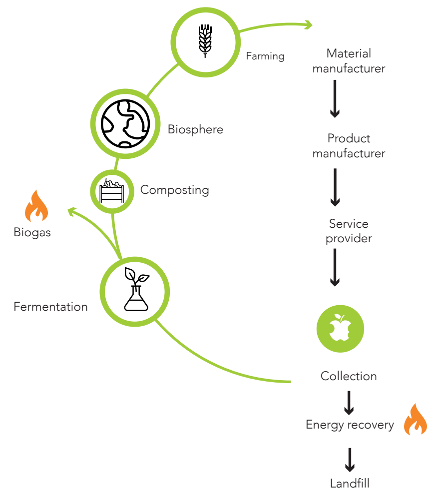


Figure 28

Treatment of fruit and vegetable waste and its circular evaluation

Biological waste has been low on the radar within Amsterdam. Most of it is not collected separately, which means that currently it is not a substantial waste flow within the municipality. The small part which is collected is treated by Orgaworld in the harbour of Amsterdam. Within this facility the fruit and vegetable waste is digested and eventually composted. This transforms the fruit and vegetables in biogas, heat and energy which can be used by the Amsterdam households or as fuel for waste trucks. A high percentage is already recycled. However, retrieving biochemical building blocks could make this waste flow even more valuable. The biggest challenge for this waste flow is increasing the collection, which will result in less incineration and more valuable recycling.

(Image by author, based on Gemeente Amsterdam, 2015c)



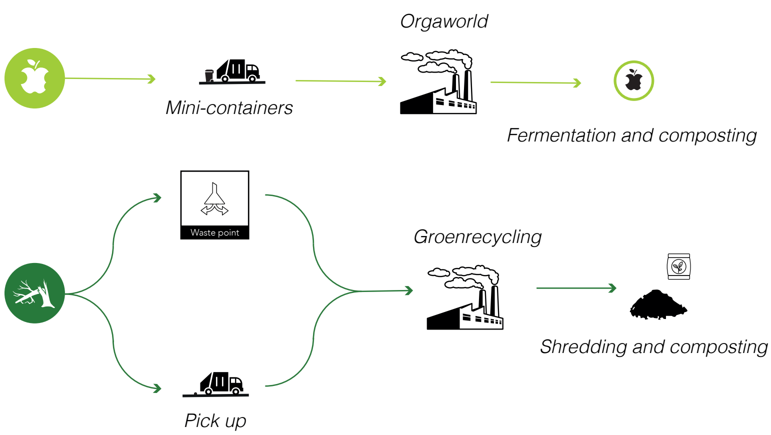


Figure 29

Treatment of garden waste and its circular evaluation

Most of the houses in Amsterdam do not feature gardens. Nevertheless, garden waste is treated separately within Amsterdam. Garden waste can be brought to one of the six waste points or it is collected in the city centre of Amsterdam. The garden waste is transported to Groenrecycling which is situated in the harbour of Amsterdam. Within this facility the branches and other garden waste are being shred into small pieces and turned into compost. In this way, the garden waste returns into the biosphere. However, garden waste can have a higher value when used within chemical industries. Retrieving biochemical building blocks from garden waste is one of the main goals for the future to make increase the use of this waste flow for this purpose (Royal HaskoningDHV, 2014).

(Image by author, based on Gemeente Amsterdam, 2015c)

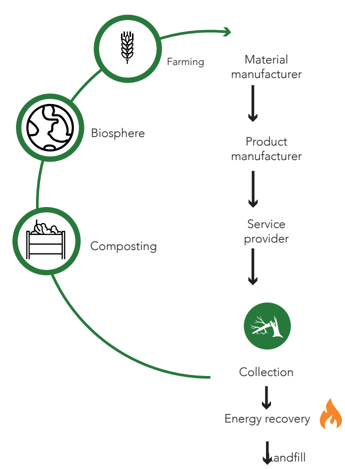


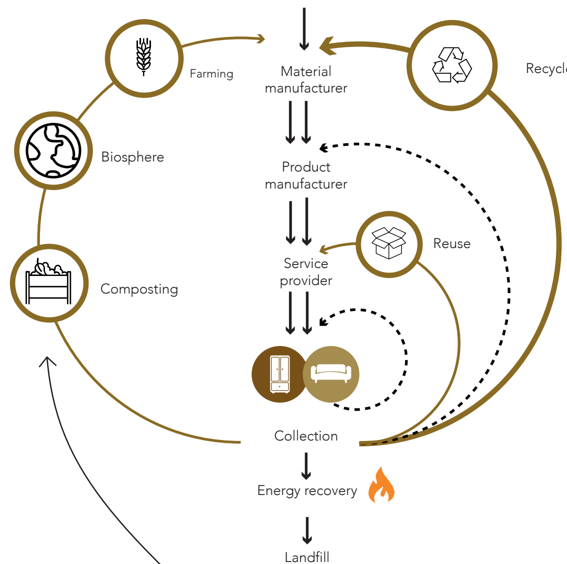
Figure 30

Treatment of furniture and its circular evaluation

Within this thesis two types of furniture are distinguished; wooden furniture and other furniture. Both types of furniture are being reused by bringing them to thrift shops which sell them to new owners. Nevertheless, most of the furniture is taking apart at van Gansenwinkel. During this process, 50% of the furniture ends up in a incineration facility. Wooden furniture can be seen as biomass and composted (when it is not treated timber). 26% of the furniture's materials can be recycled into new materials.

Incineration is still the main treatment option for this type of waste, since furniture consists of a lot of different materials and should be taken apart completely, which costs a lot of money. Because of the complex composition of furniture, a better option might be to focus on repair, reuse and refurbish. With these types of treatment, the furniture does have to be taken apart completely and the value of the existing furniture stays intact. Especially with wooden furniture, their might be a wide range of options for reusing and making connections to wood waste.

(Image by author, based on Gemeente Amsterdam, 2015c; van Gansewinkel, n.d.)



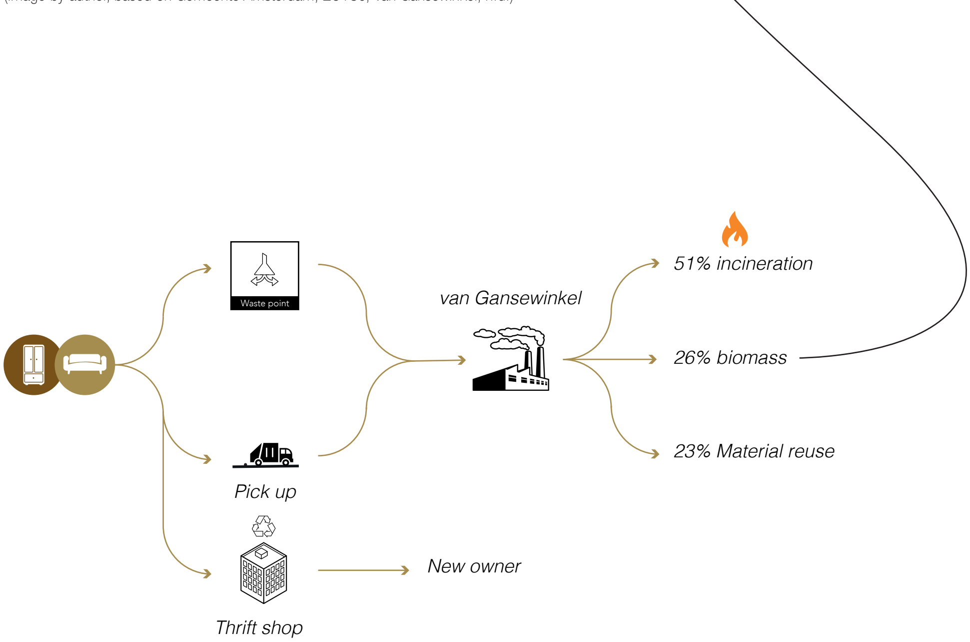
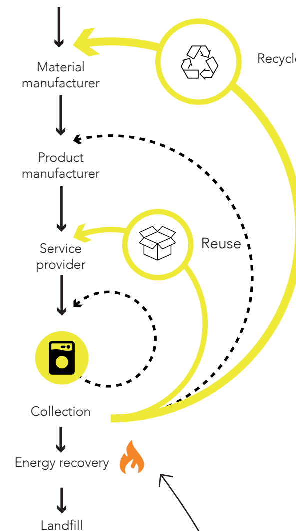


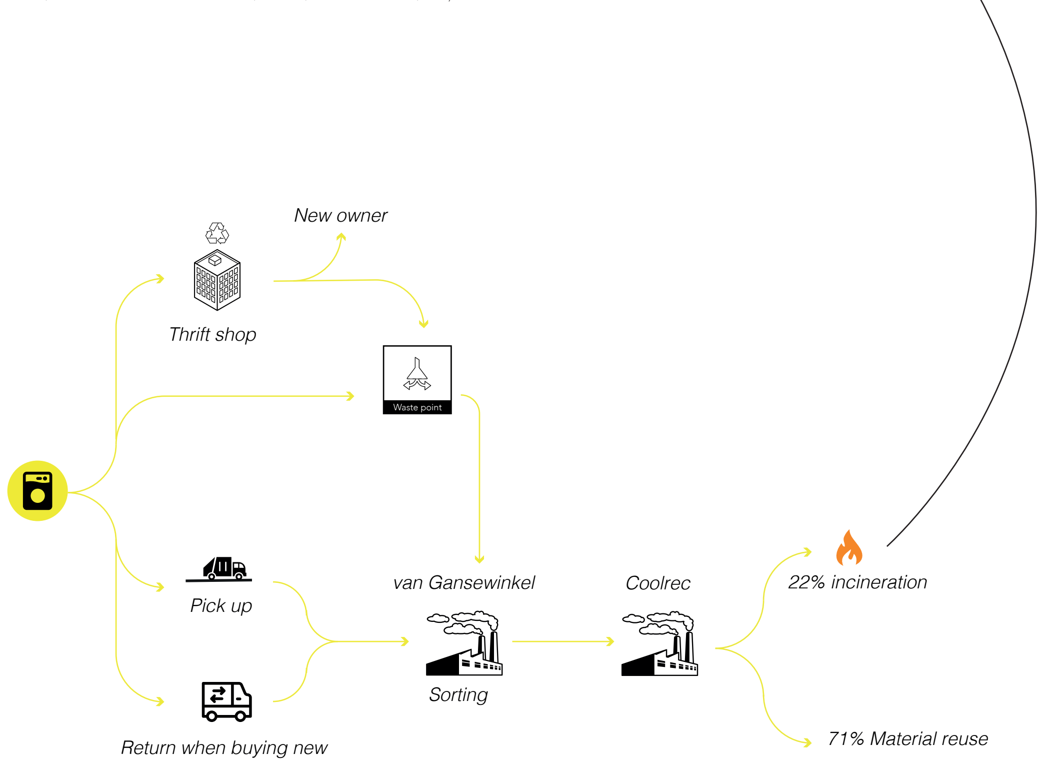
Figure 31

Treatment of electronic appliances and its circular evaluation

There is a wide variety of electronic appliances which are treated in multiple ways. Appliances like washing machines can be brought to thrift shops to make them available for reuse by other residents. Most of the appliances of this sort are being collected when buying a new one. The retail company picks up the old appliance when delivering the new one. Most of the electronic waste is being sorted at van Gansewinkel in the port of Amsterdam. After being sorted it is transported to Eindhoven where a new facility, Coolrec, has been built to disassemble the products. In this way all the different kind of materials can be recycled . However, there is not much focus on the repair and refurbishment side of maintaining value. In a new treatment system, the disposal of electronic devices should be minimized and the lifetime of the product should be extended to maintain higher value.

(Image by author, based on Gemeente Amsterdam, 2015c; van Gansewinkel, n.d.)





07.4 Conclusions: room for improvement

Quantities and volumes of waste

It is important to keep in mind that different types of waste have different volumes and related spatial impact. This spatial impact will change when separation rates increase, since the composition of collected residential waste will change.

Separation rates

Most of the waste flows are not yet collected separately according the set separation goals of the municipality (65%). Metal and wood are the only ones that reach the level. Especially packaging plastics, fruit and vegetable waste and textile need a lot of improvement.

Collection system and infrastructure

The way waste is collected and the related infrastructure depends on which city district you live in. The differences are probably created by the difference in urban fabric, which determine what kind of infrastructure can be implemented. Waste can be categorised into two different types, daily or periodically disposed. Both have different collection systems. There is a unilateral approach to waste collection by applying mostly street containers or pick up services. It raises questions if such a non divers collection system can be applied on a diverse city. Proposals for a new system should include an analysis of the different types of urban form as a starting to point. In this way, solutions can be found which are integrated and adjusted to the city. It becomes possible to collect homogeneous waste flows everywhere in the city and not just in the areas where mini-containers and street-containers are possible.

Circularity of current treatment systems

All the waste types do already have a certain level of circular waste treatment. However, most of the treatment is based on material reuse which is not the most valuable option. For paper, packaging plastics, packaging glass and metal, the best way of treatment has already been reached. These types of waste are not products which can be reused or repaired. Most of these types of waste are already reused for 95%, so no improvement is needed. The other (mostly product related waste streams), have room for improvement.

Now the current situation is clear, new goals can be set and a new systems created. In the next chapter the concept of circular economy will be applied to the treatment system to improve it. Within this chapter, circular concepts are translated into spatial systems which can be implemented. For the continuation, the waste stream of metal will not be addressed anymore. Since the separated collected fraction is already above the goal and treatment is already fully circular and sustainable.

→

Separate waste collection
(Xander Bakker Design Studio)

Proposing a new system

Defining the characteristics of a new
waste treatment and collection system

08

Circular waste treatment and its spatial translation

A proposal for a new system has to be made. Based on the knowledge of the current systems, new principles can be created for the treatment and collection of residential waste in Amsterdam. In this chapter, the concept of circular economy will be used to propose a new treatment system for residential waste. This chapter will form the core of this thesis where is tried to translate these circular concepts into spatial systems. This conversion is needed to understand and find possibilities about how circular thinking can be integrated in urban environments. The new systems developed here are the ones which will improve the waste treatment and in Amsterdam.

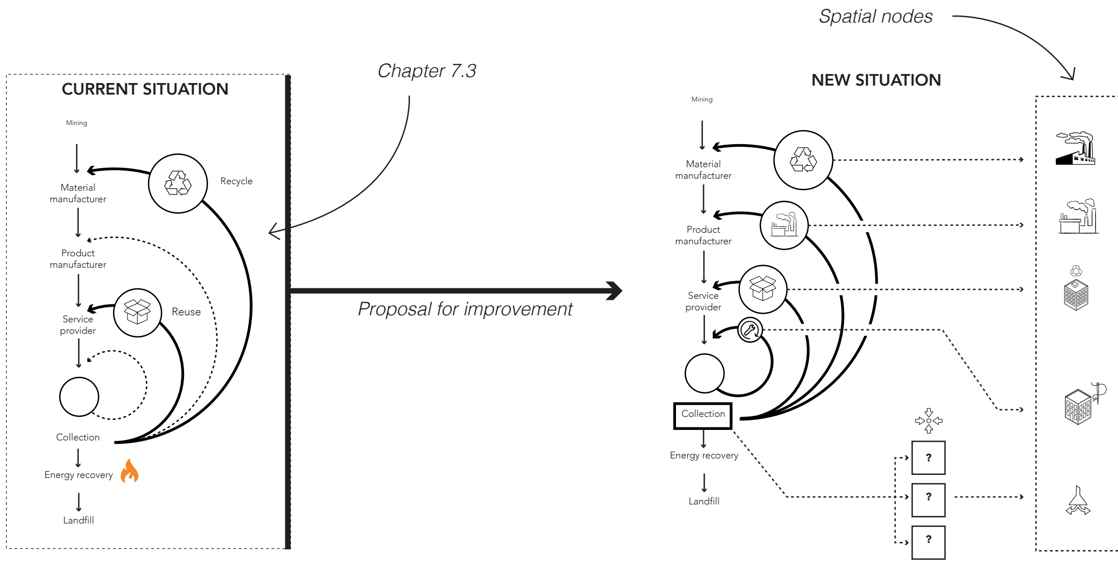


Figure 32

Proposal for improvement of waste treatment methods

Following the circular framework created by the Ellen MacArthur Foundation (n.d), proposals can be made for new treatment methods. These treatment methods need certain physical facilities (nodes). These nodes are the spatial elements of the treatment system and form the outline of a new treatment system.

(Image by author)

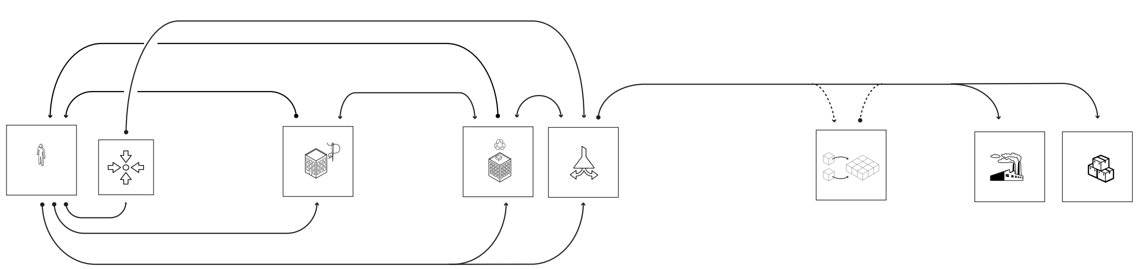


Figure 33

A new system per waste flow

The proposed new treatment methods and related spatial nodes are connected to each other. These connection in combination with the nodes creates a new treatment system per waste flow.

(Image by author)

08.1 Proposing new circular waste treatment systems

In chapter 7.3 the treatment of the different waste types has been analysed and evaluated according the circular principles of the Ellen MacArthur foundation. After the evaluation already some options for improvement were mentioned. Within this chapter, these improvements will be worked out for every waste type. A new, more circular, treatment system will be presented which can be translated into needed facilities.

Defining the new treatment system and the needed facilities.

First, the process and the used method will be explained. The same method for defining new treatment systems is applied to all the waste flows. The detailed workout for every waste flow can be found in figure 34 till 42.

To explain the method, generalized figures are shown to walk through the process. First, the current situation will be transformed in a desired more circular vision for the waste type (figure 32). This new scheme represents the new ways of treatment and explains how the current treatment can be improved. As described within chapter 4.1, within the circular framework of the Ellen MacArthur foundation, the smaller loops (which stay closer to the user), are the most favourable in the case of technological waste. These loops, for instance reuse of products make sure the most value is maintained. The final option should be material reuse (the biggest loop). For biological waste, multiple options are available and can all be applied. In this way, a new circular diagram can be made, explaining the desired ways of treatment.

Now new treatment ways are proposed a translation can be made to needed physical facilities to facilitate this new treatment system. Figure 32 shows how the different ways of treatment are being translated in actual factories, retail stores and repair shops. These facilities form the nodes of the future waste treatment system. Within the new system, the collection of waste is an important part. As concluded in chapter 7.4, waste collection infrastructure should be adjusted to the different urban forms of Amsterdam. In chapter 9 and 11, different possibilities per waste flow and per urban form type will be discussed. However, within this chapter it is taken into account that waste should be sorted or compiled at some point. That is why these facilities are already shown.

When the needed facilities are known a new system can be build. The different facilities (nodes) are connected to each other. This connections will be visualized and explained per waste flow (figure 33). In this way a new system of exchanging waste and valuable recycling is being constructed.

This method is applied to all the waste flows which will lead to a new systems per waste type. Packaging glass, paper/cardboard and packaging plastics will be discussed in figure 34 till 36. There will not be much change in these treatment systems, since a circular method of treatment is already present. However, they are visualized with the proposed method to make integration possible in a later stage. The waste flows of textile, furniture, wood and electronic appliances can be found in figure 37 till 40. Finally, the organic waste streams, fruit and vegetables and garden waste, will be elaborated in figure 41 and 42.

▶ *Continuing page 77*

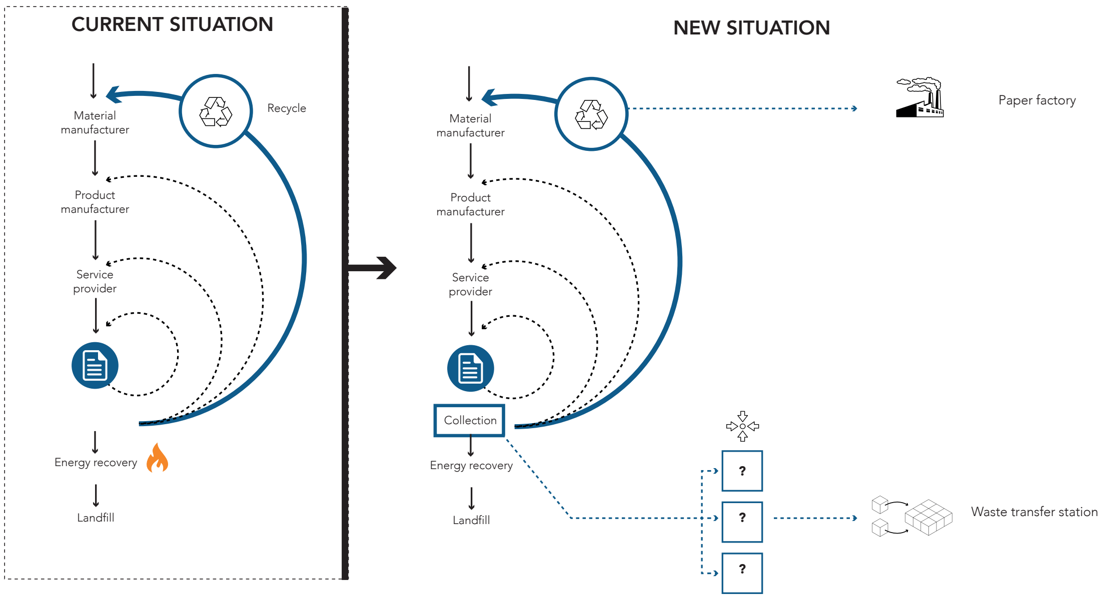


Figure 34

Proposal changes in treatment system paper/cardboard

As explained in chapter 7.3, paper and cardboard are already treated in a circular an valuable way. 96% of all the collected paper and cardboard is reused and transformed into new paper. This treatment system does not need to change. This results in the only needed facility, which is a paper recycling factory.

The following connections can be identified between the nodes:

***1.** Paper and cardboard needs a certain form of collection infrastructure to make disposal available for residents.*

***2 & 3**. The waste flow is transported towards the paper treatment facility. When this treatment facility is not present within the city itself or in the surroundings of the city, the paper waste may need a waste transfer station. In this way, a change of transport mode can take place to have the most cost efficient and environmental transport mode for longer distances.*

(Image by author)

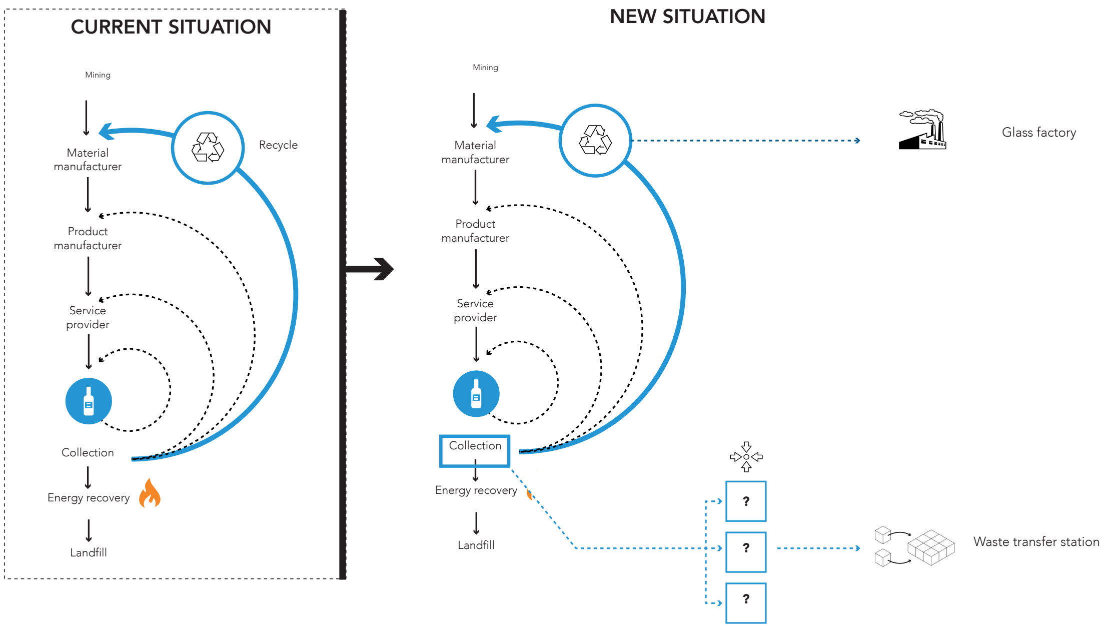


Figure 35

Proposal changes in treatment system packaging glass

As explained in chapter 7.3, packaging glass is already treated in a circular an valuable way. 96% of all the collected packaging glass is reused and transformed into new glass. This treatment system does not need to change. This results in the only needed facility, which is a glass recycling factory.

The following connections can be identified between the nodes:

***1.** Packaging glass needs a certain form of collection infrastructure to make disposal available for residents.*

***2 & 3**. The waste flow is transported towards the glass treatment facility. When this treatment facility is not present within the city itself or in the surroundings of the city, the packaging glass waste may need a waste transfer station. In this way, a change of transport mode can take place to have the most cost efficient and environmental transport mode for longer distances.*

(Image by author)

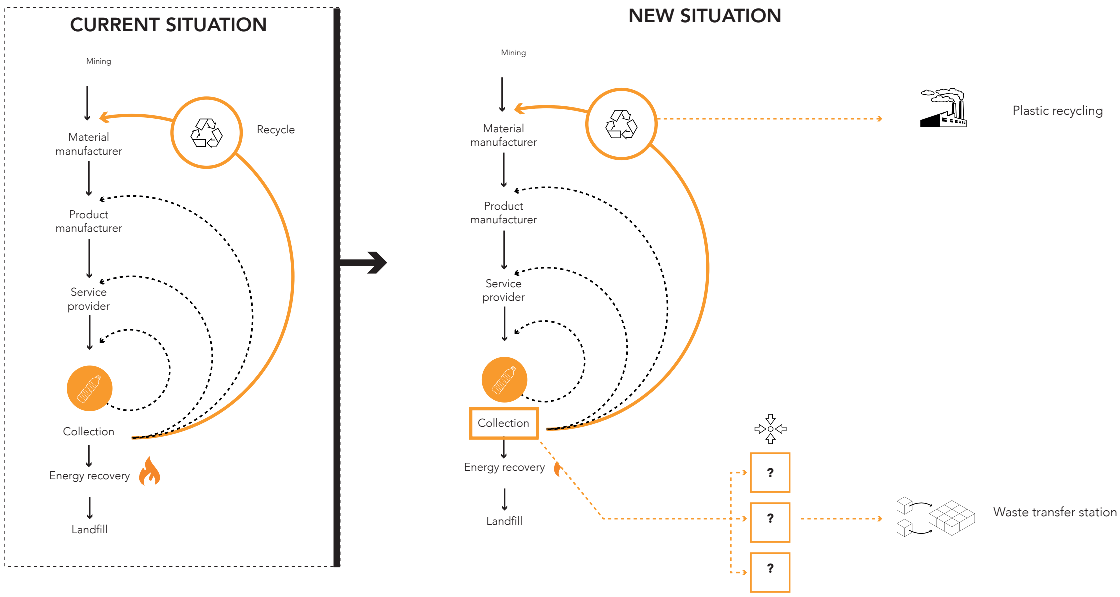


Figure 36

Proposal changes in treatment system packaging plastics

As explained in chapter 7.3, packaging plastics are already treated in a circular an valuable way. However only 75% percent of the plastic is being reused. The main reason for this lower percentage is a result of the wide diversity of plastics. To actual problem is not the treatment method. Less different types of plastics should be used within the packaging industry and collection methods should focus on qualitative flows instead of quantity. Collection methods should be developed to collect the different types of plastic separately to increase recycling rates.

The following connections can be identified between the nodes:

***1.** Packaging plastics need a certain form of collection infrastructure to make disposal available for residents. A more advanced system is needed to collect different types of plastics*

***2 & 3**. The waste flow is transported towards the plastic treatment facility. When this treatment facility is not present within the city itself or in the surroundings of the city, the plastic waste may need a waste transfer station. In this way, a change of transport mode can take place to have the most cost efficient and environmental transport mode for longer distances.*

(Image by author)

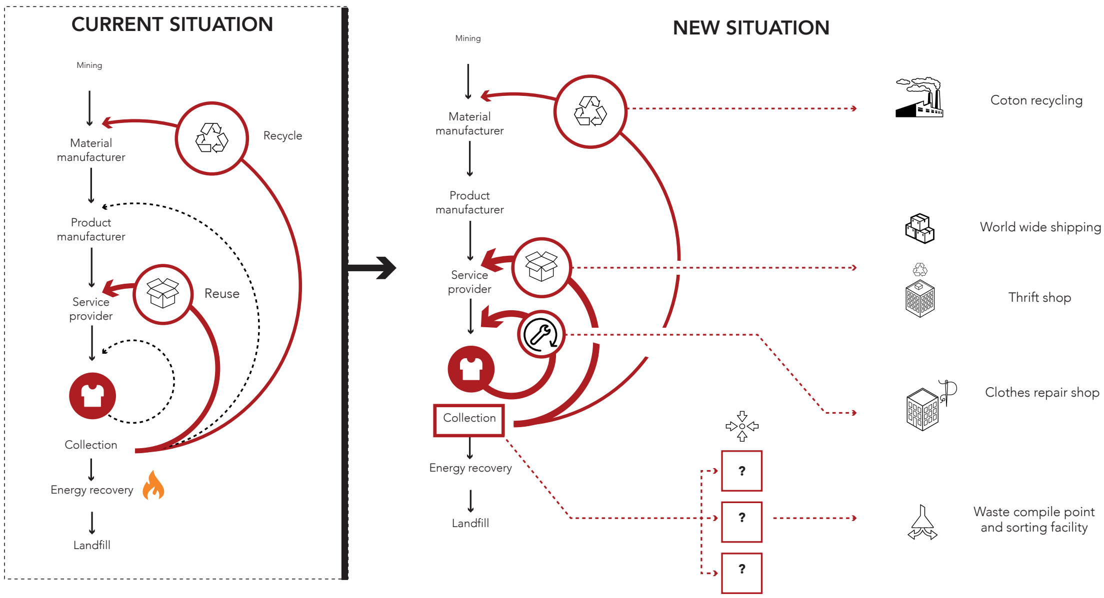


Figure 37

Proposal changes in treatment system textile

To make the treatment of textile more circular there should be more focus on the clothes repair and the reuse within the city. Clothes are already being reused, but most of them are shipped to third world countries. Local reuse is more favourable and has less negative environmental impacts since a reduction in transport

The following connections can be identified between the nodes:

***1**. Clothes can be handed in through collection infrastructure which will be defined by the urban fabric.*

***2 & 4.** Clothes can be brought to a clothes repair shop. After repair the clothes return to their original owner.*

***3 & 5.** Clothes can be brought to a thrift shop where a new owner can be found. Another option is to bring the clothes yourself to a waste point.*

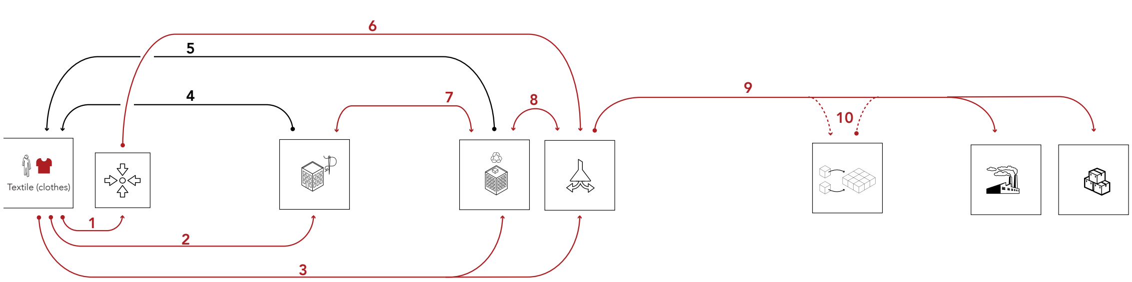
***6.** Clothes collected through collection infrastructure are compiled at waste points.*

***7.** Clothes which are brought through thrift shops and need repair before being able to be sold.*

***8**. Clothes which still have a high value can be exchanged with thrift shops. Clothes which are eventually not sold can be brought back to the waste point.*

***9 & 10.** Clothes will be brought to a recycling facility or a company which ships clothes to third world countries. When these companies are not situated within the city or surroundings, a central waste transfer station might be needed*

(Image by author)



08
Circular waste treatment and its spatial translation

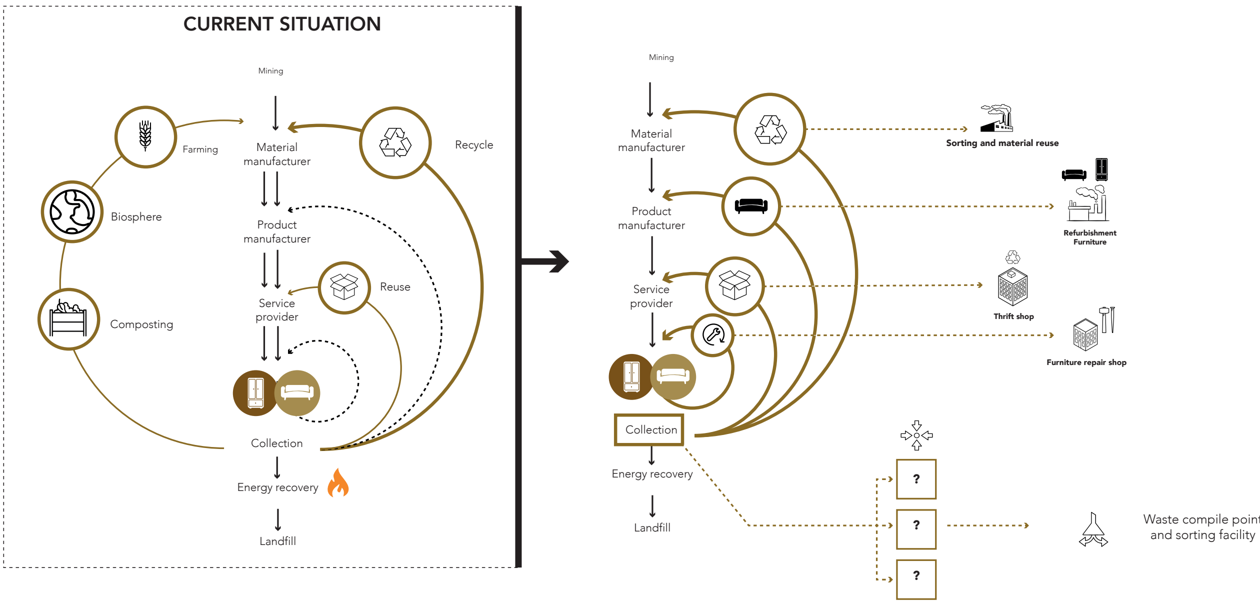


Figure 38

Proposal changes in treatment system furniture

Furniture can be visualised on both sides of the diagram. Since wooden furniture can be treated the same as wood, it can be composted and returned in the biosphere. The most value is situated in the right side of the scheme. More focus should be on the repair and refurbishment of furniture to expand the life time of the product and prevent disposing.

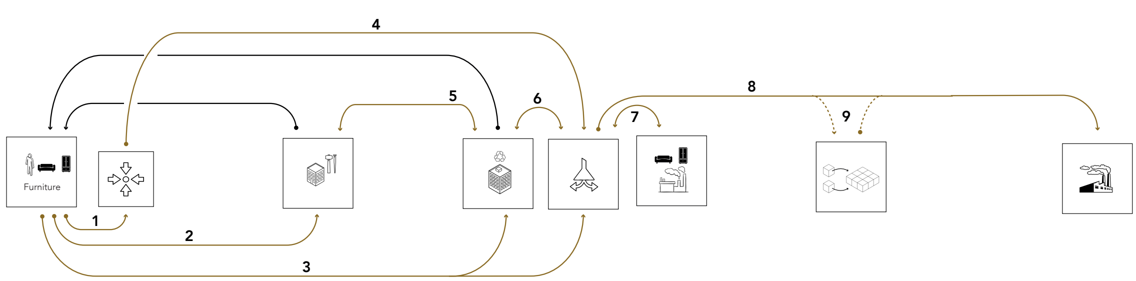
The following connections can be identified between the nodes:

1, 2, 3 & 4. *Furniture can be dropped of by residents at a repair workshop, thrift shop or waste point. Another option is to let it be picked up by wast trucks.*

5, 6 & 7. *The relation between different treatment facilities. For instance, furniture brought to the thrift shop could go for a quick repair to the repair workshop.*

8 & 9*. When no valuable way of treatment is possible the furniture should be sorted and demounted. In this way most of the materials can be reused.*

(Image by author)



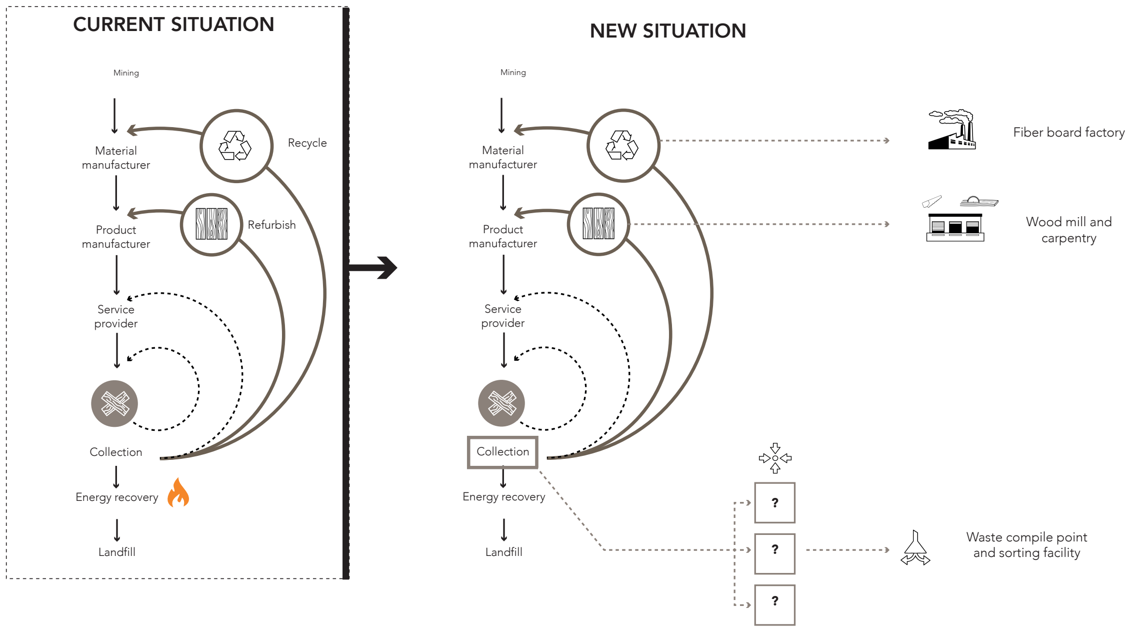


Figure 39

Proposal changes in treatment system wood

Most of the wood waste is now transformed into fibre board. Within the process wood is only reused on a material base. The other most used option is the manufacturing of wooden pallets. This treatment can be seen as a kind of refurbishment since the wooden planks are used again as planks. Improvements can be made when wood is more reused in its original shape. This could be done in wood mills are carpentry workshops. More valuable products, like furniture could be made.

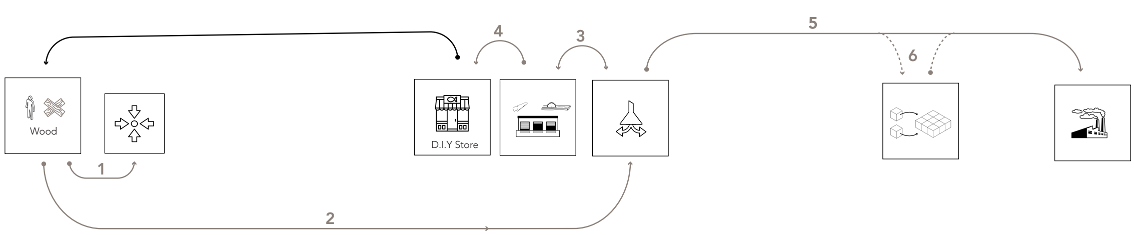
The following connections can be identified between the nodes:

***1.** Multiple possibilities for wood collection*

***2, 3 & 4.** Wood handed in at a waste point should be refurbished again and resold again in local D.I.Y. stores or used within furniture making industries.*

***5 & 6.** The final stage of treatment should be the material reuse and conversion in to fibre wooden panels. When this treatment facility is not present within the city itself or in the surroundings of the city, the wood waste may need a waste transfer station. In this way, a change of transport mode can take place to have the most cost efficient and environmental transport mode for longer distances.*

(Image by author)



08
Circular waste treatment and its spatial translation

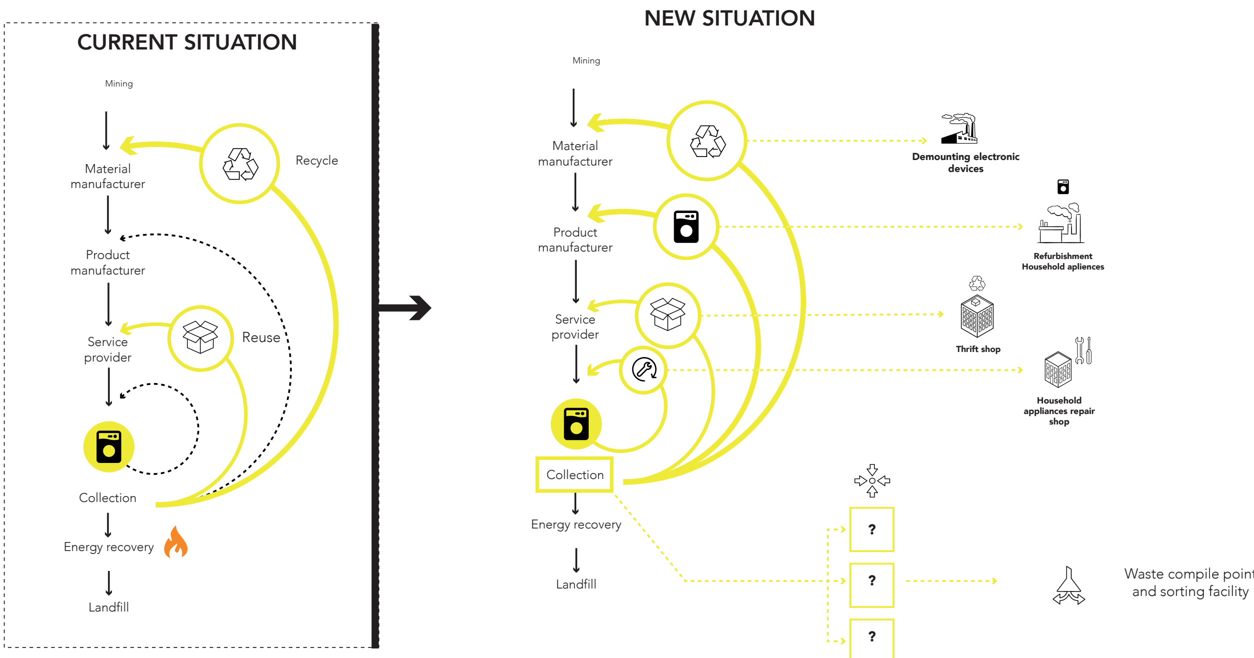


Figure 40

Proposal changes in treatment system electronic appliances

Most of the electronic appliances are currently disposed and demounted to retrieve valuable materials. A small part is reused by selling them in thrift shops. More value could be achieved by repairing or refurbishing them. Giving the products a second life.

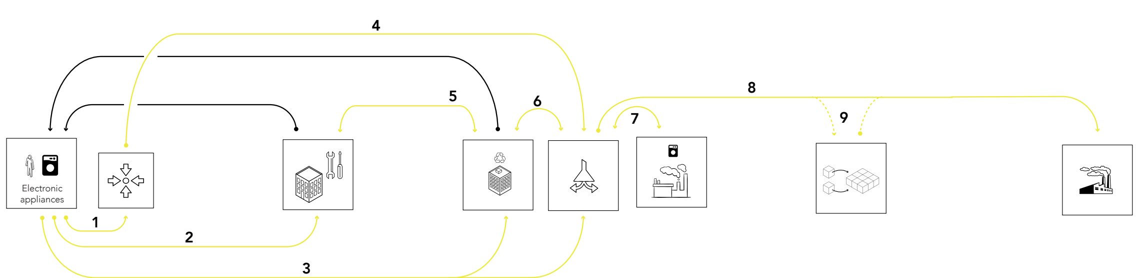
The following connections can be identified between the nodes:

***1, 2, 3 & 4.** Electronic appliances can be dropped of by residents at a repair workshop, thrift shop or waste point. Another option is to let it be picked up by waste trucks.*

***5, 6 & 7.** The relation between different treatment facilities. For instance, electronic appliances brought to the thrift shop could go for a quick repair to the repair workshop.*

***8 & 9.** When no valuable way of treatment is possible the electronic appliances should be sorted and demounted. In this way most of the materials can be reused.*

(Image by author)



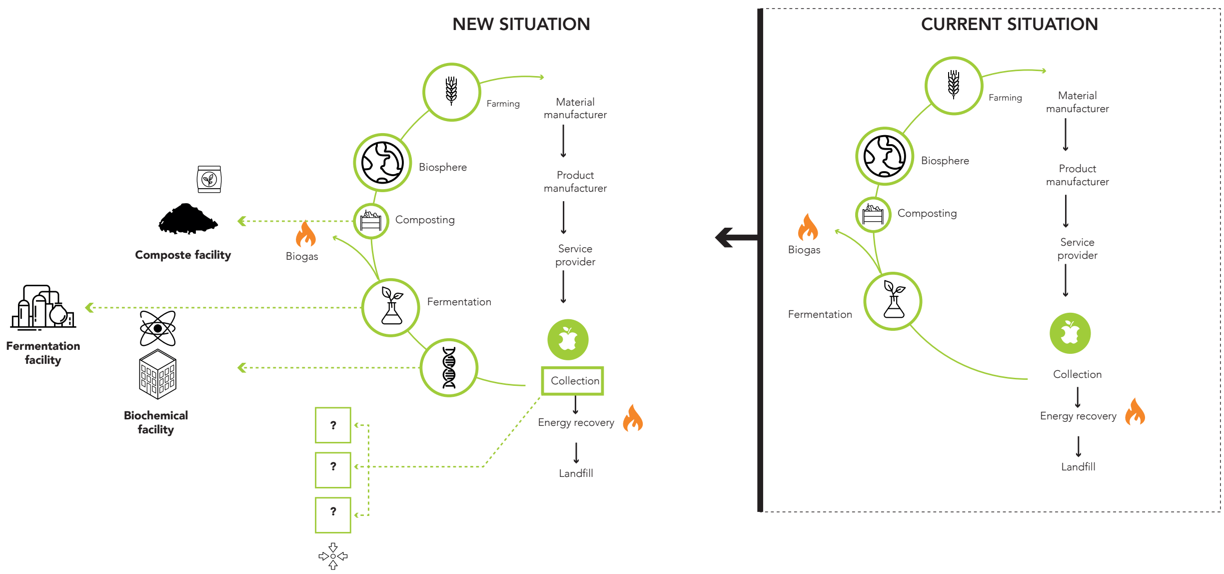
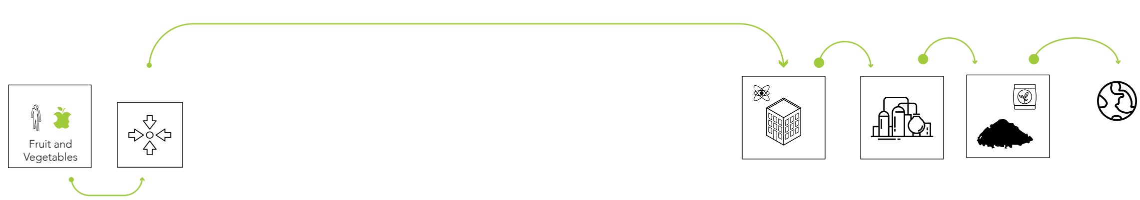


Figure 41
Proposal changes in treatment system fruit and vegetable waste
When we talk about organic waste, the left side of the circular economy framework is used. When treating organic waste, the end goal is always to let the nutrients return into the biosphere. However, in between, other valuable resources can be taken out. Currently the waste is digested, which results into biogas, electricity and heat. After composting it returns into the biosphere. However, new technologies are rising which make it possible to retrieve valuable biochemical building blocks. These resources can for instance be used when manufacturing bio-plastics.

The following connections can be identified between the nodes:

The relations between the different facilities are in the case of biowaste quite simple. After collecting, first the biochemical building blocks should be retrieved. The left overs from this process could be digested and turned into heat, electricity and biogas. Eventually, all that is left over will be composted and returned into the biosphere.

(Image by author)



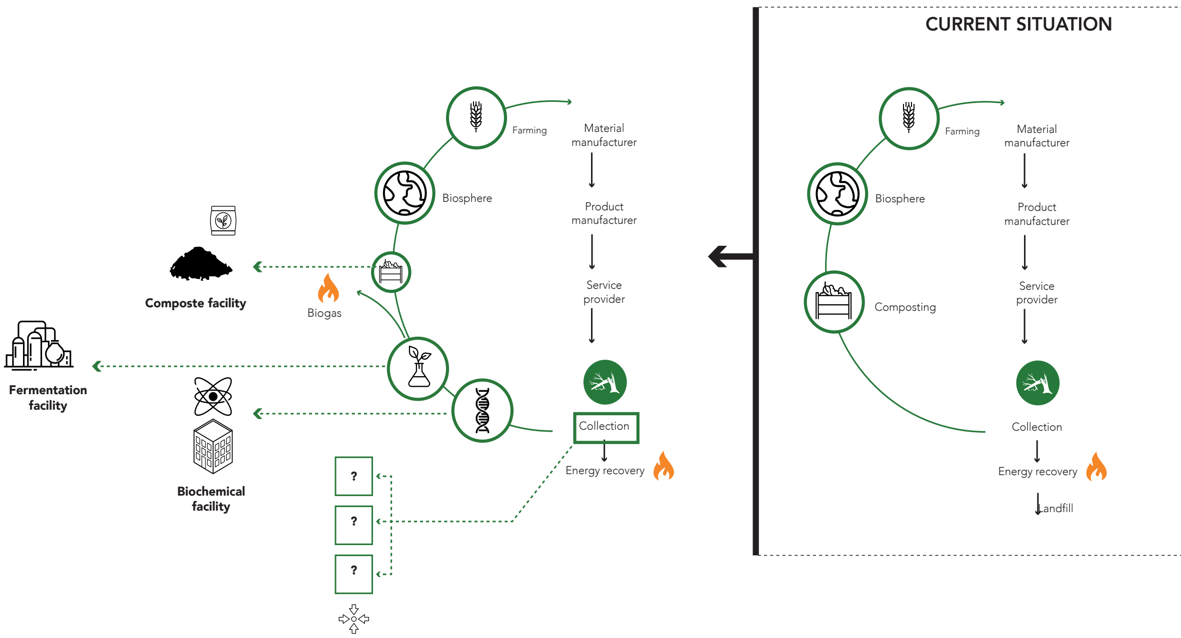


Figure 42

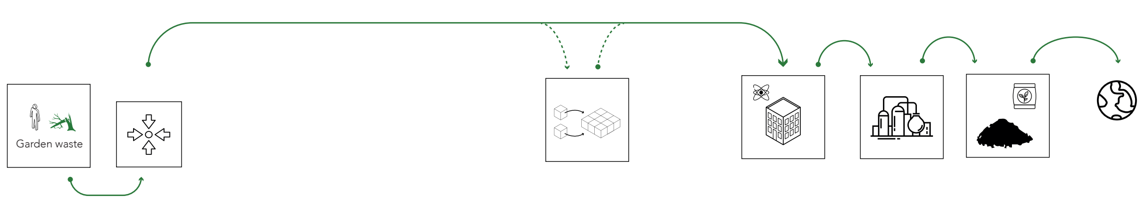
Proposal changes in treatment system garden waste

Fruit and vegetable waste and garden waste have the same treatment principles.

The following connections can be identified between the nodes:

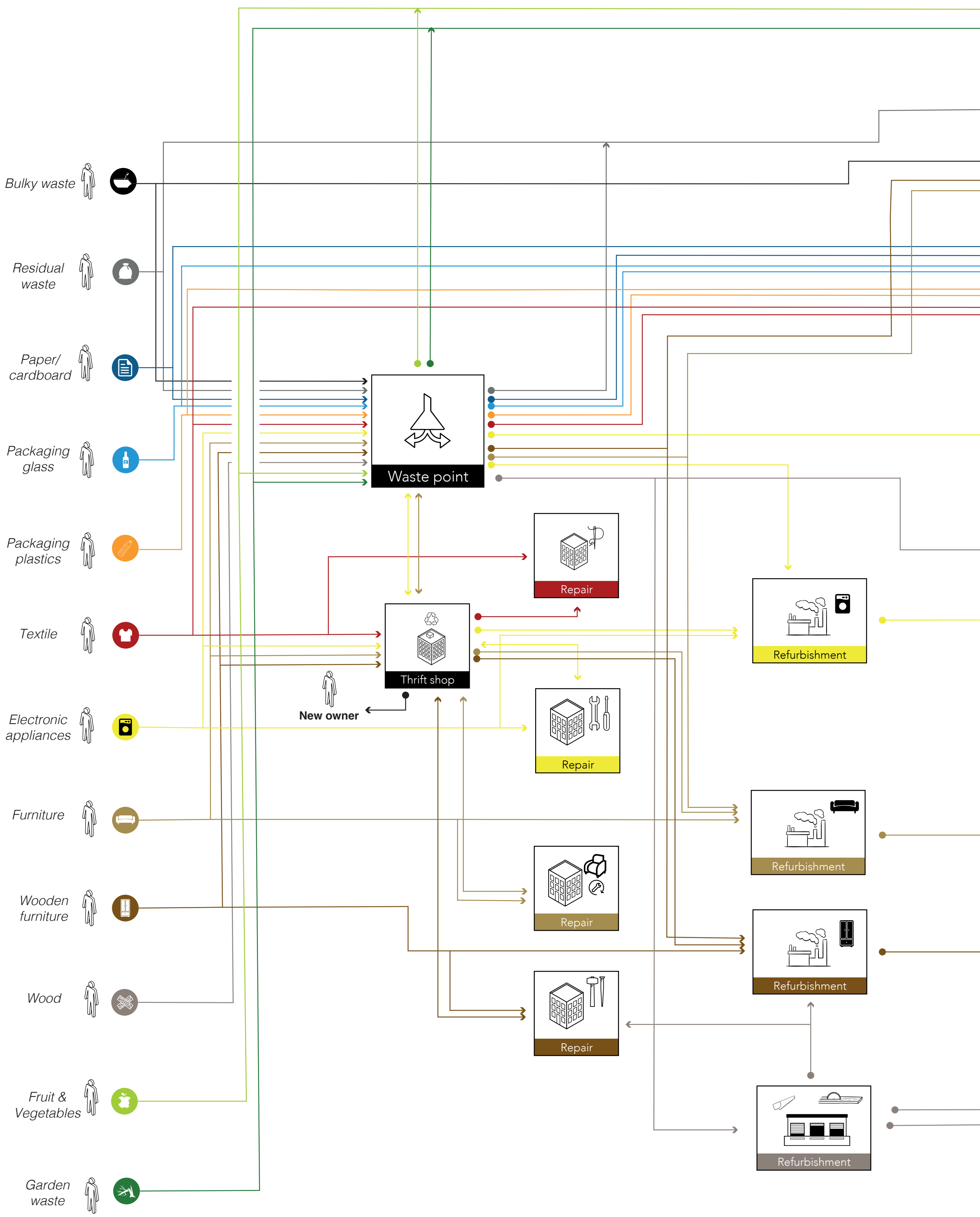
As said before, the system looks the same compared to fruit and vegetable waste. However, garden waste, especially branches, which is dry biowaste could be transported over longer distances. This means that dry biowaste could be a global market. Wet biowaste should be treated as fast as possible to prevent the waste from starting to rot (Port of Amsterdam, n.d.).

(Image by author)



On the previous pages, for all the waste flows proposals were made to improve the treatment in a circular way. For every waste flow a new system was created. However, all the systems interact with each other and make use of similar facilities. The complete residential waste system is the combination of all these subsystems. When visualizing this complete system, combining all the subsystems, the complexity becomes visible. On the next page, in figure 43, this complex system is visualized. Within this diagram, all the connections are not made yet, since for this thesis the subsystems have been simplified. To be able to continue, the complex system will be divided in three different waste treatment groups. Of these groups, the spatial characteristics can be determined. These are necessary to create proposals for urban integration. This process will be further discussed in chapter 8.2.

08
Circular waste treatment and its spatial translation



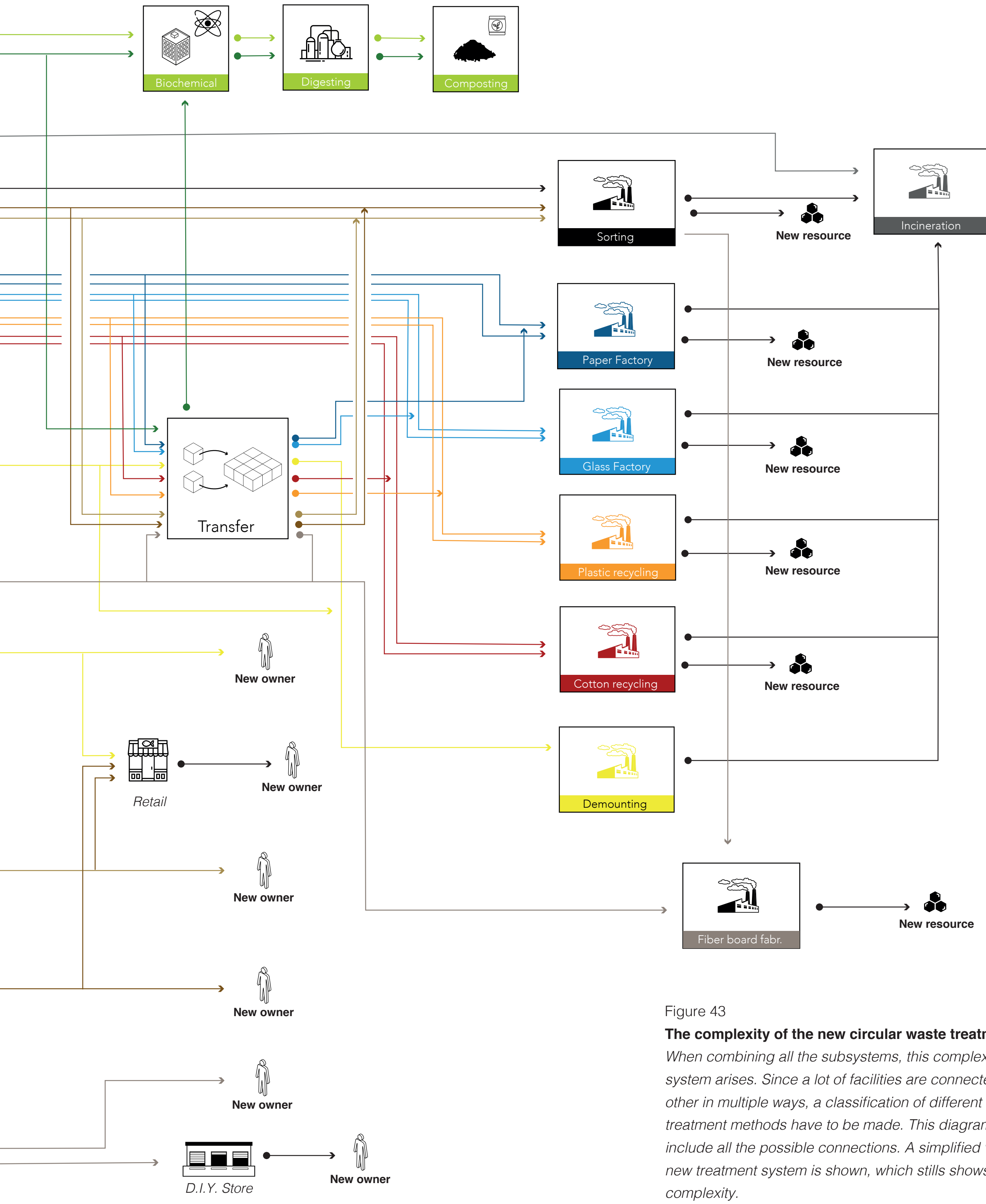


Figure 43

The complexity of the new circular waste treatment system.

When combining all the subsystems, this complex interacting system arises. Since a lot of facilities are connected to each other in multiple ways, a classification of different waste treatment methods have to be made. This diagram does not include all the possible connections. A simplified version of the new treatment system is shown, which stills shows the immense complexity.

(Image by author)

08.2 Positioning waste treatment within the urban environment

The complexity of the whole system becomes clear when looking at figure 43 (previous page). This complexity is mainly caused by the fact that different waste flows make use of the same facilities (nodes). The system will be simplified to make it better understandable and usable in the further development to determine the spatial characteristics of the new system. This is of importance to create proposals for urban integration.

Figure 44 shows an overview of all the different nodes, involved within the circular treatment of the waste flows. All the waste flows need some kind of collection infrastructure, which is shown on the left of the diagram. As explained before, the exact method for collection will not be given yet at this stage since the collection method should be adjusted to the type different types of urban form. The diagram shows immediately a division in three different types of waste treatment. Bulky waste, residual waste, paper / cardboard, packaging glass and packaging plastic are all focused on material reuse and recycling. Textile, electronic appliances, and furniture are all products. These products have the ability to be repaired, reused and refurbished before being recycled. The final group of waste treatment involves organic waste.

First, these inter waste flow connections will be explained for the three different waste treatment groups (figure 45-47). When the three waste treatment groups are explained, it is possible to elaborate on the spatial characteristics of these wast treatment groups and the desired location within an urban environment to implement them. Compiling all these analyses together, will create a general model for a city which shows the working of the new residential waste treatment system.

▶ *Continuing page 84*

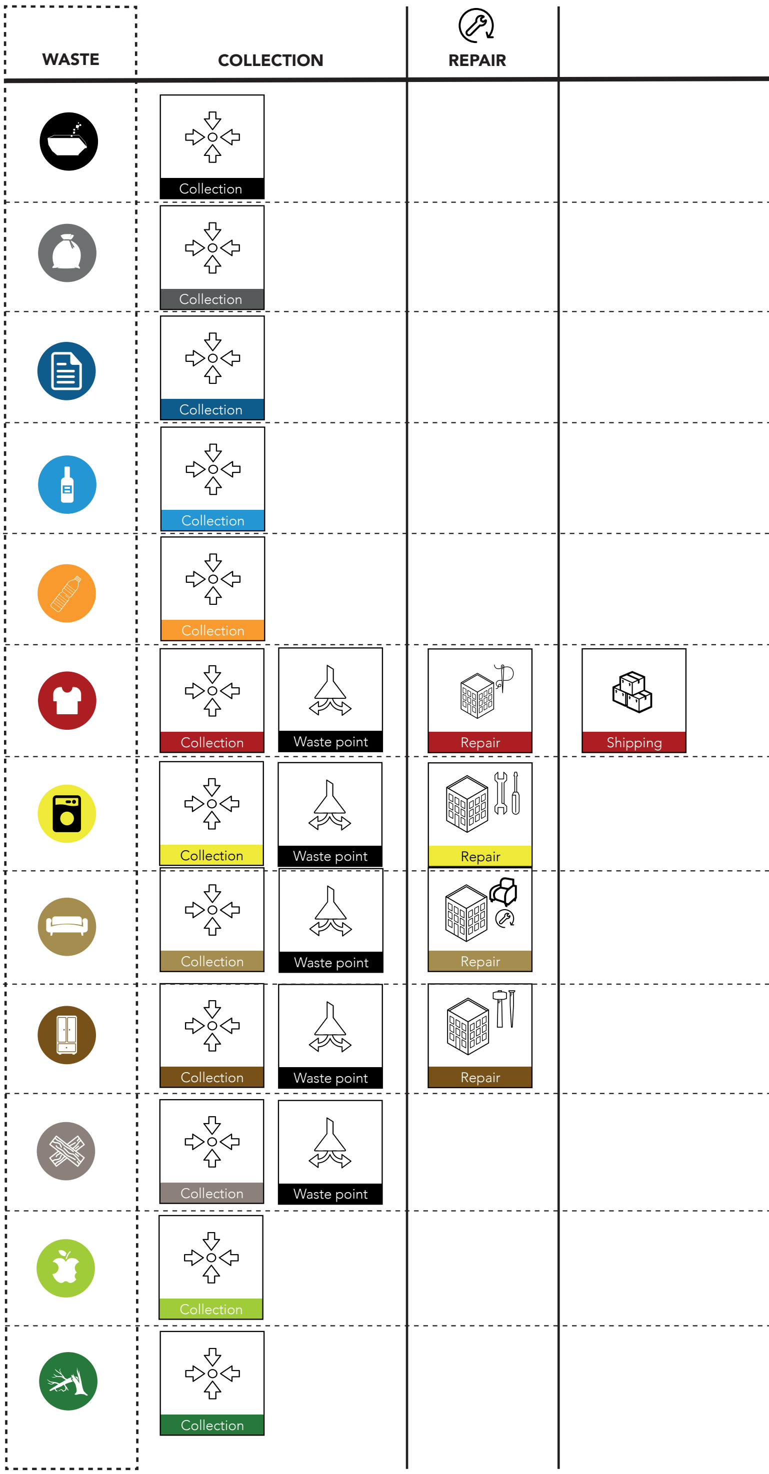
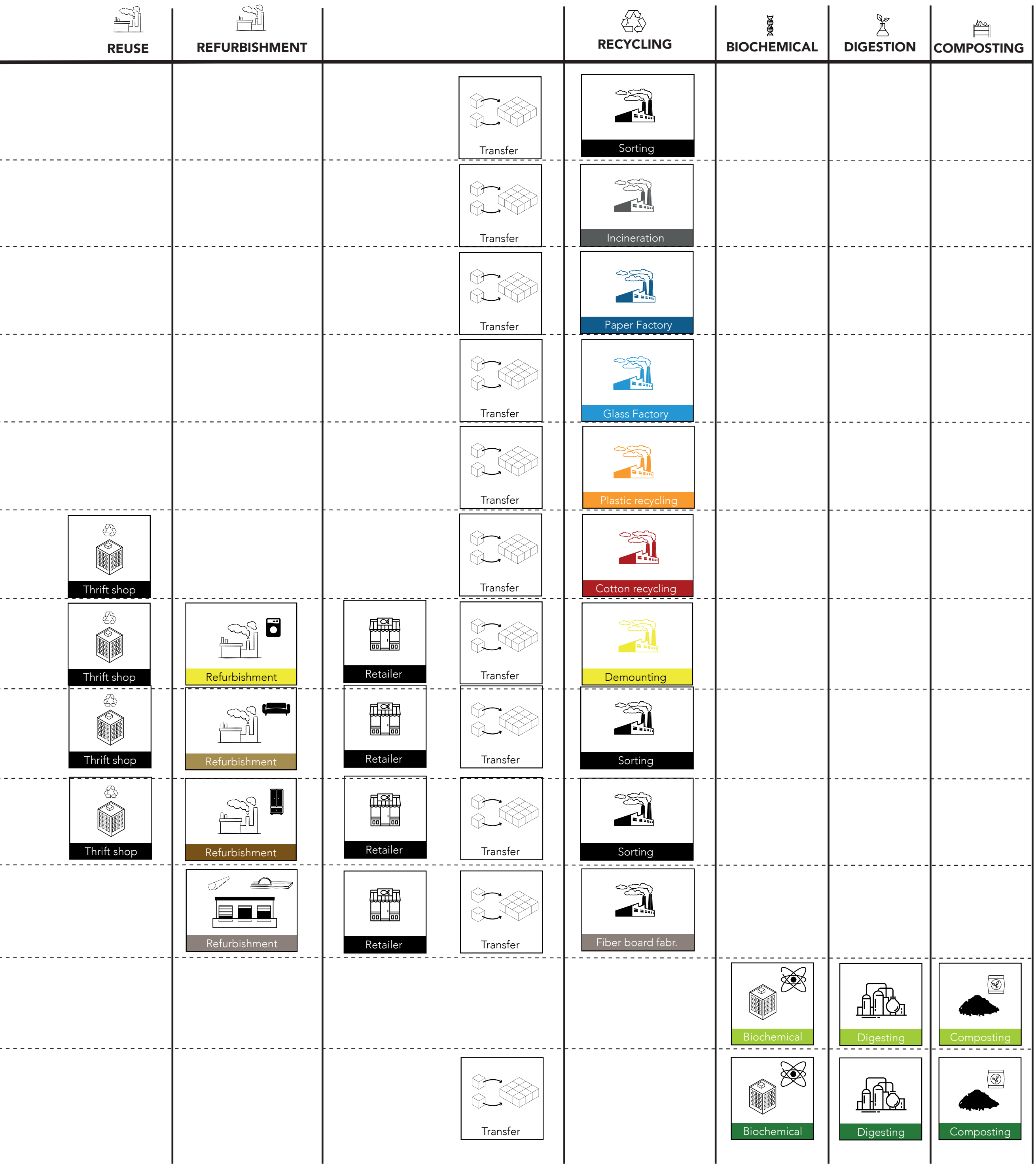


Figure 44

Overview of all the nodes involved within waste treatment, per waste type

This diagram compiles all the information about the new waste treatment system.

(Image by author)



⟶
Figure 45
Waste treatment group 1: recycling and material reuse
The first group of treatment involves recycling and material reuse. Within this group, paper/cardboard, packaging glass and packaging plastics are being collected and treated on a central location. For these waste flows was shown that material reuse is at this moment the best circular way of treatment. Within this group, bulky waste and residual waste are also incorporated. It is not expected that these waste flows will be eradicated completely since there will be always a fraction of the waste which can not be treated in a circular way. However, the goal should be to minimize this fraction. Both are incorporated within this group since they work with large scale facilities which are similar to the facilities of the other three waste flows. It is expected that all five will be placed in the same area.

Since a more central way of treatment is involved, it is not necessary to have the treatment of these waste flows in every city. When the treatment happens within another region a waste transfer system might be needed to compile the waste and ship it in a environmental friendly way to the waste treatment facility.

1. *The similarity in waste treatment between paper / cardboard, packaging glass and packaging plastic.*
2. *All the 5 types of waste use a large scale facility for their way of treatment.*
(Image by author)

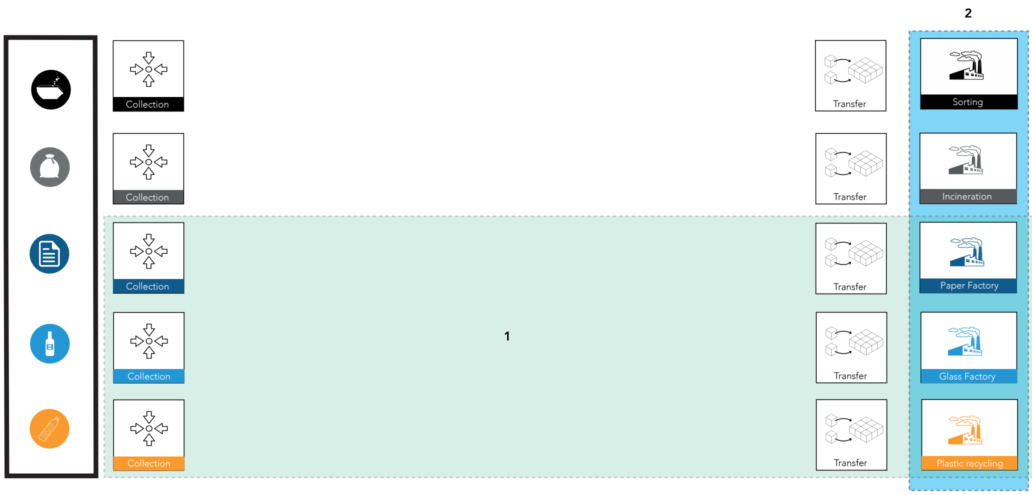
⟶
Figure 46
Waste treatment group 2: repairing, reusing, refurbishing and recycling products
The second waste treatment group involves products. Compared to the products in group 1, which are hard to reuse, do the products in group 2 have more potential for valuable recycling methods. The linkage within this group is mostly the use of the same types of facilities. All the products are linked to each-other by the option to being reused through thrift shops.

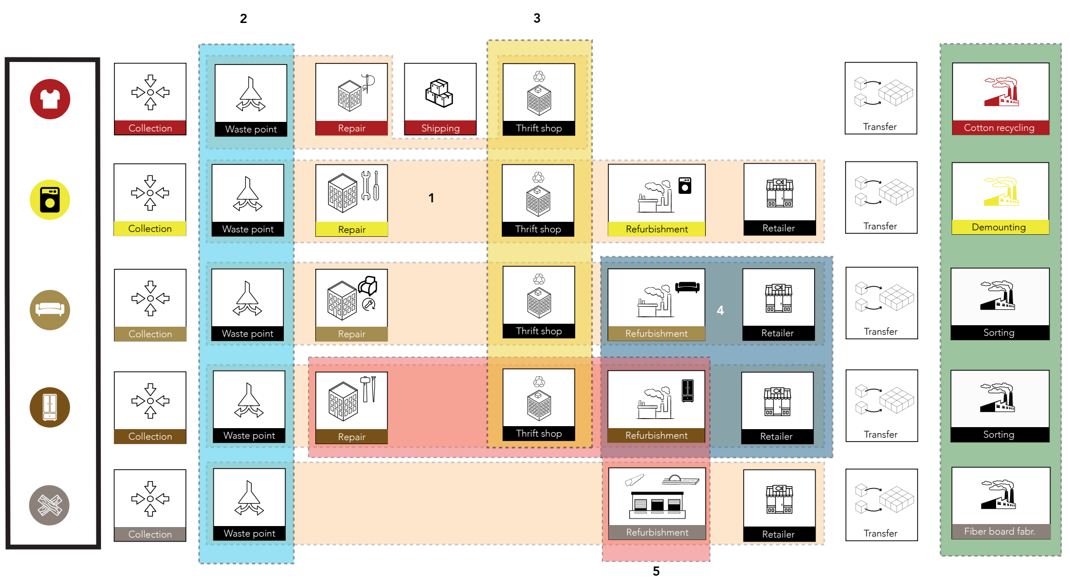
Not only thrift shops form a link between the waste flows. Reusing through thrift shops and repair shops have a small scale character. These facilities stand close to the people and have human scale. Here is the sharp contrast with the group 1 waste treatment. Because of this more de-central character, multiple smaller waste points which are connected to these treatment facility nodes are an obvious choice, since it connects the collection methods and treatment facilities within the city. Wood is added to this waste treatment group since it is a material with different characteristics compared to the materials in group 1. Wood has the potential to be reused in a valuable way, for instance in the furniture repair and building industry.

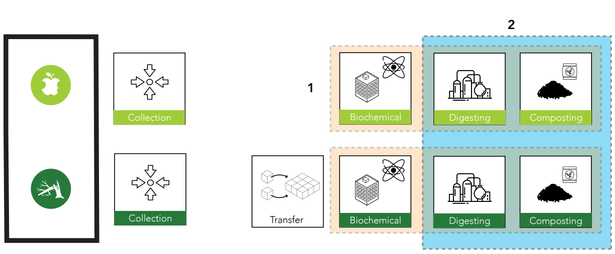
1. *The shown connections within one waste flow*
2. *The de-central waste point to connection the collection methods to the smaller scale waste treatment facilities throughout the city.*
3. *The waste flows are linked to each other by reusing through thrift shops.*
4. *Refurbished furniture can be sold in a furniture store.*
5. *Wood can be used within the repair or refurbish process of wooden furniture. A wood-mill and a carpentry workshop are added.*
6. *When repair, reuse or refurbishment are not possible recycling facilities are needed which are connected to waste treatment group 1.*
(Image by author)

⟶
Figure 47
Waste treatment group 3: returning biowaste back into the biosphere.
The third group involves all the biological waste produced by residents. From both waste flows, biochemical building blocks can be retrieved; rest flows can be digested and eventually composted to return to the biosphere in the form of fertilizer. Dry biological bulk (garden waste) can be transported and stored for a longer time (Agentschap NL, 2012) . This makes it possible to do the treatment of this waste flow in other regions instead close by the city.

1. *The shown connections within one waste flow*
2. *Digesting facilities compost their residue automatically. In this way are these two nodes most of the time already combines.*
(Image by author)


2
Collection
Transfer
Sorting
Collection
Transfer
Incineration
Collection
Transfer
Paper Factory
1
Collection
Transfer
Glass Factory
Collection
Transfer
Plastic recycling


2
3
Collection
Waste point
Repair
Shipping
Thrift shop
Transfer
Cotton recycling
Collection
Waste point
Repair
1
Thrift shop
Refurbishment
Retailer
Transfer
Demounting
Collection
Waste point
Repair
Thrift shop
Refurbishment
4
Retailer
Transfer
Sorting
6
Collection
Waste point
Repair
Thrift shop
Refurbishment
Retailer
Transfer
Sorting
Collection
Waste point
Refurbishment
Retailer
Transfer
Fiber board fabr.
5


2
Collection
1
Biochemical
Digesting
Composting
Collection
Transfer
Biochemical
Digesting
Composting

08
Circular waste treatment and its spatial translation

Spatial characteristics of waste treatment groups

Three different waste treatment groups have been identified. It is now possible to look into their spatial characteristics and determine where within the urban environment they can be integrated. Since waste treatment is mostly associated with heavy industries, which happens at industrial sides, the negative environmental impact of the different facilities or nodes of the system are analysed. The negative environmental impact will give information about the options to implement waste treatment facilities and where to look for synergies with other urban functions.

To determine the negative environmental impact of the different facilities data will be used of Dutch regulations and policies. In the booklet '*Handreiking bedrijven en milieuzonering'* by VNG (2009), all the regulations concerning negative environmental impacts are stated per economic activity and facility. VNG determined for every activity the minimum distance between the activity and housing. These distances are based on potential sound, dust and noise pollution which can be hazardous or annoying for residents. Besides that, an estimation of the risk of the type of activity is given (for instance the release of toxic pollutants) and an estimation of the expected amount of traffic attracted by the activity (both industrial and residential traffic). All these different factors lead eventually to a given minimum distance.

These regulations form a good base to investigate where the activities can be implemented. Not only on a regulatory base, but the policies give good inside in the negative environmental impacts which can downgrade living quality. As said, within this thesis the Dutch policies about environmental impact are used. However, other rules maybe applied in other countries which will have effect on the model presented in this chapter.

Waste treatment group 1

The treatment and recycling of materials mostly happens within large scale industrial facilities. By looking at these facilities (see pictures) it becomes evident that integration within the urban environment will not be possible. Looking at the negative environmental impact of these type of facilities, this is assumption is confirmed (figure 48). The activities within this group mostly concern industrial activities which need at least 300 meters between the activity and housing. Next to that, since it is a centralised treatment system, a lot of incoming traffic can be expected.

Because of the need for enough space and the connection to infrastructure that supports heavy traffic flows, this way of treatment has to be placed at the borders of cities or within rural areas. The most evident place would be industrial areas which already facilitate these kind of activities. When considering waste flows as a global market, the connection to a port for inland and world-wide shipping would be convenient.

Waste incineration plant
(AEB Amsterdam)

REPARCO, paper recycling

(Recycling today)

MALTHA, glass recycling

(Glas in beeld)

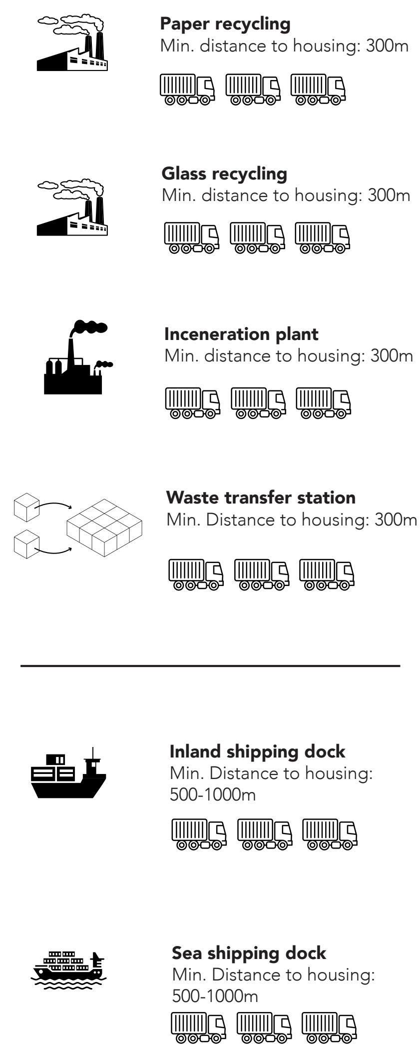


Figure 48

Negative environmental impact of facilities / nodes waste treatment group 1

The negative environmental impact expressed in minimum distance between the node and housing. The minimum distance is based on noise, air, and smell pollution or potential danger. The trucks resemble the amount of expected traffic flows to and from the node.

(Image by author, based on data VNG, 2009)

Waste treatment group 2

The second waste treatment group has a focus on the repair, reuse and refurbishment of products. Within this thesis, furniture, electronic appliances and clothes are the subject of investigation. As shown in figure 49, the facilities connected to this treatment system have less negative environmental impact compared to the facilities in group 1. This makes it possible to integrate the treatment facilities within the city. The negative environmental impact of the facilities really depends on the size of the facility. When furniture is being made in a small workshop, more implementation possibilities are possible.

Since this treatment system has more a human scale (see pictures) and is more decentralised compared to the previous system, more treatment points need to be placed around the city. All the treatment points can host different combinations of facilities. For repair and thrift shops and waste points it is desired to have multiple points around the city to make them easy to reach for residents to recycle their products in a circular way. Refurbishment facilities, especially on a larger scale have more an industrial character which do not have a lot of contact with residents. That is why less facilities of this kind are needed and can operate outside the city on a larger scale.

The collection of the products has a different approach compared to the other two waste treatment groups. Waste is not compiled and transferred at one central location outside the city. Within this system the waste is compiled at decentralised waste points to keep the waste close by the different treatment facilities. These waste points should be placed within the lower density urban areas. When products are eventually disposed and only suitable for material reuse, the products can be brought to the designated recycling facility or waste transfer point.

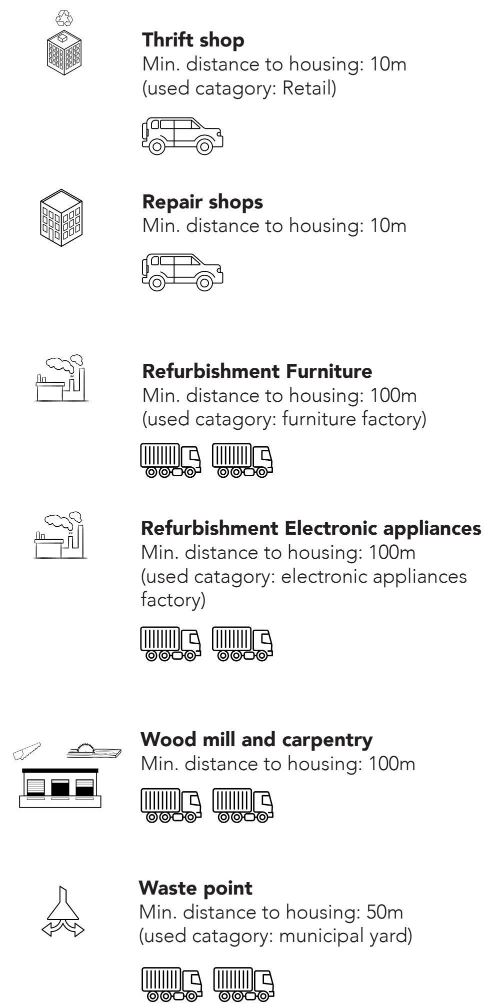
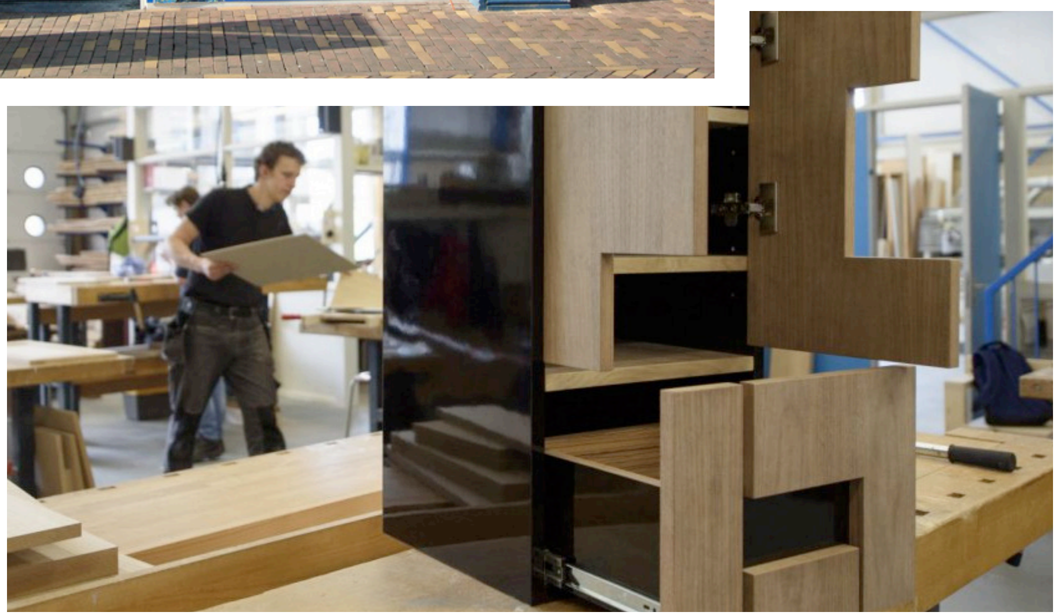


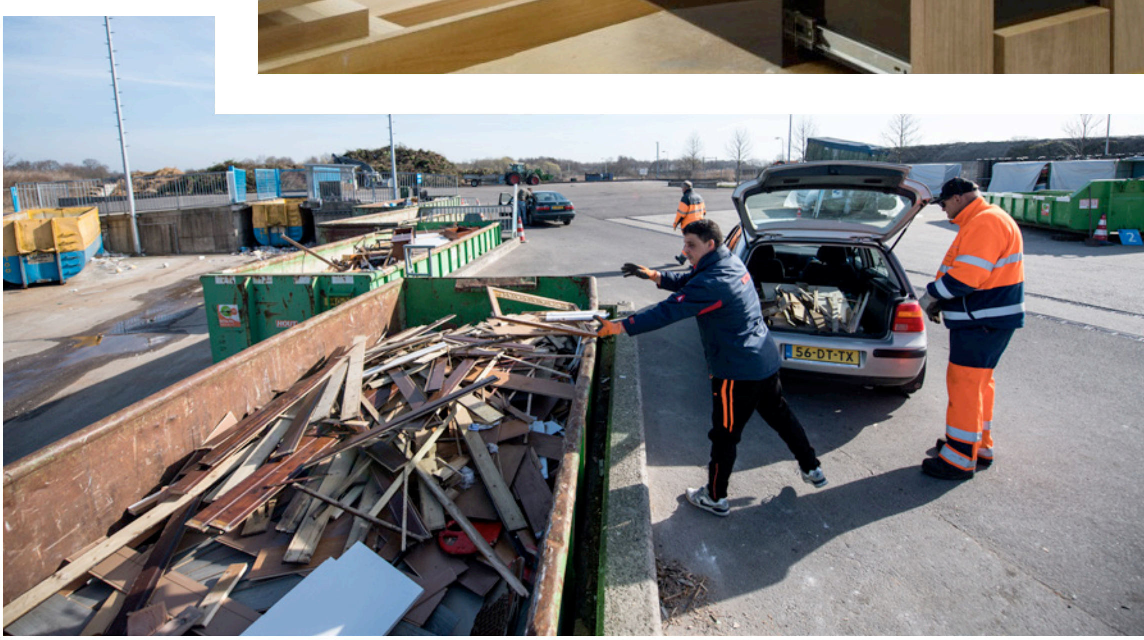
Figure 49
Negative environmental impact of facilities / nodes waste treatment group 2
The negative environmental impact expressed in minimum distance between the node and housing. The minimum distance is based on noise, air, and smell pollution or potential danger. The trucks resemble the amount of expected traffic flows to and from the node.
(Image by author, based on data VNG, 2009)

Mobile phone repairshop
(Winkelstad Veenendaal)

Making Furniture
(ROC Amsterdam)



Waste point
(Beeldbank Assen)



08
Circular waste treatment and its spatial translation

Waste treatment group 3

The last treatment group concerns the treatment of biological waste. Biological waste can be treated in three different ways. The most valuable treatment way is using the biochemical building blocks for biological material production. It depends on what kind of materials or products are produced what the negative environmental effects are of the facility. This method is for instance used in chemical industries like paint manufacturing. These facilities have a larger minimum distance to housing compared to facilities which create building materials from biowaste. In this model, an average distance has been used (figure 50).

Digesting and composting are methods which can be used on multiple scale. It is already possible to compost your own biowaste in your backyard. Even digesting facilities can be build on a small scale. Within this model, the larger facilities are explained. For biowaste treatment methods, large amounts of biowaste are needed, which can be collected at central places. Besides the biowaste produced by the city itself, dry biowaste, like wood, is a material which is shipped around the world to be used as a resource (Agentschap NL, 2012). For this reason it makes more sense to use large scale facilities at the border of cities. When they are placed within port areas, it becomes possible to recycle biowaste on a large scale.

In this way, the third treatment group has a lot similarities to the first treatment group. The biggest difference is the facilities that are necessary for this treatment system.

Treatment of biowaste is discussed here on a large scale. To make the treatment profitable, large amounts are needed. However, treatment of biowaste can also happen on a very low scale (see pictures). Biowaste can turned into compost even in you backyard. This could also be solution for low density neighbourhoods where there is the possibility to close the loop within the neighbourhood.

Worldwide shipping of biomass
(Martiem nieuws)

⟶
Small scale composting
(Nudge)

Digesting facility
(Orgaworld)

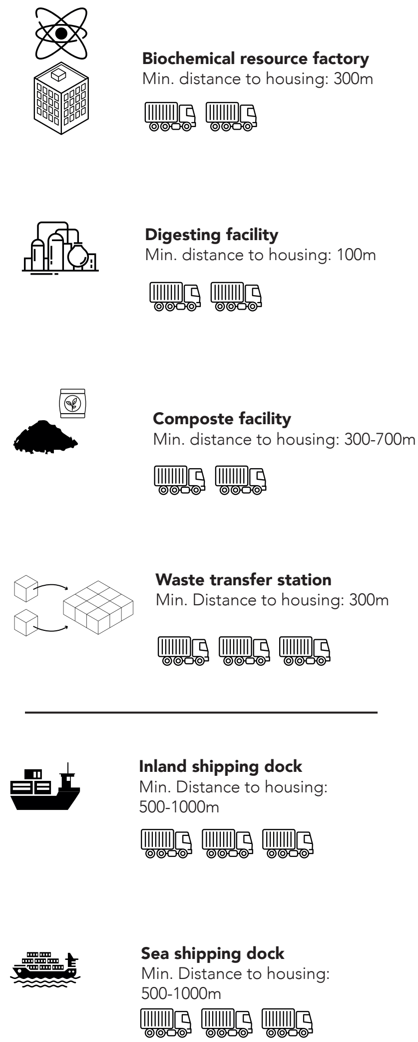


Figure 50
Negative environmental impact of facilities / nodes waste treatment group 3
The negative environmental impact expressed in minimum distance between the node and housing. The minimum distance is based on noise, air, and smell pollution or potential danger. The trucks resemble the amount of expected traffic flows to and from the node.
(Image by author, based on data VNG, 2009)

09

New waste collection principles

Amsterdam is already working hard on finding solutions to increase the collection of separated fractions. Research is being done on how the goal of 65% by 2020 can be reached. In this chapter, the future plans of the municipality will be discussed and further recommendations will be given. New principles will be created which are an addition to the plans of the municipality. In this way, the current future plans are evaluated and new principles connect to the current policies of the municipality. Chapter 9.1 discusses these future plans of the municipality. In chapter 9.2, new crucial principles will be added to improve the collection even further.

09.1 Waste implementation plan Amsterdam

The municipality of Amsterdam describes three main ambitions in their residential waste implementation plan. (Gemeente Amsterdam, 2016b). Firstly, the separate collected fraction should increase to 65% in 2020 (19% in 2013) to increase the possibilities for waste recycling. Secondly, improving the services to increase the possibilities to dispose waste separate and to motivate the residents to do this. Finally, an efficient organisation to reduce costs and make investments in the future possible.

To achieve these goals multiple principles are created. The main principles are discussed below:

1. Source separation is the starting point. However, to achieve the 65% by 2020, separation in waste treatment plants is necessary. Source separation results in qualitative waste flows, which is perfect to us for recycling. However, source separation requires the cooperation of the residents of Amsterdam. A change in the current infrastructure is needed to facilitate waste disposal in the most optimum way for the residents.

2. The loop of fruit and vegetable waste should be closed locally. Providing infrastructure to collect this waste flow separately is expensive and will not compensate the benefits. Local initiative should be supported to treat fruit and vegetable waste within the neighbourhood.

3. Optimizing an expanding the current network of waste containers. Currently, most of the waste collection infrastructure is focussing on the collection of residual waste. A shift has to be made to homogeneous waste flows and containers for residual should be reduced. Besides this shift, more containers should be implemented in recognizable waste collection stations.

4. Reducing the amount of residual waste by incentives. A reduction of residual waste should be achieved by persuading residents to dispose less residual waste by rewarding them.

5. Collection of bulky waste by appointment. To improve the service, bulky waste should be collected by appointment. In this way, residents do not have to wait till the weekly collection day. Another goal is to stimulate residents to drop off their waste themselves at one of the waste points in Amsterdam.

These five focus points show already a clear vision for the future to improve the situation. However, the visions still stay on an abstract level and more improvement can be made. Especially the spatial component of the measurements are not present in this vision. In the next chapter, new principles will be added to transform the vision of the municipality in to more concrete goals. These goals can lead to implementation and a plan for action.

09.2 Adding principles to improve waste collection

The discussed vision of the municipality in the previous chapter is a good starting point for improvement. However, the principles stay on a abstract level and they could be more ambitious. In this chapter, principles will be added to the municipal vision to strengthen the vision and make it ready for implementation. This will give a better understanding of what exactly should happen to improve the future. When applying these principles, they can be tested and valuable recommendations can be derived from these implementation proposals.

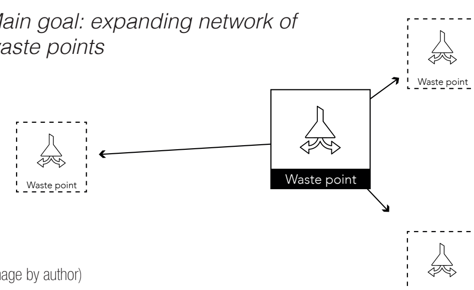
The principles, which will be used in this thesis, are discussed in two categories. First the periodically disposed waste flows and their collection infrastructure will be discussed. The daily disposed waste flows are the subject in the second part (next pages). Eventually, more concrete proposals for the improvement of the waste collection system are given which can be implemented in chapter 11 and 12.

Periodically disposed waste flows

The waste flows which are not disposed daily, as described in figure 21, can be brought to waste points or picked up by the municipality. The municipality states to improve the pick up service by making it more on demand, and expanding the network of waste points throughout the city. This expansion of the waste point network is one of the main spatial problems concerning the waste collection system (explained in chapter 3.3). For these waste flows it is important that the collected products (like electronic appliances and furniture) are not damaged or devalued during the transport. The product has to stay intact, to make repair, reuse and refurbishment possible.

Currently the waste flows are collected via waste trucks, which compress the products and in this way destroy value. This collection method should change to collect waste without loosing value. This collection method and service should stay available throughout the whole city since a lot of residents of Amsterdam are not in the possession of a car. However, more focus should be on expanding the network of waste points throughout the city. In this way, residents are responsible for the disposal and they will get more aware of the disposal methods. People will think twice before disposing a product, or they start thinking about the most sustainable way for disposing.

Main goal: expanding network of waste points

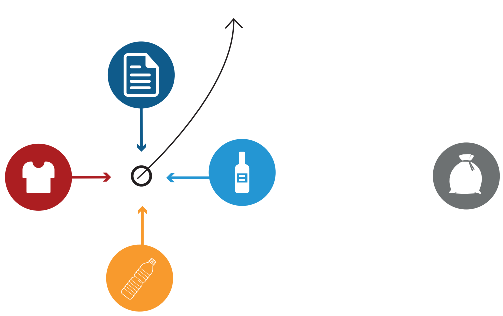


(Image by author)

09
New waste collection principles

Positioning of infrastructure

Within the Netherlands, there is a certain norm concerning the maximum distance between a residency and a residual waste street container. In 2013, the 'Raad van State', the most important advisory board of the government, stated the fact that a container should be placed at preferably 75m and maximum of 150m away from every residency (Raad van State, 2013). This walking distance can be used as a guideline to positioning the containers within a neighbourhood. However, maybe a fixed distance is not the correct answer to the positioning question. Smart locations have to be picked on walking distance or along cycling routes to make waste separation as easy as possible. The municipality proposes to create recognizable waste collection areas, where waste can be separated easily. These points have to be positioned at these smart locations to make it as easy as possible for residents to dispose their waste in a sustainable way. There should be a preference for homogeneous waste flow collection infrastructure compared to heterogeneous waste flows. In chapter 11 becomes clear how this positioning needs to happen and how such collection areas look like in different neighbourhood types.



(Image by author)

Quantity and distribution

An estimation has to be made on the expected waste containers which are needed to collected the waste. As already described within chapter 7.1, the volume of waste is the most important aspect when thinking about waste spatially. Different types of waste have different volumes and these volumes change when trying to collected 65% in separated fractions. Currently, only around 30% is collected separately, which means that most of the volume is stored within residual waste. When the separation rates increase, the volume of residual waste will decrease and the volume of the separated fractions increase.

By examining the volumes of waste produced in Amsterdam, the expected change over the coming years, and comparing them to the available waste containers, an estimation can be made on the needed infrastructure (figure 51). As an example, when packaging plastics currently takes up 0,04 m^3 within a total generation of 2 m^3 of waste per person per year, this volume will increase by 7,9 times when reaching a 65% separation rate. Now this 0,04 m^3 is collected throughout the whole city by 240 containers. This means that in the future 1896 containers will be needed to collect the increased volume. These calculations can only give an estimation and does not take into account a lot of external effects. However, it makes clear that it is not necessary to place thousands of new containers, but most of the job is a reconfiguration of the existing infrastructure. With these calculations an estimation can be given on how many residents make use of one container. In the case of packaging plastics, this results in 1:443 ratio. For the waste flows of paper, plastics, glass and textile, these calculations could be done since containers are already placed within Amsterdam at this time. Fruit and vegetable containers are not available yet. Fruit and vegetable waste will be discussed on the next page.

▶ *Continuing page 94*

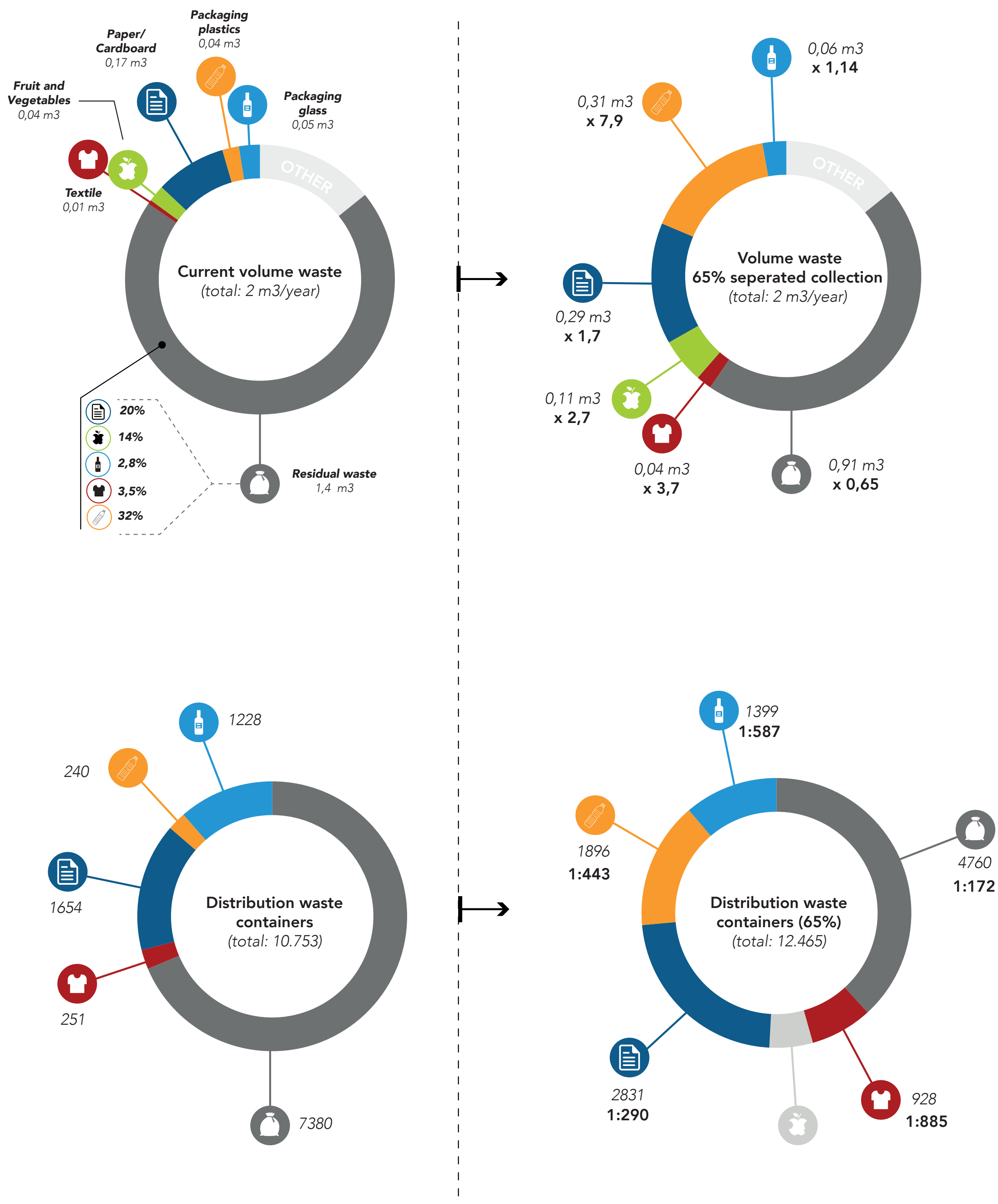


Figure 51

Changing configuration of waste containers

Reconfiguration of current waste collection infrastructure is the biggest challenge since the total volume will not grow, however the distribution of volumes will.

(Image by author, based on Gemeente Amsterdam, 2015c)

09
New waste collection principles

These estimations show a drastic decline in the amount of residual waste containers and especially an increase in containers for packaging plastics. The municipality agrees in their vision with this statement. However, the municipality proposes to reduce the amount of residual waste containers from 1 container for 60 residents to 1 container per 100 residents (Gemeente Amsterdam, 2016b). The calculations show that a larger reduction is needed to deal with the changing volumes. Aiming for a 1 to 172 ratio is as well more ambitious. Choosing for a further reduction will help to improve the situation and more easy to reach their goals.

Flexibility

In continuation of the previous principle, the principle of flexibility will be explained. Since reaching a separation of 65% is a transition, it is important that the infrastructure can adapt to the differences in waste generation per neighbourhood and changing volumes. Currently, in the case of street containers, still different types of containers are used (see picture below). Within a new system, these technologies should be made uniform for the whole city to make it possible to change the composition of containers within a neighbourhood. Flexibility also applies to the fact that in some periods or during events more waste is being produced. A system that can react to these fluctuations of waste volumes is necessary.

Different types of infrastructure
(Twan Cortenraede)

Mini-containers

The best, and easiest way to separate waste is by doing this right at the source at the residence itself. Houses with the availability of a garden do have the space to separate their waste into mini-containers. The urban forms build with terraced and detached housing are the areas where this principle can be applied to (these areas are defined in chapter 10). Packaging plastics ,paper and fruit and vegetable waste are suitable for this type of mini-containers. These mini-containers are used within a lot of Dutch municipalities. When separating waste, residual waste becomes just a very small fraction. This is also visible when you see how large the volume of packaging plastics is. From own experience at my parents home this is also the fact in real life. Because of their mini-container for packaging plastics, their residual waste container is never full and only has to be emptied once a month. To encourage waste separation, it is important to make the separation of waste as easy as possible. For this reason, it is more important to provide mini-containers for the separated fractions, instead for residual waste. More effort has to be made in this way to not separate your waste. Multiple municipalities in the Netherlands are already experimenting with this so called reversed collection of waste (ROVA, n.d.).

Reversed collection of waste. Giving preference to homogeneous waste flow collection at home

(Image by author)

Small scale composting

A high percentage of the total waste production of an inhabitant of Amsterdam is fruit and vegetable waste. this waste flow can be collected through mini-containers, however, this collection method can only be applied in areas where residents have place to position such a container in their garden. The municipality states that the collection of this waste flow through street containers is to expensive and the revenues are not worth the investments (Gemeente Amsterdam, 2016b). For this reason a more valuable option is the composting of biowaste on a small scale in the neighbourhoods. In Amsterdam already a number of initiatives are implementing these systems in Amsterdam. These initiatives should be expanded and become a city wide vision on how to deal with residential biowaste. In this thesis proposals are made on how these facilities can be integrated within residential areas. These facilities can work well in the recognizable waste collection points throughout the city.

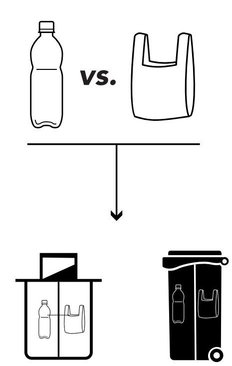
Packaging plastics

Packaging plastics is described is an homogeneous waste flow, which is collected separately. However, over 250 different types of plastics are used within the packaging industry which makes clear that reaching actual homogeneous flows is almost impossible (NOS, 2018). The plastic which is collected currently has most of the time a low quality and after treatment the plastic is just of moderate use. Most of the plastic still ends up in the incinerator (Tooms, 2017). It makes clear that the most important challenge is to reduce the amount of different types of plastic within the packaging industry and improve the homogeneity of the collected fractions. This theses will not address this more technical aspect of waste separation, however, it wants to state that within the waste collection infrastructure a possibility should be available to present the types of plastic waste separately.

Including small scale composting activities in the recognizable waste collection points throughout the neighbourhood

(Image by author)

Increasing quality of packaging plastic waste by minimizing the use of different types of plastics and collect them separately



(Image by author)

Rewarding and monitoring

To motivate and persuade residents to change the waste disposal habits, a rewarding systems could be valuable. This option to reward residents is already proposed by the municipality. More detailed principles are needed to make this system happen. To be able to reward residents for their improved waste disposal, a monitoring system is needed. Such a system should be able to calculate the change in waste disposal, including a reduction in waste and an increasing separate disposal. It is hard to monitor the waste disposal for every individual. For this reason, waste should be collected more in clusters, for instance per building block or street. With the recognizable waste collection points this can happen. Improvement for a building block can be monitored and options can be created to reward the residents appointed to this waste collection point. In this way a whole block is responsible for improving the waste collection, which creates a certain form of social control and stimulating each other. In this way, stronger communities are created and residents motivate each other to change their behaviour. When improvement is made, rewards will be given which support the neighbourhood, like the financing of a summer street party or investements in the public space.

Waste collection in clusters according to streets or building blocks

(Image by author)

Conclusion: main vision and principles

The principles of the municipality are a good starting point for improving the waste collection in Amsterdam. However, more specific ideas are needed. As an addition to the municipal vision more detailed principle are created. These principles will be tested and implemented in the next chapter. This implementation process can result in concrete recommendations. These are the main principles to improve the residential waste collection system:

1. Expanding the network of waste points throughout the city to dispose products and furniture.

2. Reverse collection of material based waste flows. Giving preference to separated waste flows.

3. Recognizable waste stations throughout the neighbourhood. Every waste collection station is assigned to a certain cluster to make monitoring possible.

4. Local treatment of biowaste.

5. Monitoring of waste disposal and rewarding in clusters

These four principles form the core of the new waste collection system and are interesting spatial challenges.

Urban integration of circular systems

Defining urban integration possibilities for waste collection infrastructure and circular waste treatment systems according to the different urban forms of Amsterdam

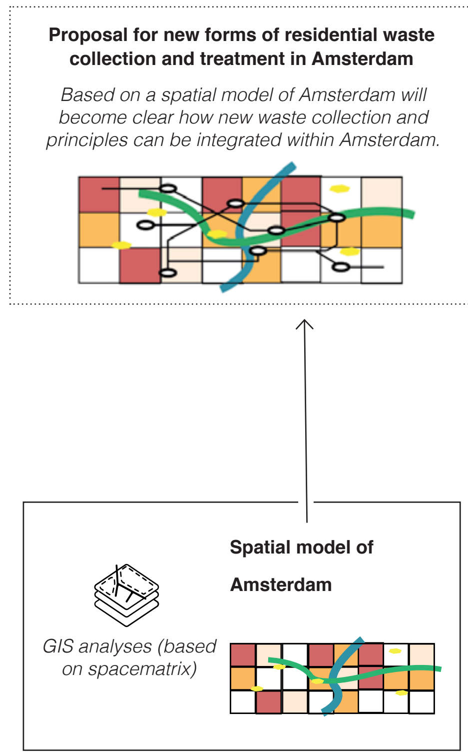
10

A spatial model of Amsterdam

Introduction

To be able to propose integration options for the new waste collection principles and circular treatment systems a spatial understanding of Amsterdam is needed. Amsterdam is an historic city which knows a lot of different types of neighbourhoods. Solutions for the historic city centre can be totally different compared to the post war modernist expansion neighbourhoods. As concluded in chapter 7.2, a new system for especially waste collection should be adjusted to this diverse spatial characteristics.

To understand Amsterdam spatially and to able to define challenges and opportunities for this variety of urban forms, a spatial model will be created. In this way, Amsterdam can be spatially categorized. These categories will be the case study areas of the implementation process, to propose a wide variety of solutions to improve the situation and create possibilities to reach the set goals and circular ambitions.



A spatial understanding of Amsterdam to determine spatial challenges and opportunities for integration of the different systems

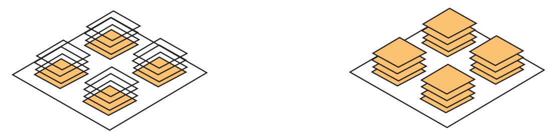
(Image by author, see chapter 6)

The different types of urban form within Amsterdam

To create a new and better integrated collection system, a categorization of Amsterdam's urban forms have to be made. The different urban forms can be determined by examining the differences in densities. By calculating the building densities for all the neighbourhoods of Amsterdam, a spatial model arises which can categorize Amsterdam. This spatial model of Amsterdam will constructed by making use of GSI (Gross Space Index) and FSI (Floor Space Index) calculations explained by Berghauser Pont et. al. (2010) in the book '*Spacematrix: space, density and urban form'.* By calculating the GSI and FSI values of a certain area, the building density and intensity can be determined. The relation between both parameters relate to a certain type of urban form. GSI represents the footprint of the buildings within a certain area. Easily said, the percentage of a certain area which is covered by buildings. FSI gives information about the building intensity by calculating the total floor area of buildings within a certain area. In this way the difference between high rise and normal houses becomes visible. In figure 52, the calculation methods for both parameters are explained.

The GSI and FSI is being calculated of a certain area, which is called the area of aggregation. Within this thesis, the 477 neighbourhoods of Amsterdam are used for these calculations. However, not the whole area of an neighbourhood can be used for waste collection infrastructure. To get a better understanding of the urban form, the areas which are covered by water, railway tracks and highways area removed from the area of aggregation (figure 53). These three layers have such a characteristic that they are permanent and can not be adjusted or used within the proposals.

▶ *Continuing page 100*



$$\textbf{GSI} = \frac{B}{A}$$

B = *Footprint buildings (m2)*

A = *Area of aggregation (m2)*

$$\textbf{FSI} = \frac{F}{A}$$

F = *Gross floor area (m2)*

$$F = \frac{\text{Building height}}{\text{Floor height (3m)}} \times \text{Building footprint}$$

A = *Area of aggregation (m2)*

Figure 52

GSI and FSI calculations

(Image by author, based on Berghauser Pont et al., 2010)

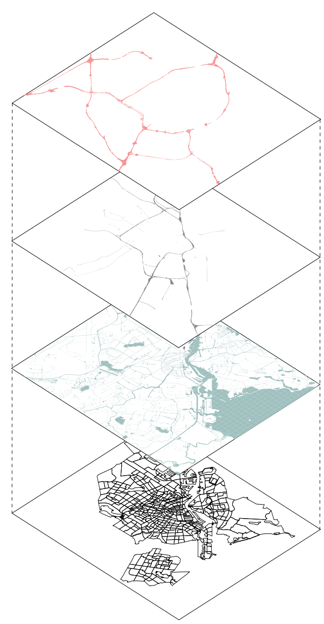


Figure 53

Area of aggregation

(Image by author)

10
A spatial model of Amsterdam

Figure 54

GSI value for every neighbourhood of Amsterdam

(Image by author, based on GEO data municipality of Amsterdam)

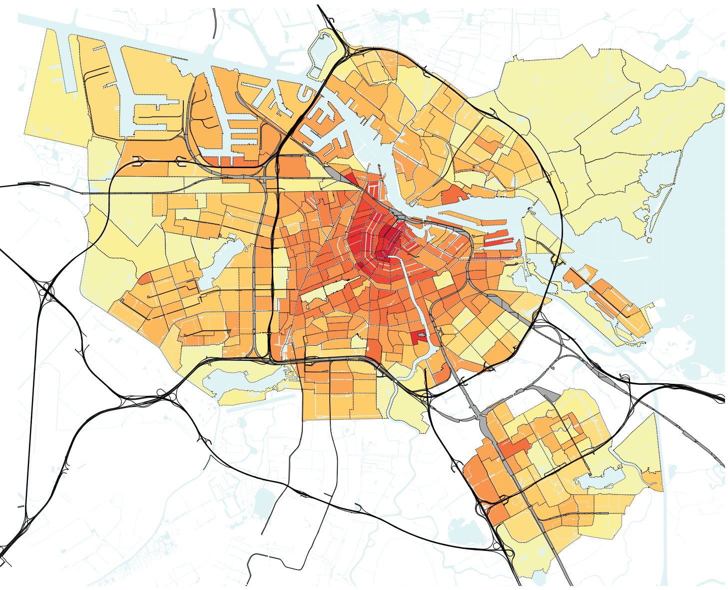
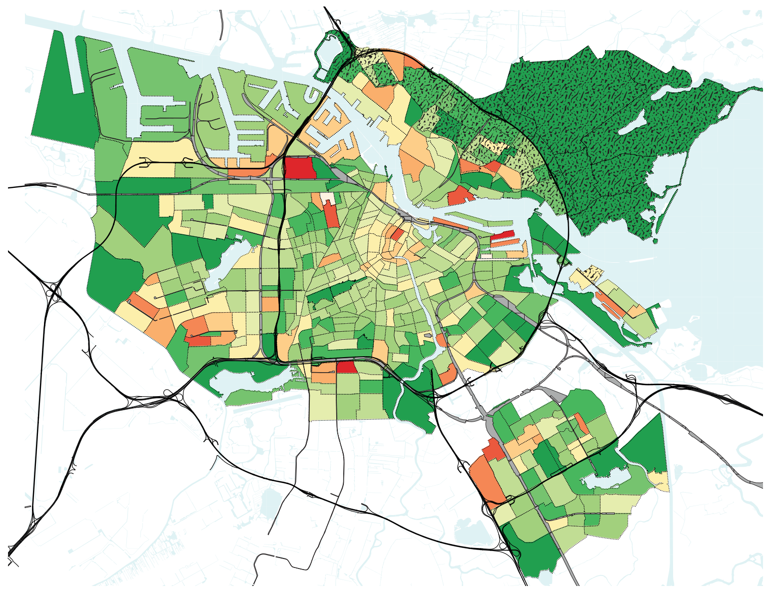


Figure 55

FSI value for every neighbourhood of Amsterdam

For some area, the building height data was not accurate. This led to incorrect values. The missing data areas are visualized within the map.

(Image by author, based on GEO data municipality of Amsterdam and BAG 3D data)



With the area of aggregation determined, the GSI and FSI can be calculated by using GIS. Through GIS the footprint of the buildings, building height and area of aggregation can be calculated which results in a GSI an FSI classification of Amsterdam per neighbourhood (figure 54 & 55). Within these calculations all the neighbourhoods of Amsterdam are taken into account. However, not all the neighbourhoods are mainly used for residential use. Since a spatial model related to residential waste collection is made, the neighbourhoods that are used for more than 50% by other functions instead of residency, are filtered out. In this way, the categorization becomes more accurate and areas which are not related to residential waste are ignored. The neighbourhoods which are not taken into account can be seen within figure 56. Some of these neighbourhoods (especially the ones occupied by industry) are designated locations for future housing development. In the future, the GSI and FSI of these

Figure 56

Excluded areas

Based on dominant functions (more than 50% of area) which are not residency

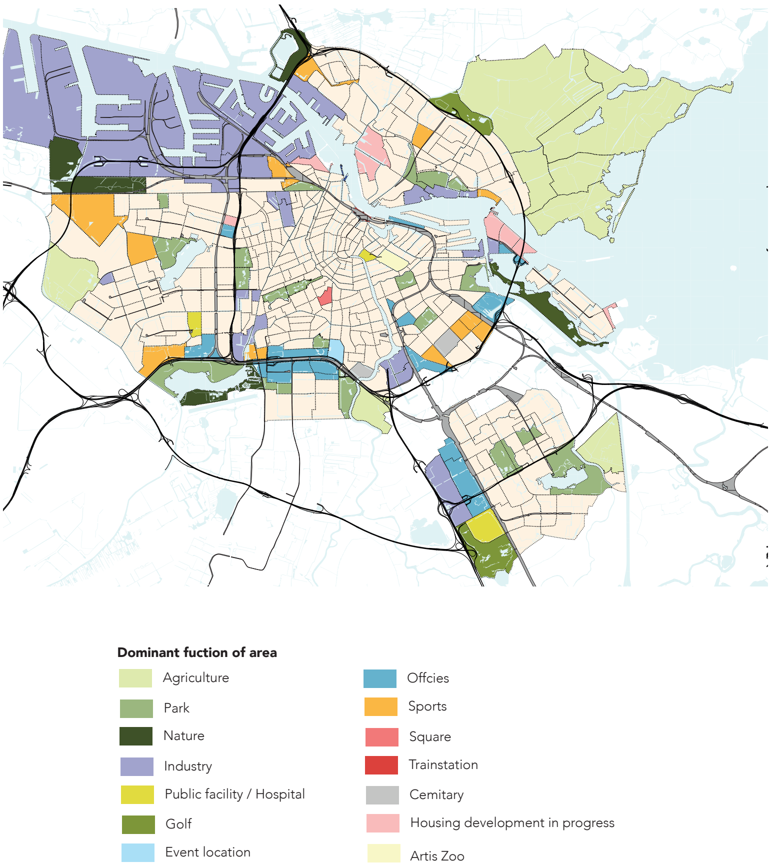
(Image by author, based on GEO data municipality of Amsterdam)

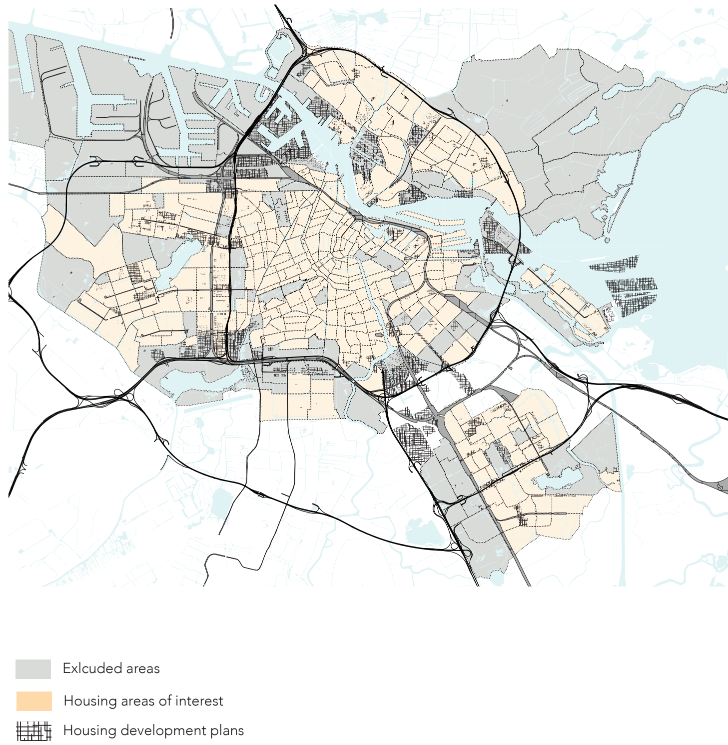
Figure 57

Excluded areas and housing development

Housing development can change the spatial model of Amsterdam since GSI, FSI and function of a certain area changes in the future. These spatial changes will also create opportunities for new integration possibilities in these areas.

(Image by author, based on GEO data municipality of Amsterdam)





neighbourhoods can change drastically and should be included within the spatial model for waste collection. Within figure 57, these possible housing development locations are shown. Since most of these housing development projects are still within an exploration face, the future GSI and FSI can not be determined. That is the reason why they will not be taken into account within this research.

Now the GSI and FSI values have been calculated, and the areas of interest have been determined, a classification of Amsterdam can be made. When combining the FSI and GSI of every area, clusters arise which can be coupled to different types of neighbourhood. These neighbourhoods have the same type of buildings and building densities. Within the different neighbourhoods multiple types of buildings and density can occur. For this classification the most dominant type of housing within

▶ *Continuing page 102*

every neighbourhood is used. This may result in a more scattered graph visualization. This classification helps to propose new ways of waste collection, adjusted to different urban forms. Within this thesis, seven types of urban form will be used and analysed. The position of these seven clusters and their related GSI and FSI value range, can be seen within the graph presented in figure 58. The location of the different neighbourhood types of can be found in figure 59. All the different types will be explained, and especially their spatial characteristics, which will determine how spatial integration of waste collection infrastructure is possible. The knowledge about the different urban forms is not only useful for implementing waste collection infrastructure. This knowledge can be used ass well when trying to fit in waste treatment facilities and related functions.

Seven case study neighbourhoods related to these different urban forms have been selected. Within chapter 11, these neighbourhoods will be analysed and design and integration possibilities for waste collection will be proposed. The principles created within chapter 9.2 will be the starting point for this implementation process.

Figure 58

GSI and FSI value graph

By combining the FSI (y-axis) and GSI (x-axis) values, a scatter plot can be created. Within this graph, certain clusters can be identified where neighbourhoods are displayed with the same density and urban characteristics. In this way seven urban categories have been determined for Amsterdam.

(Image by author)

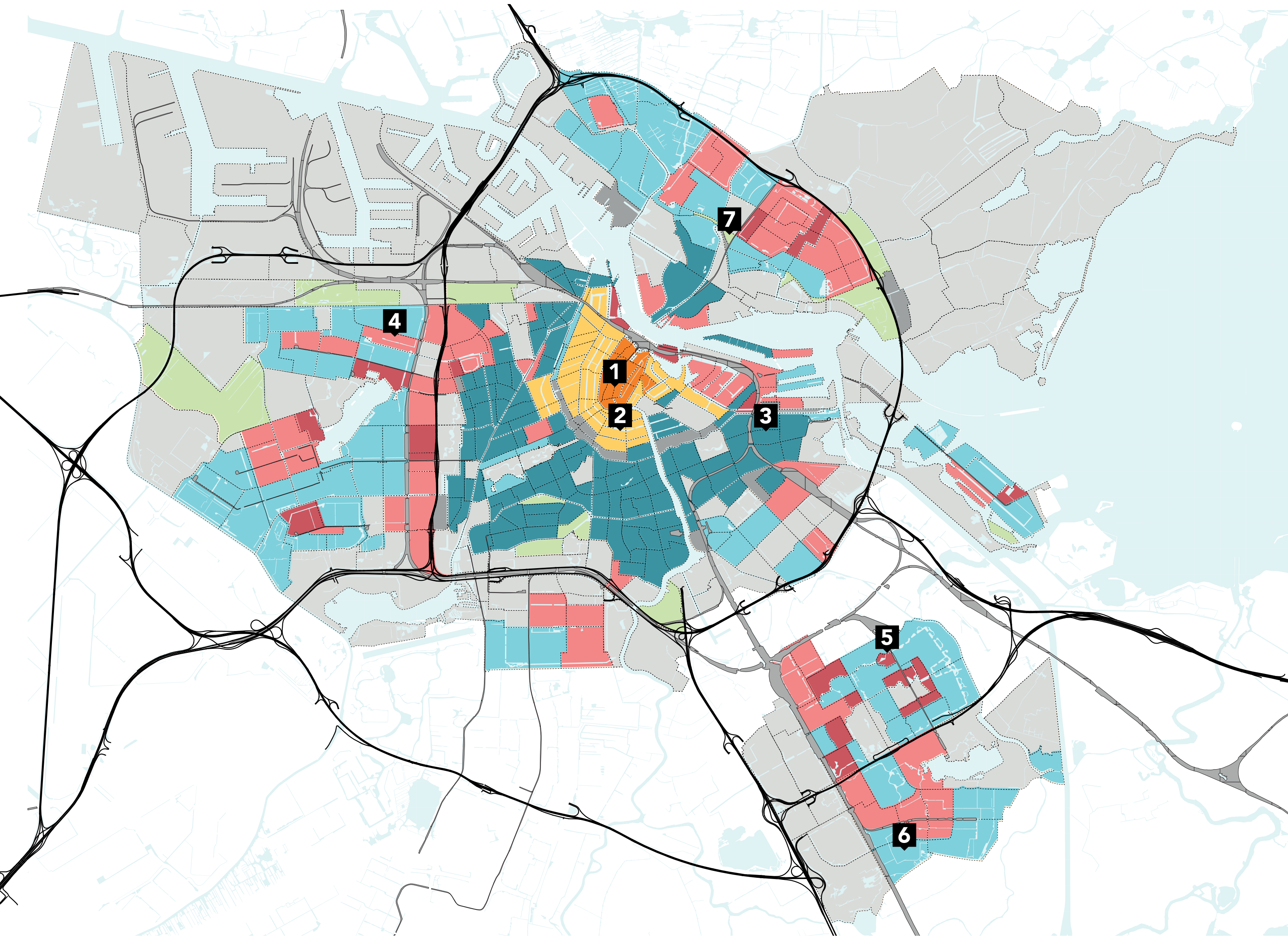


Figure 59

Classification of Amsterdam

When exporting the given GSI/FSI clusters on a map of Amsterdam, the urban forms and locations become visible. The different urban forms are strongly related to the expansion pattern of Amsterdam in a radial manner

(Image by author)

11

Urban integration of waste collection infrastructure

Seven case study areas are selected and for every neighbourhood type challenges and opportunities can be stated related to waste collection infrastructure. The principles created in chapter 9.2 are the base for finding integrative solutions to increase the possibilities to collect waste separately within every neighbourhood. In this chapter, for every neighbourhood type (based on the seven case study areas) challenges and opportunities are found. Proposals for solutions are shown for these neighbourhoods. The solutions are not just specific for the case study area, but should be able to be applied in all the neighbourhoods with the same characteristics. This results in a wide variety of options to improve the waste collection system. The solutions will not only focus on increasing the amount of locations to dispose your waste separately, but will also address the importance of finding collection methods which retaine value. Case study area 7 is not analysed within this chapter. Only a few amount of neighbourhoods consist of detached housing. These areas do have the same characteristics compared to terraced housing.

In the following chapters the different areas will be analysed. The chosen areas can be found in figure 59 in the previous chapter.

1

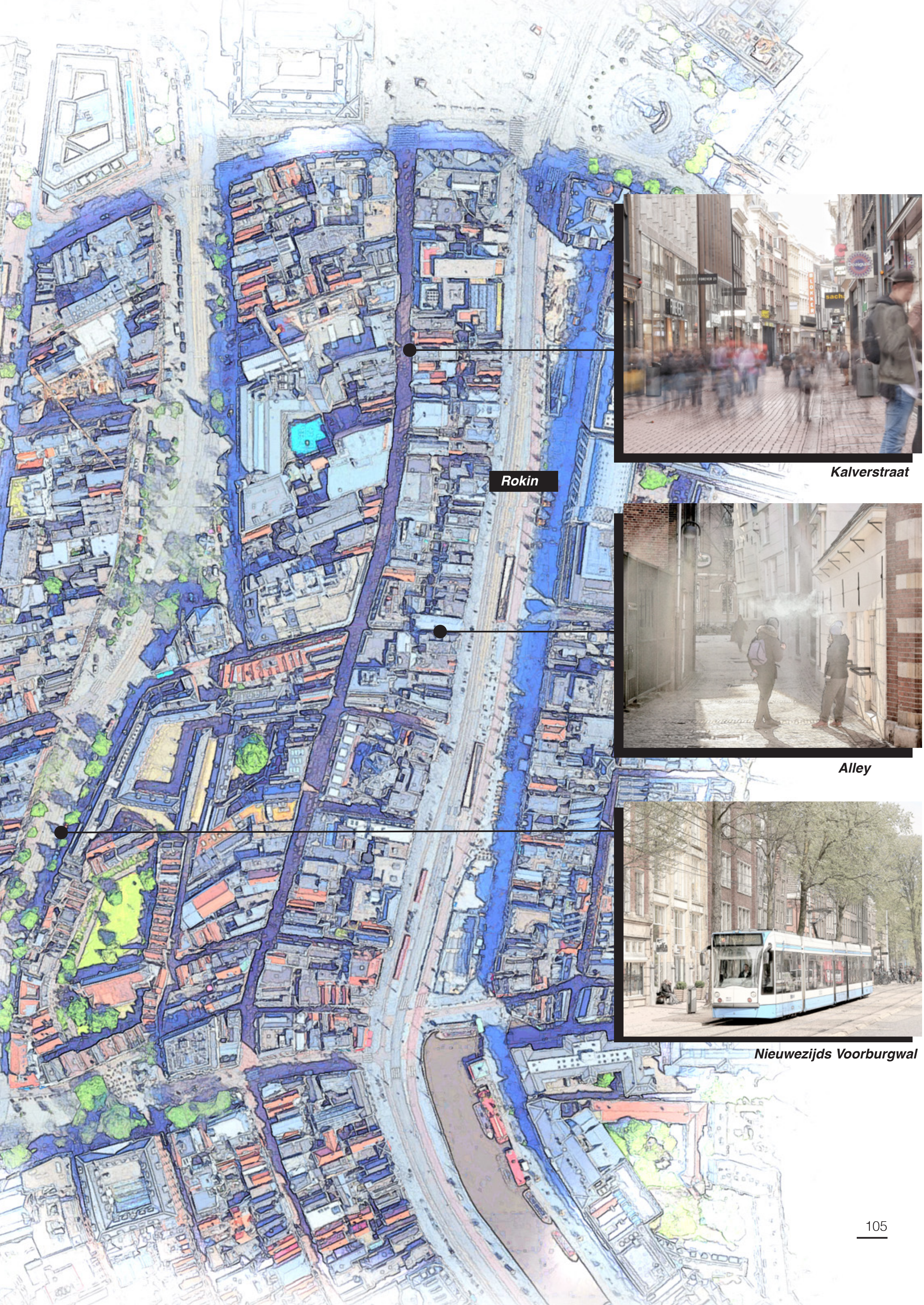
11.1 City centre, crowded streets and limited space

The city centre of Amsterdam is the area of Amsterdam with the highest building density. These neighbourhoods all have a GSI of 0,5 or higher, which means that more than 50% of the ground surface is occupied by buildings. However, within the city centre, buildings are not only used for living. Because of the high percentage of economic activities, these mixed use areas have a quiet low residential density (Gemeente Amsterdam, 2017c). In this way, the amount of waste produced (speaking of residential waste) is lower than expected than within this type of building density. The city centre is characterized by small alleys and buildings without gardens. A couple of larger streets cross through the city centre in a Nort-South direction which form the main infrastructure lines for cars and public transport trams. The Begijnhofbuurt, shown in figure 60, gives a good overview of these characteristics. The street Rokin forms a main artery facilitating car transport and public transport and. On the left, another infrastructural line, the Nieuwezijds Voorburgwal, shows the same characteristics. The neighbourhood is crossed by one of the most busy shopping streets of the Netherlands, the Kalverstraat. Both streets are connected by small alleys which cut through the densely build buildings.

Another trend which is visible in the city centre of Amsterdam is the increasing amount of tourist. Especially in the weekends, the streets described here, are crowded

▶ *Continuing page 106*

Figure 60 →
Begijnhofbuurt
The Begijnhofbuurt between Rokin and Nieuwezijds Voorburgwal. The busiest shopping street of the Netherlands, the Kalverstraat, splits the neighbourhood in two.
(Imap: Image by author, based on Google Earth; Photo's: Michael Nagel)


Rokin
Kalverstraat
Alley
Nieuwezijds Voorburgwal

11
Urban integration of waste collection infrastructure

by people. Sidewalks are packed and all tourist walk the same route (Poel & Boon, 2015). Because of these crowded streets, it is not favourable to use the limited amount of street space for waste collection infrastructure.

Currently, waste is collected through garbage bags on the street which shows that the municipality has no clue how any form of containers can be integrated within this urban form. When trying to reach that 65% separation rate, new infrastructure is needed to create possibilities to dispose residential waste separately.

The main challenge for these neighbourhoods can be stated as following:

The challenge for the city centre is to integrate some form of collection system, which does not claim precious moving space and provides more options for residents to dispose their waste separately.

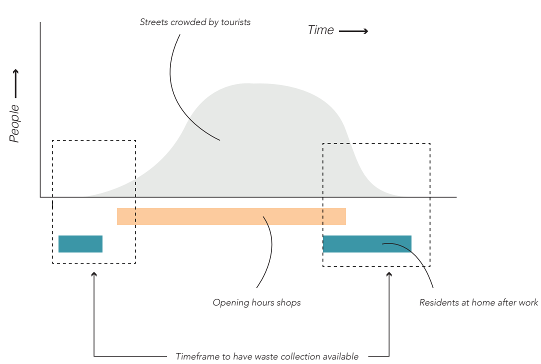


Figure 61

Using the time dimension to integrate waste collection infrastructure

The containers are only available in the early morning and after shop closing time. During the day, the space can be used for the tourists to stroll through the city

(Image by author)

Analyses

As described before, is the main challenge to integrate containers within this dense neighbourhood by trying to avoid to use space on the streets and sidewalks which should be left open for the overflow of tourist. The main streets are used for public transport and facilities (Rokin and Nieuwezijds Voorburgwal). In the centre lays one of the most busy shopping streets of the Netherlands, the Kalverstraat . The alleys which connect the main north-south axis, are one of the few spaces which are not used, however, they are too narrow for containers when still functioning as a route to cute through the neighbourhood. A clever solutions could be to integrate the containers

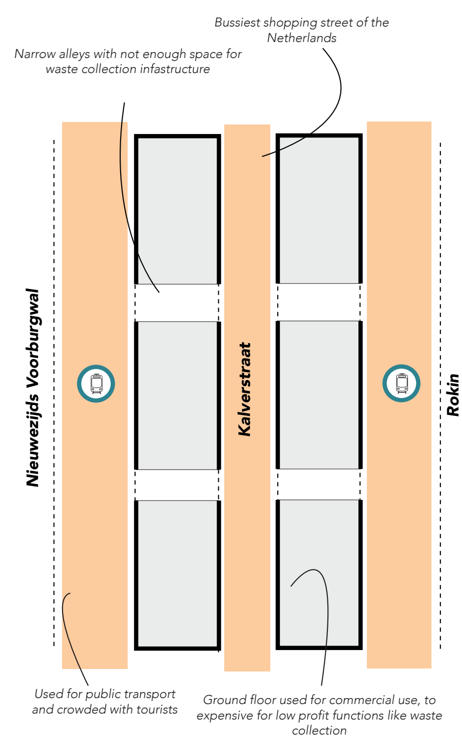


Figure 62

Analyses Begijnhofbuurt

Three main axis with adjacent commercial spaces. Limited space for waste collection infrastructure and to high value for waste collection integrated within buildings.

(Image by author)

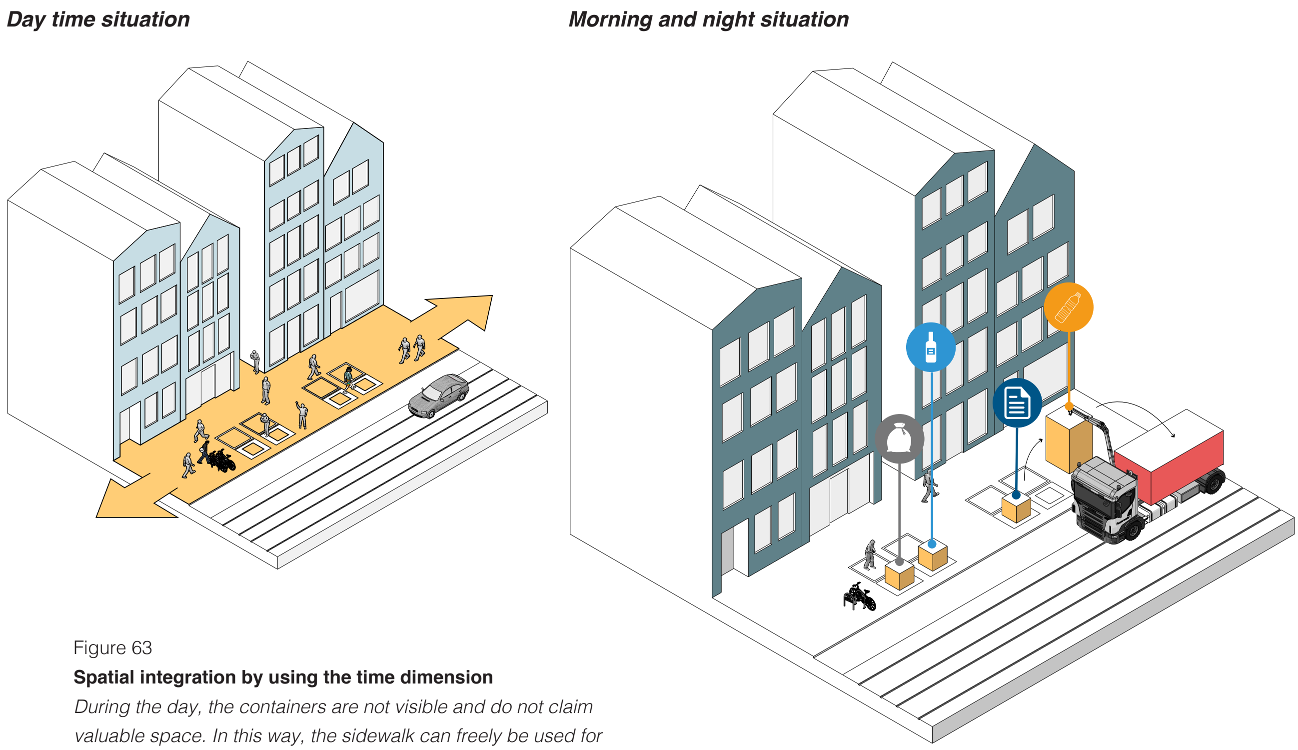


Figure 63
Spatial integration by using the time dimension
During the day, the containers are not visible and do not claim valuable space. In this way, the sidewalk can freely be used for all the pedestrians. During the night, when less people are on the street, the containers pop-up out of the ground. Residents coming home from work are now able to drop off their waste.
(Image by author)

within the buildings to save precious public space on the streets. However, this part of Amsterdam is on of the most beloved locations for economic activities to settle. This means that buildings are very expensive and it is hard to financially maintain a public (non profit making) facility (figure 62).

Proposal

When space is limited, other dimensions can be used. The streets are not crowded throughout the whole day. Residents at the same time, are also not home during the day because of their daily work routine. The crowdedness of tourist is mostly related to the opening hours of the shops. In the morning and evening, probably less people will be on the streets and it will be less problematic to sacrifice space for waste collection infrastructure.

A flexible system that can operate in the morning an evening can be a solution (figure 61). The proposal is inspired by underground toilets which raise out of the ground during the weekends. These toilets were placed within Amsterdam's night life districts to prevent urination on the streets. Only in the weekends the toilets are visible and available for residents and tourists enjoying the Amsterdam nightlife.

Such s system could also be applied with waste containers. The entry points of the waste container will only come up out of the ground when the shops are closed and residents are at home (figure 63).

2

11.2 Canal rings, using water instead of roads

Around the city centre the typical historic housing of Amsterdam appears along side its famous canals. The circular canals around the city centre form the lay out for the closed block housing which can be found within this urban form. These neighbourhoods are covered for 15%-20% by water and have an average GSI of 0,5 or higher. This leaves only limited space for waste collection infrastructure placed on the streets and sidewalks. Larger streets which host the public transport and shopping facilities, cross the canals perpendicular. The streets parallel to the canals are most of the time narrow one-way streets which even have to facilitate parking spaces. Figure 64 shows the van Loonbuurt from a top down perspective, which clearly shows the described spatial characteristics. The houses do have gardens, however, because of the closed blocks, the gardens can only be accessed through the front door, and for most houses, the ground level of the house is not at street level. This makes the gardens not suitable for having mini-containers.

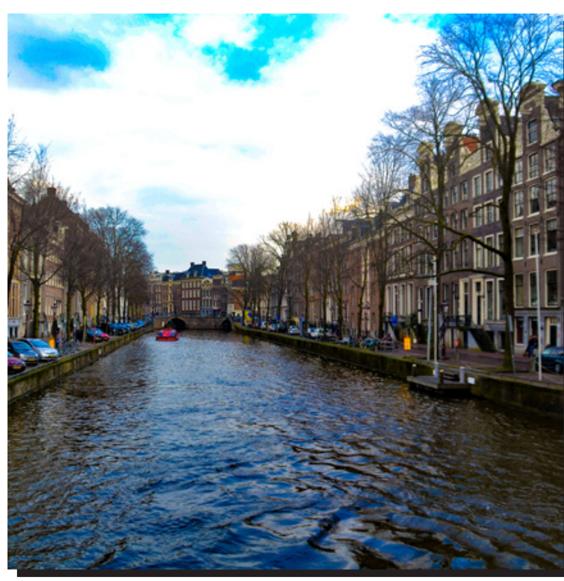
Within this urban form, the residential density is higher compared to the city centre. These neighbourhoods have mostly a residential function. That makes these areas a great challenge, since there is really limited space and a lot of residents which produce waste. Currently, similar to the city centre, no waste collection infrastructure in the form of separate containers is available in these neighbourhoods. Waste is mostly collected through the collection of garbage bags placed on the streets.

The challenge for the canal rings will be to integrate waste collection infrastructure in an area where almost no space is available within the streets. New solutions have to be found, especially because these neighbourhoods host a lot of residents and almost non of the waste is collected separately. A lot of improvement can be made.

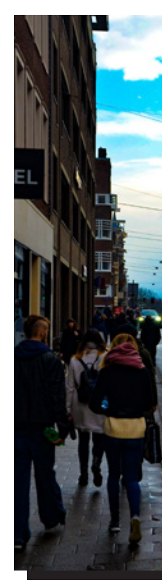
▶ *Continuing page 110*

Figure 64
Van Loonbuurt
The canal rings of Amsterdam (Herengracht, Keizersgracht and Prinsengracht) crossed by the Vijzelstraat
(Map: Image by author, based on Google Earth; Photo's: Twan Cortenraede)

Keizersgracht



Herengracht




Prinsengracht
Vijzelstraat

11
Urban integration of waste collection infrastructure

Analyses

The canals of Amsterdam have all a quite similar structure which will not allow waste collection infrastructure integrated within the street profile. The streets parallel to the canals are one-ways streets, including parking space and trees. Sidewalks are already minimized to just one meter wideness. The perpendicular streets are most of the time the more busy streets which host the public transport, multiple functions and economic activities. It is preferred to keep these streets as open as possible since of the large amount of functions and movement in these streets (figure 65). A new location for waste collection infrastructure has to be thought of compared to the conventional street container. These types of neighbourhoods are of course characterized by the water and its canals. The solution maybe the restoration of the historical use of these canals, which was the transport of goods through the city. Just a small change is needed to use the canals as waste collection and transportation infrastructure for Amsterdam.

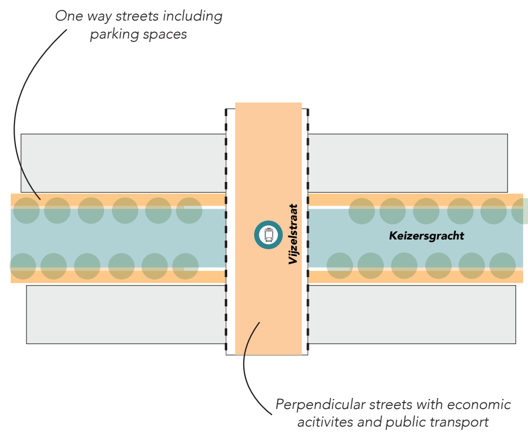


Figure 65
Structure canal ring neighbourhoods
(Image by author)

Proposal

Within the canal structure, some space is unused and could be used for waste collection infrastructure. The areas around the bridges are not used for car parking. The street rises at this point from around 0,8m above the water to 2,4m because of the height of the bridges. These locations are ideal to create some kind of waste point at the water (figure 66). The crossing at the bridges are also the ideal locations for placing these waste points. People are most likely to move towards the perpendicular axes where most activities take place and public transport is situated. These streets are also the most busy cycling routes (Gemeente Amsterdam, 2017b). It is most likely that residents pass by these points every day, which makes it easy to dispose their waste (figure 67).

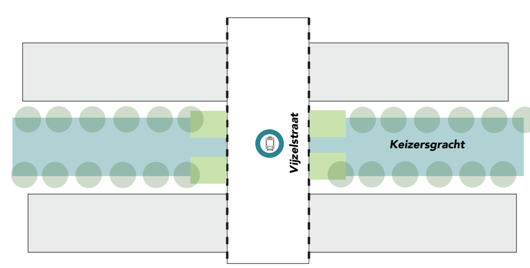


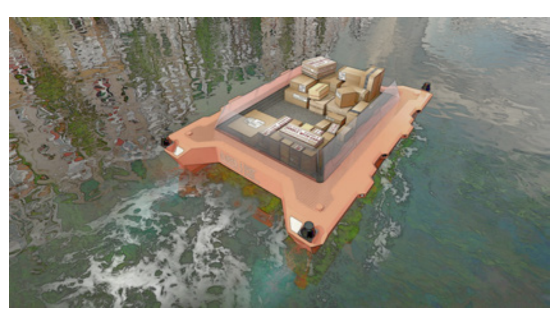
Figure 66
Location of proposed water based waste stations near bridges
(Image by author)

By making use of the water the connection with another technological research program can be made. AMS (Advanced Metropolitan Solutions) and MIT (Massachusetts Institute of Technology) are working

Figure 67
Location of water waste stations.
Showing the perfect locations for the water waste stations. Preferred locations are at cycling routes, crossings with public transport and commercial streets. Not all canals may be suitable since of the water activity by tour boats.
(Image by author)

together on the project Roboat, which focusses on the creation of autonomous floating vessels which can be used for the transpiration of people, goods and even waste (AMS, n.d.). This integration proposal could contribute to this more technological driven research project by focusing on the spatial integration and usage of the system. It provides ideas on how these vessels could be used for collecting waste in dense urban areas.

Roboat
(AMS Institute)



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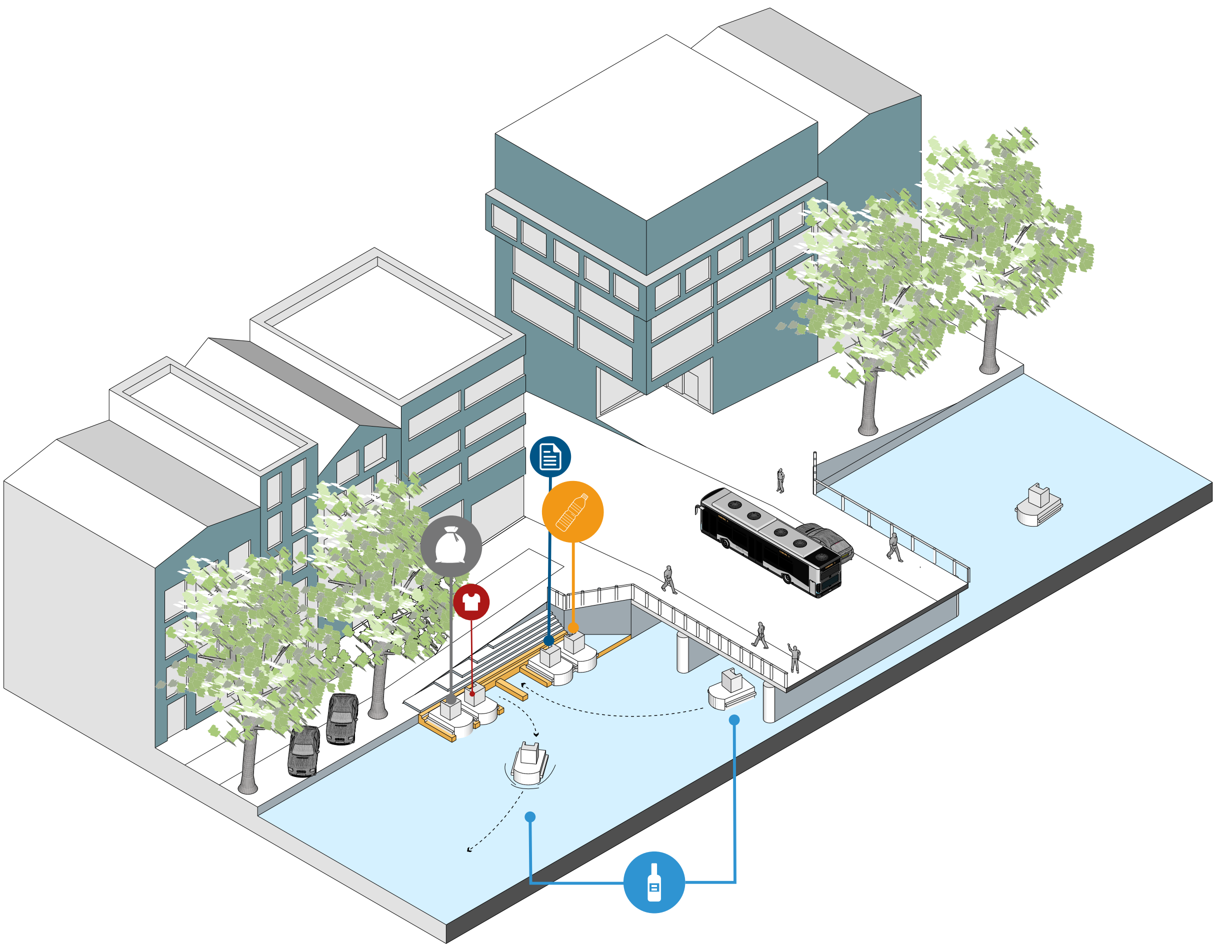
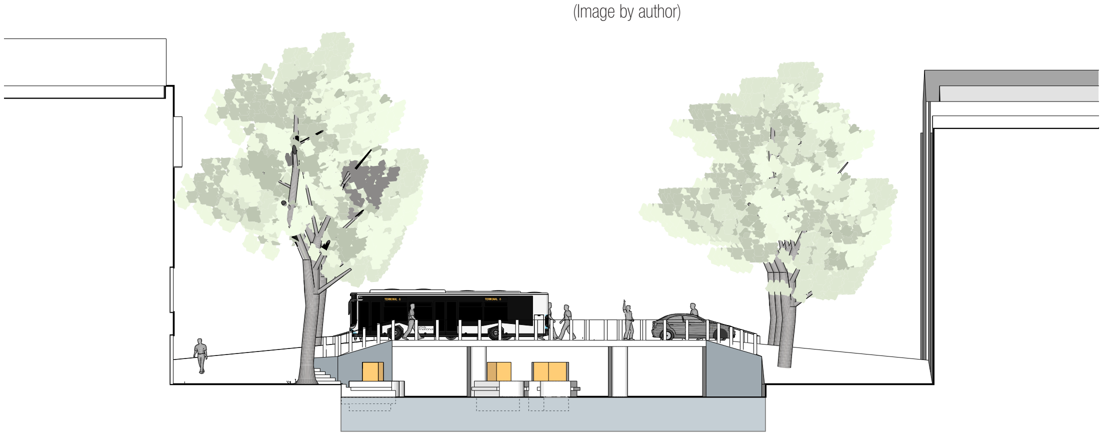


Figure 68

Automated floating waste vessels

A pontoon can be attached to the cay where waste container vessels are able to moor. Since they are autonomous, new waste containers automatically appear when a vessel is full. In this way, the collection can be very efficiently and there will be no problems with full containers

(Image by author)



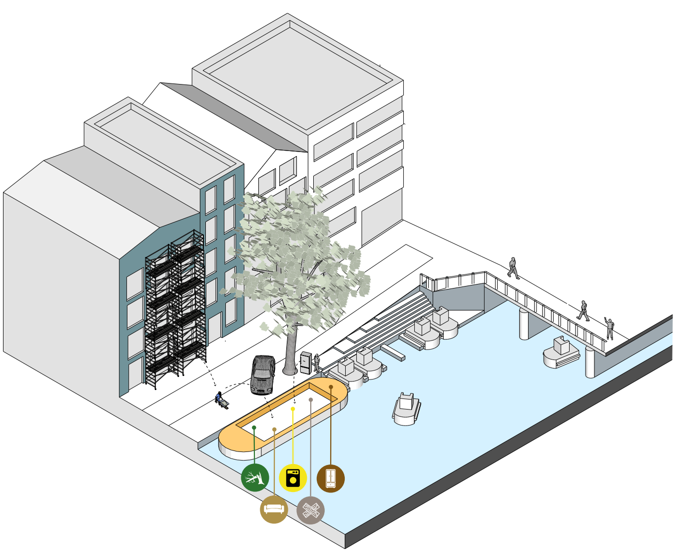


Figure 69

Disposal of bulky waste through water containers

Larger products, which are now collected via waste trucks could be collected via larger waste vessels. It gives also the possibility to collect the product without losing value. These containers could also be a solution for waste production during renovation projects of the house or garden.

(Image by author)

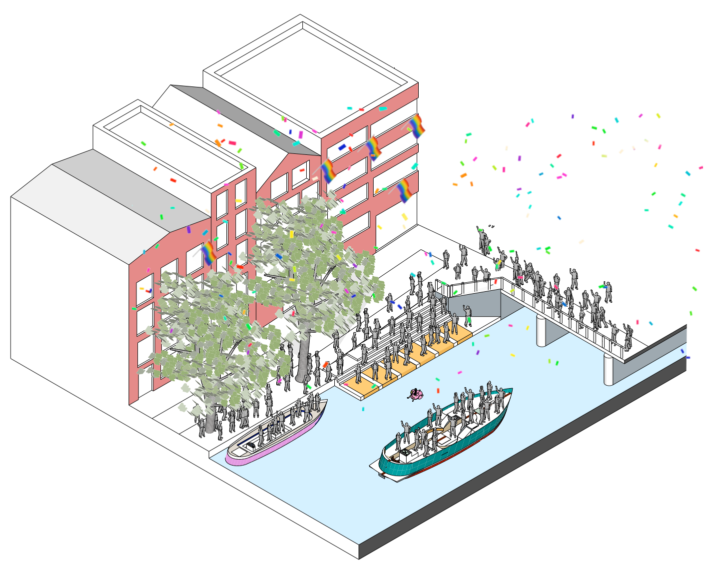


Figure 70

Changing functions, gay pride

During large events like the annual gay pride, the pontoons could be used as save tribunes to party and watch the boat parade. When the event is over, the automated vessels will change the pontoon again into a water waste station

(Image by author)

Design and functioning

The design of these water based waste stations should be simple and flexible. By attaching a pontoon to the quay it becomes possible for the autonomous vessels to moor. When the containers are full, a new waste vessel will automatically arrive at the pontoon, replacing the filled up vessel (figure 68). This full vessel can navigate to the waste treatment facility or waste transfer station. By using the water infrastructure as a transport mode, less trucks are needed for waste transportation in the city centre. The vessels are more environmental friendly and because of its autonomous functioning, it can operate very efficient.

The water waste station system also has a high flexibility. Pontoons can be moved around the city and placed at locations where for a shorter period of time high volumes of waste are expected. Also the configuration of the pontoon can easily be changed. Different waste types and their related containers can be added or removed from the pontoon. The pontoons are not only usable for waste collection via containers. At the moment, bulky waste is picked-up at home after an appointment has been made. This system can now also happen via the water by navigating larger containers to nearby located pontoons. This function could also be helpful when renovating your house or doing a large garden clean-up for summer. People can reserve a vessel for a particular type of waste and have it stationed in front of their house for a longer period of time (figure 69). Another option could be the removal of the containers with big events along side the canal. For instance during the annual gay pride when hundreds of thousands of people gather around the canals to watch the party boats. To provide more space for the watching people, the pontoon could be transformed in a floating deck (figure 70).

These examples show how such a system can adapt to fluctuating waste volumes and types. Waste collection can become more precise and adjusted to the residents needs.

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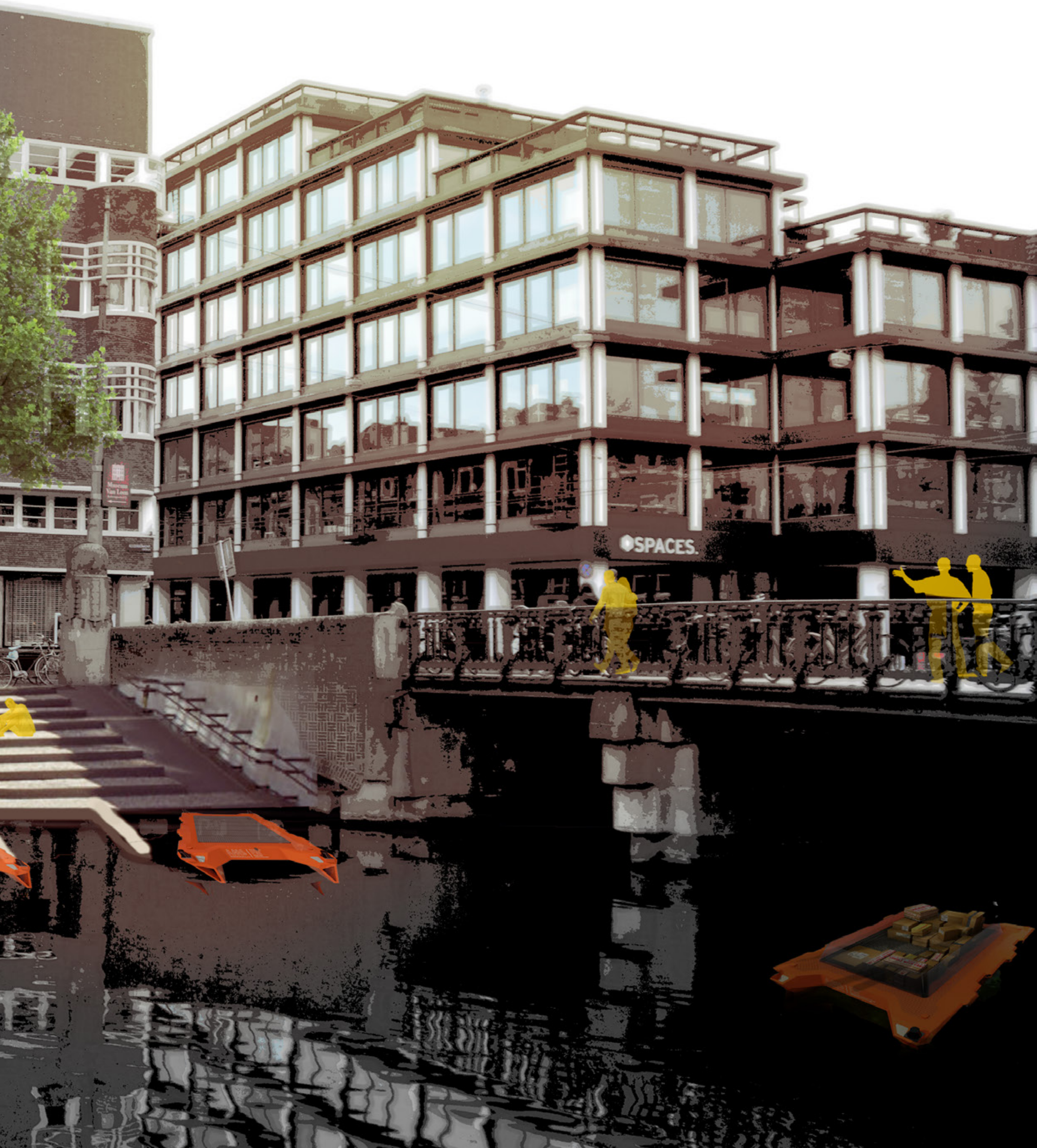
Urban integration of waste collection infrastructure


SPACES.

3

11.3 Reconfiguring the current collection infrastructure

The rest of the city within the highway ring (except for Amsterdam North) is characterized by closed block housing. Figure 71, shows the Indische buurt in Amsterdam Oost, which is an example of this type of housing. The building density has become a bit lower compared to the two urban forms discussed before. Most of the houses consist of upper and lower housing, which means one residency is placed on street level and another one on top. Streets are wider and even inner courtyards and gardens are visible. This less dense urban form gives more opportunities to integrate waste collection infrastructure. This fact is advantageous since these neighbourhoods have the highest residential density which results in a lot of waste per square kilometre. The streets are mostly occupied by public transport and car infrastructure. This makes these areas more flexible, since reconfiguration options of the street profiles are possible. Within these areas, a lot of waste collection containers are already placed within the neighbourhood. It means that already a smart reconfiguration on the current available infrastructure can be solution. These reconfigurations can be accompanied with design solutions to encourage waste separation among residents.

Within these types of neighbourhood it is the most important to place and integrate the waste collection infrastructure in such a way that residents are able to separate their waste with minimum effort. These residents have just small living spaces and are not able to store a lot of waste within their homes. Easy and smart placed drop-off points are the main challenge over here.

▶ *Continuing page 119*

Figure 71
Indische buurt, Amsterdam
(Map: Image by author, based on Google Earth; Photo's: Twan Cortenraede)

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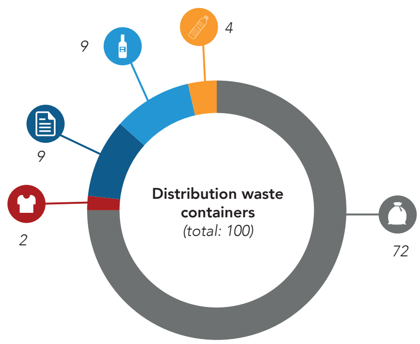
Urban integration of waste collection infrastructure



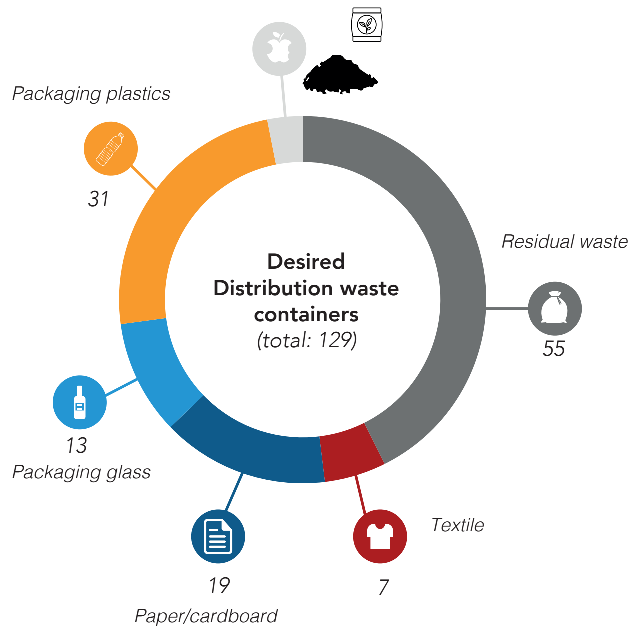


Figure 72

Actual and desired distribution of street containers within this neighbourhood

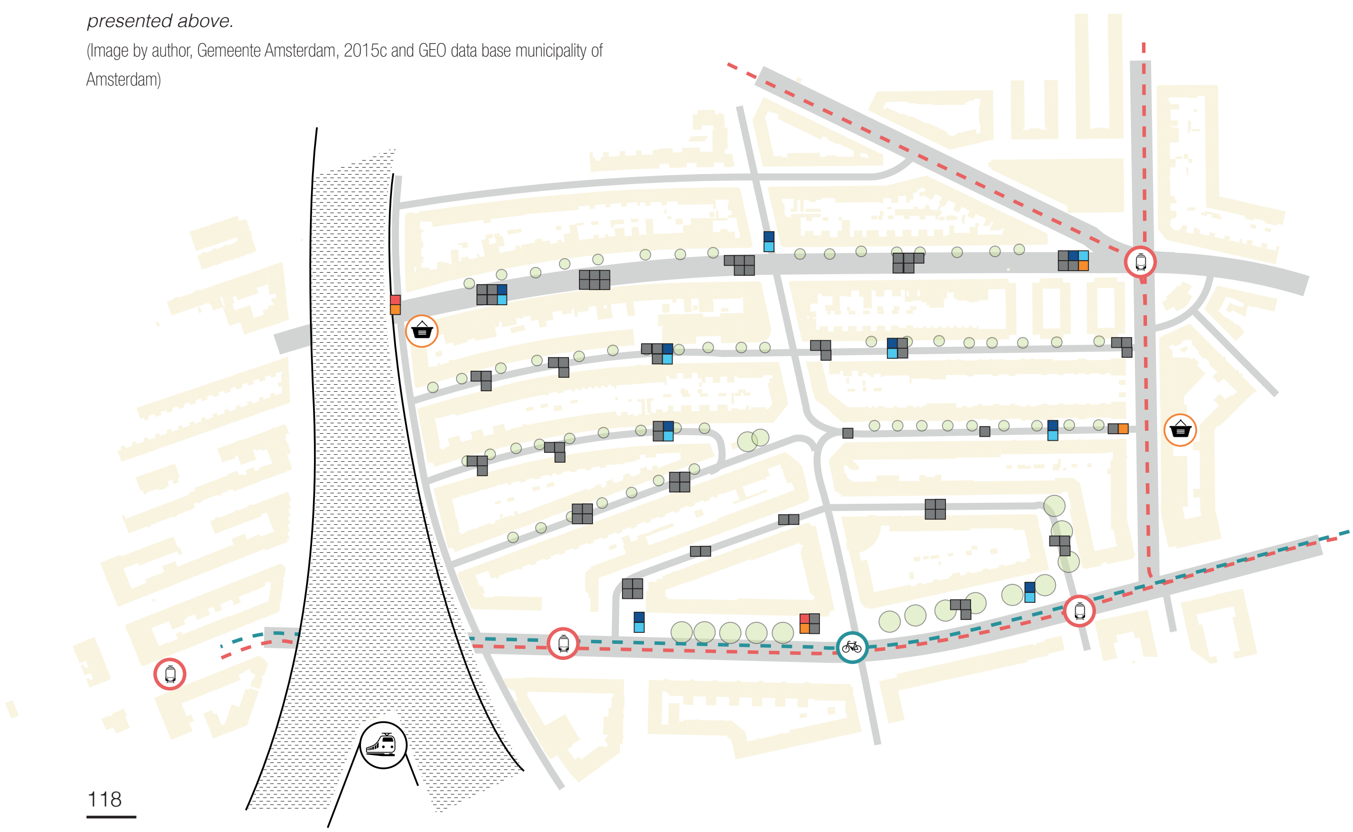
(Image by author, Gemeente Amsterdam, 2015c)

Figure 73

Distribution of waste containers throughout the Indische Buurt

The location of the containers might differ slightly from the actual situation. This is due the usage of GIS data from the maps data bank of the municipality which is not fully up-to-date. The colour of the cube is connected to the colour of the waste flows presented above.

(Image by author, Gemeente Amsterdam, 2015c and GEO data base municipality of Amsterdam)



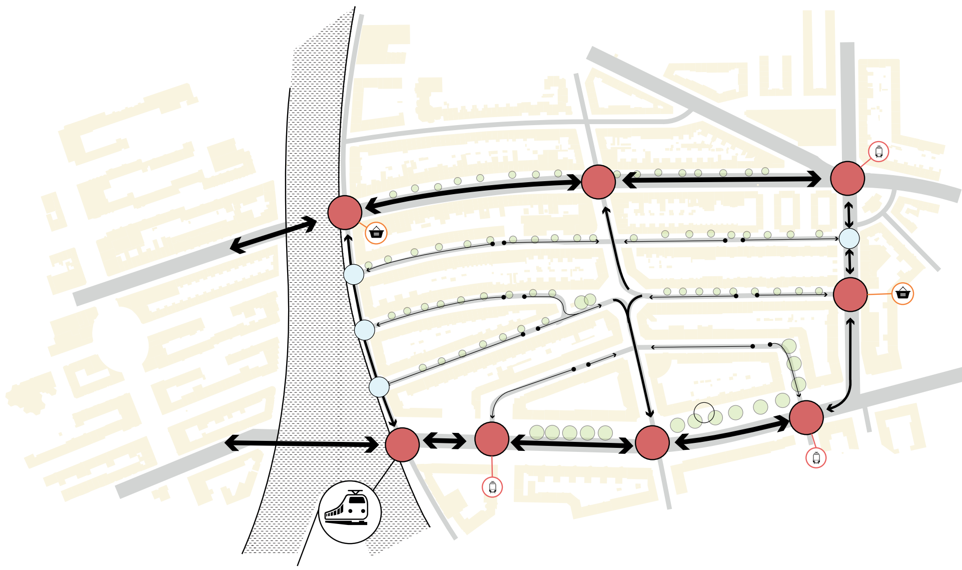


Figure 74
Locations where residents exit their neighbourhood and where they are attracted to
The explanation of the colours and size of the locations can be found in figure 75 (next page).
(Image by author)

Analyses
For the analyses and proposal we focus on the Noordwestkwadrant Indische buurt Zuid in Amsterdam Oost. As already described, do these types of neighbourhoods already have a extended system of waste containers integrated within the urban fabric. The integration itself is not the real challenge, however, the distribution and allocation of the containers can be improved. As described before a strong focus is visible on residual waste containers throughout Amsterdam. This focus has to shift to a better distribution of specific waste type containers. In the Indische buurt we can clearly see this residual waste container dominance (figure 72).

As described in chapter 9.2 (figure 51), a reconfiguration of the current infrastructure has to happen. When applying the same calculations a new desired distribution of waste containers becomes visible. This gives an estimation on how many containers for every waste flow are needed in the area (figure 72). Biowaste will not be collected through street containers. Since in this area no mini-containers can be provided at home, local composting should be the way to treat this waste flow locally.

Currently, the waste containers are placed throughout the neighbourhoods and also within the smaller residential streets (figure 73). These streets are packed with car parking, cycling parking and are totally paved. Just a few trees green up the city profile. These almost fully paved neighbourhoods are vulnerable regarding changes caused by climate change. These neighbourhoods are more likely to be affected by the urban heat effect or chances of flooding during heavy rainfall (Het parool, 2013 September 30). Creating space in these streets by removing the waste collection infrastructure creates more space for adapting to these new circumstances.

Proposal
The goal is to reduce the amount of residual street containers and replace them with containers collecting the other homogeneous waste types. The most important thing is to place those containers at recognizable locations where the residents living in the block pass by daily. These locations can be determined by looking into the movement patterns. All the residents have the leave the block to move to activities to sustain their daily lives. By looking into these activities, the movement patterns can determined. In figure 73 these activities are visualized. Locations people are attracted to daily are supermarkets, public transport or they make use of important cycling routes.

▶ *Continuing page 120*

11
Urban integration of waste collection infrastructure

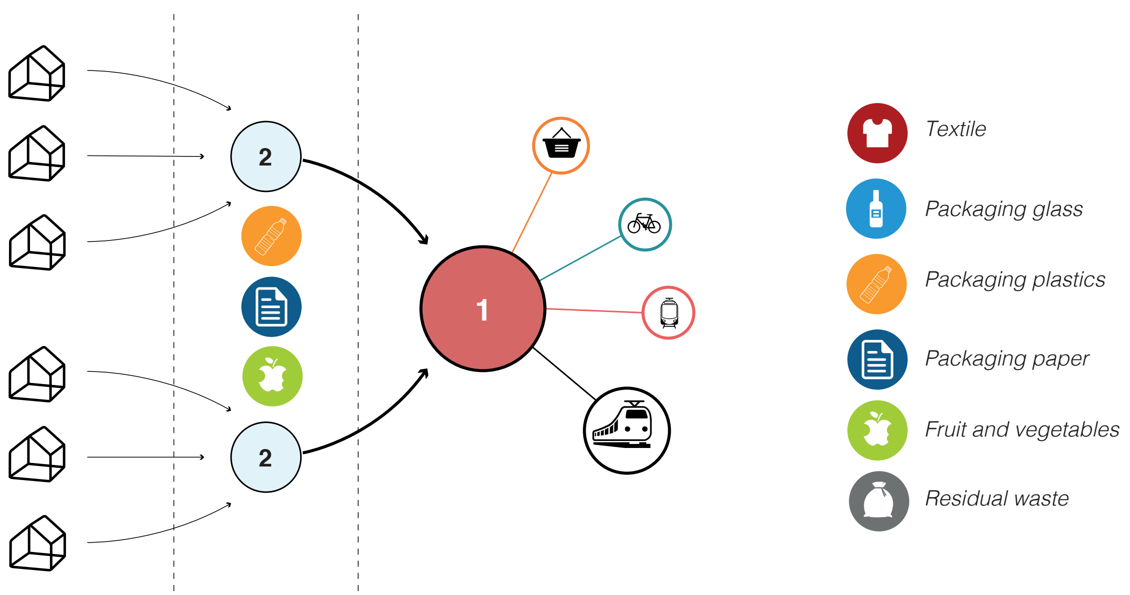
The ideal locations to place new waste collection points is at those points where it is most likely the residents exit the neighbourhood. These locations are visualized in figure 74. There are two different types of locations which are based on the fact how many people are likely to pass by. At the different locations, different types of waste will be collected. An explanation of these locations can be found in figure 75.

Figure 75
Different waste containers at different locations
There is a difference in needed waste containers per waste flow. Not at every location collection infrastructure for every waste flow has to be present. This means that there are two types of locations. At type 1, most of the residents pass by because of they connect to a certain activity, or because at these points routes and streets come together. Location 2 are the ones where only the residents of a certain street or block pass by daily. At these locations only the most important and largest waste flows are collected. At the number one locations, all the waste flows can be disposed. In this way, the preference is also given to homogeneous waste flows instead of residual waste
(Image by author)

As stated in chapter 9.2, this new waste collection points should become recognizable points where waste can be recycled. They will be a combination of conventional containers and local biowaste composting. According to the needs of residents, other waste types could be added.

Design and functioning

Figure 76 shows how such a waste collection point could like. It is positioned at the end of the street. It is a collection of containers and there is the possibility to dispose biowaste in a composting unit. Space is left over to make it possible to add waste collection infrastructures. This could also be infrastructures to dispose other waste types, like batteries or other small household waste. At his location, no residual waste containers are placed. These are only placed at the locations explained in figure 75. In this way, it becomes more easy to dispose separate waste flows and harder to dispose residual waste. This will stimulate residents to change their waste disposal behaviour.



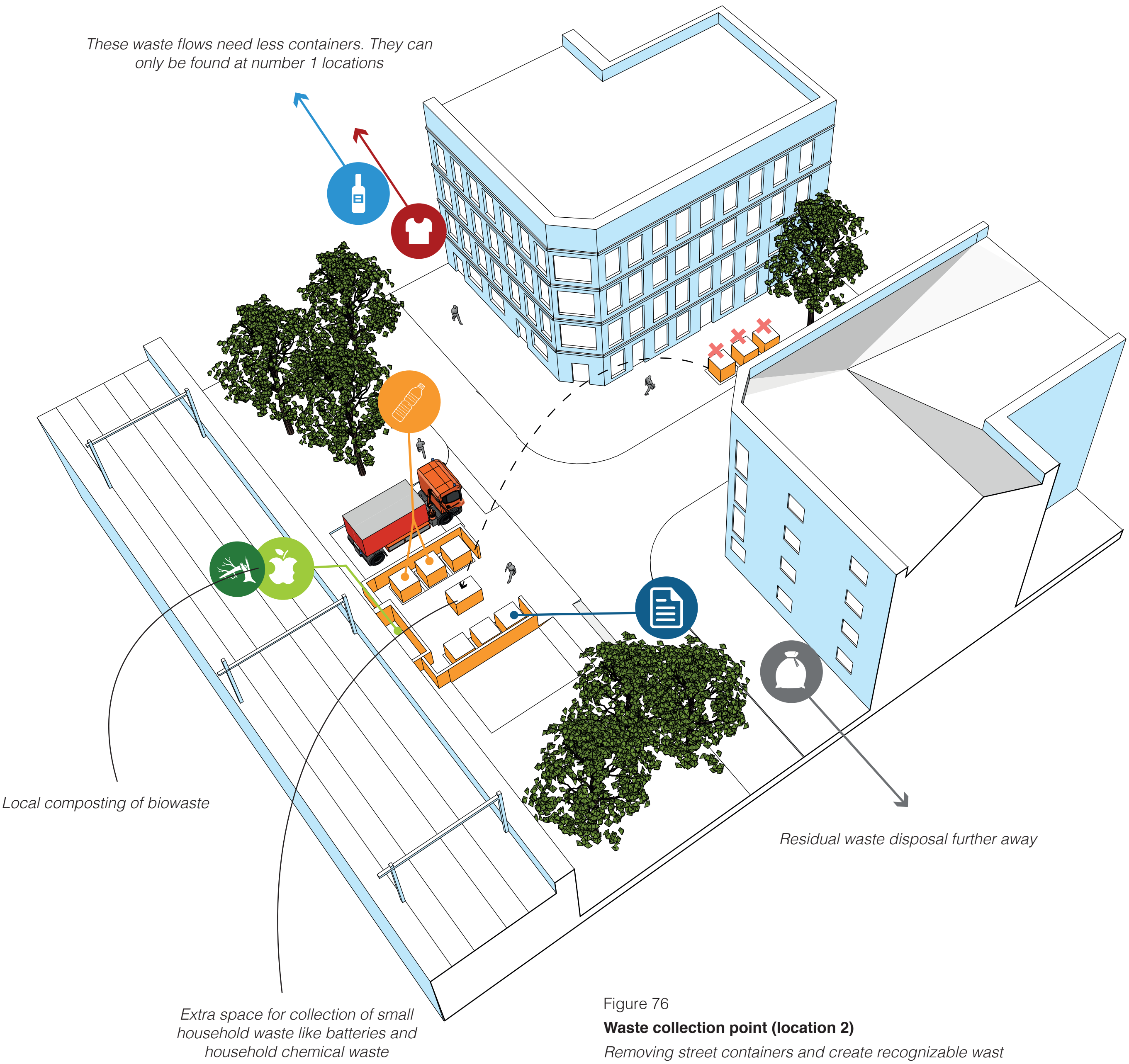


Figure 76

Waste collection point (location 2)

Removing street containers and create recognizable wast collection points at the border of the neighbourhood.

(Image by author)

4

11.4 Five story flats, expanding waste points

After World War 2, Amsterdam was expanding fast and was in need of a lot of new housing. In a short amount of time, a lot of new neighbourhoods were created from a modernist perspective. The fourth urban form of Amsterdam addresses these typical five story flats. The map showing al the categories (figure 59) also include new apartment buildings. In this chapter the older, modernist neighbourhoods will be addressed. Nevertheless, proposals for these types of neighbourhoods could also be applied within in the new apartment development areas. Buurt 2, in Amsterdam Nieuw-West is one of those neighbourhoods (figure 77). The neighbourhoods are categorised by old five story flats separated by green spaces. During the time after the war, most the houses that were build were for social rent. This fact created neighbourhoods where nowadays unemployment rates are the highest in Netherlands. Next to that are income levels low and most of the residents are from a non western ethnic background (Gemeente Amsterdam, 2017d). Because of these characteristics these neighbourhoods are most of the time labelled as problematic.

When walking trough the neighbourhood, the challenge concerning the waste containers are similar to the previous described neighbourhood. The containers are present, however, there should be more available and less focussed on just residual waste. There is enough space available for conventional street containers placed on the sidewalks. A reconfiguration of the present infrastructure could already improve the possibilities to dispose waste separately.

These types of neighbourhoods are also characterized by the designated locations to place bulky waste on the side walks. In some areas in Amsterdam Nieuw-West, bulky waste is even collected every week (Gemeente Amsterdam, 2015c). This way of collection results in a high loss of value, since all the different types of waste are collected together and products are broken down within a waste truck. Besides the loss of value, does it also result in a low valuation by the residents of the public space. In the next part, these problems will be discussed further.

These modernist neighbourhoods ask for a reconfiguration of the current collection infrastructure and a new method to collect bulky waste, without loosing value and degrading public space.

▶ *Continuing page 124*

Figure 77
Buurt 2, Amsterdam Nieuw-west
(Map: Image by author, based on Google Earth; Photo's: Twan Cortenraede)


Dobbe Kamer
1

11
Urban integration of waste collection infrastructure

Analyses

In Amsterdam, only 33% of the bulky waste, like electronic appliances and furniture, is dropped off by the residents themselves at one of the six waste points (Gemeente Amsterdam, 2015c). In city districts like Amsterdam Nieuw-west, these types of waste can be placed at designated area and it is picked up every week. This way of waste collection does have its downsides. Within the neighbourhood, a lot of residents rate the condition of the street scenery only with a 5.4 out of 10. Next to that, is the bulky waste presented a lot of times on wrong places or not at the right time. This results in nuisance in the form of rats or waste being dumped in the public green (Gemeente Amsterdam, 2017d).

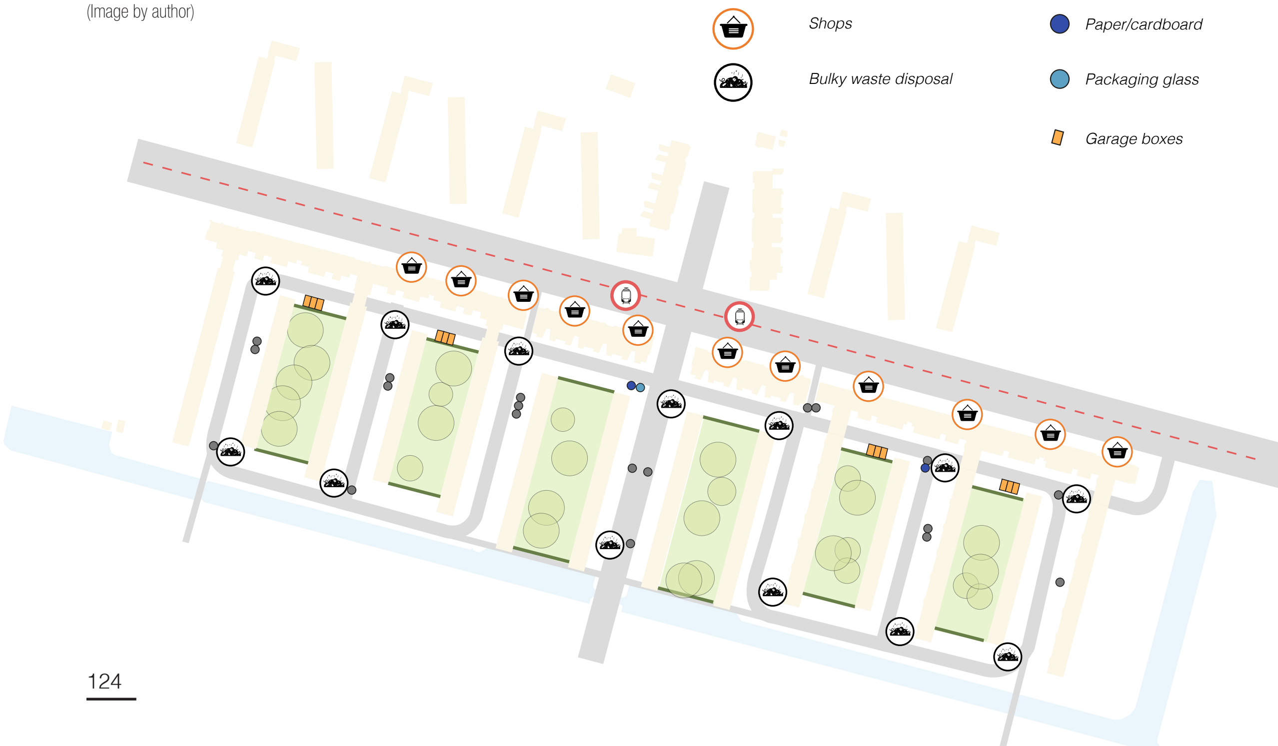
As described in chapter 9.2, it is important the collect these waste types with a minimum loss of value. When the valuable waste is dumped on the street, damaged and transported in waste trucks, value will be lost. A new method should be developed to reduce the nuisance in the public space and to preserve value.

The chosen modernist neighbourhoods all have a quiet similar structure. Five story flats are separated by large (mostly unused) green areas (figure 78). Another feature which is characteristic for these areas are the garage boxes placed at every housing block. Currently, these garage boxes are used by residents, however, some are already being transformed for public use. For instance, a garage boxes at the Theodorus Dobbestraat are transformed in a neighbourhood centre where multiple activities can take place. These garage boxes may be a perfect solution to facilitate a more valuable waste collection method which does not affect the public space.

Figure 78

Current situation Buurt 2 ,Amsterdam Nieuw-West

(Image by author)



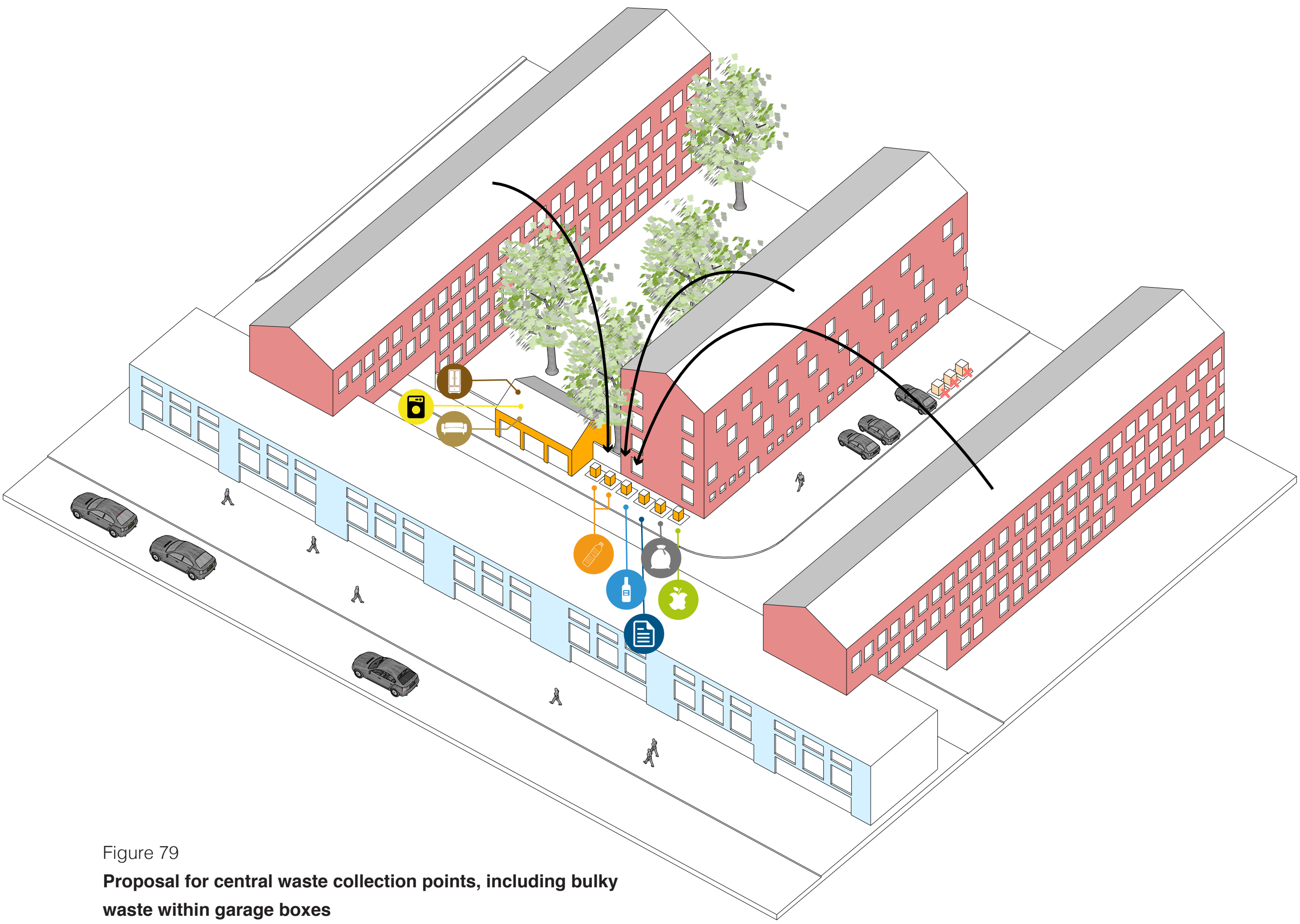


Figure 79

Proposal for central waste collection points, including bulky waste within garage boxes

(Image by author)

Proposal

Like the previous proposal in the 'Indische buurt' (chapter 11.3), recognizable waste collection stations have to be created. However, in these types of neighbourhood these location will not only include streetcontainers and biowaste composting locations. To deal with the problems concerning the collection of bulky waste, electronic appliances and furniture, indoor location facilities have to be added (figure 79).

As described in the previous part, do most of these neighbourhoods have certain amount of garage boxes separated from the building blocks. Some of these garage boxes are already being used for other activities (figure 77, picture 1). The decision can be made to use a number of these garage boxes for the collection of these periodically disposed waste flows. In this way, the collection will not happen within the streets, which will reduce the disturbances and pollution. The second advantage is that the products can be stored and eventually collected without loosing value.

These collection points give as well the possibility to collect waste in certain clusters, which makes monitoring more easy (explained in next pharagraph. There are even possibilities to expand these types of collection points in the local treatment facilities. This proposal will be discussed in chapter 12.2.2.

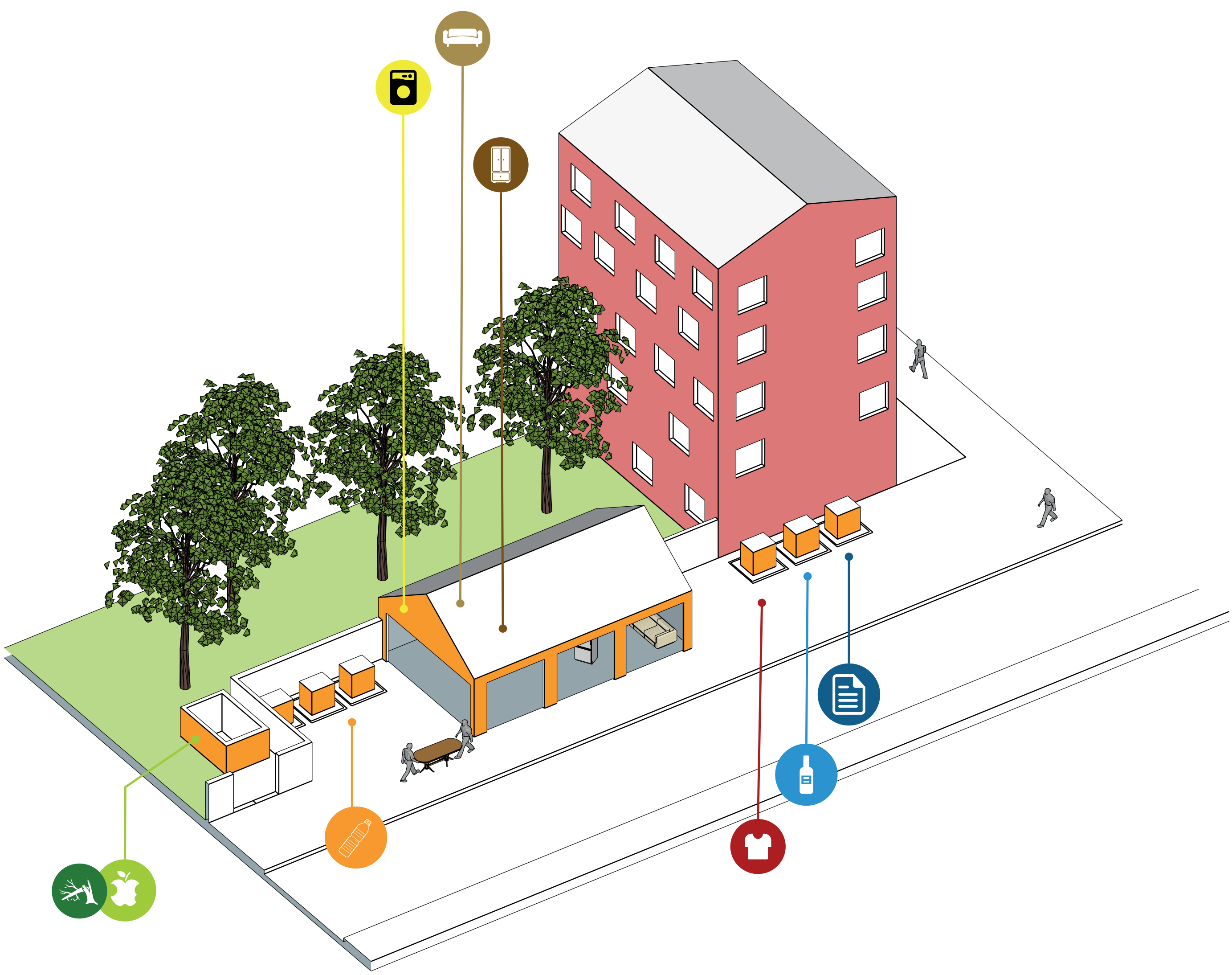
▶ *Continuing page 127*

11
Urban integration of waste collection infrastructure

Figure 80

Waste collection station with indoor collection of bulky waste

(Image by author)



Design and functioning

The transformed garage boxes have now turned into recognizable waste collection points (figure 80). Products can be stored indoor and daily waste separation happens at one location. The garage box should be available for a certain amount of blocks. In this way, every neighbourhood has its own location where products can be disposed.
It becomes possible to monitor these waste flows and feedback can be given to the residents.

These waste points should have a certain form of management and control. The best way to organize these waste collection points is by making residents themselves responsible for an improved waste collection. Volunteers from the neighbourhoods can become in charge. When these are not available other solutions can be found.
An option could be to oblige residents which are in possession of an alimony to run the waste station a few days a week. Decisions could also be made to open up the waste collection points only during the weekends or by appointment to reduce the costs of management. An important fact is to let residents be aware of the valuable goods that are stored within the garage box. By opening up the garage box and creating some kind of shop windows, residents are able to see the products and even considering buying them. In this way, the garage box does not just serve as a collection and storage point, it already tries to close loops within the neighbourhood.

Another option could be to link the waste point to already existing urban systems. An example could be to link a certain waste collection point to an already existent thrift shop. The garage box becomes in this way a collection point and storage unit for this particular thrift shop. The connection to other urban systems and adding functions to these garage boxes will be discussed in chapter 12.2.2. These locations have the potential to become local circular treatment facilities where loops are closed within neighbourhoods.

5

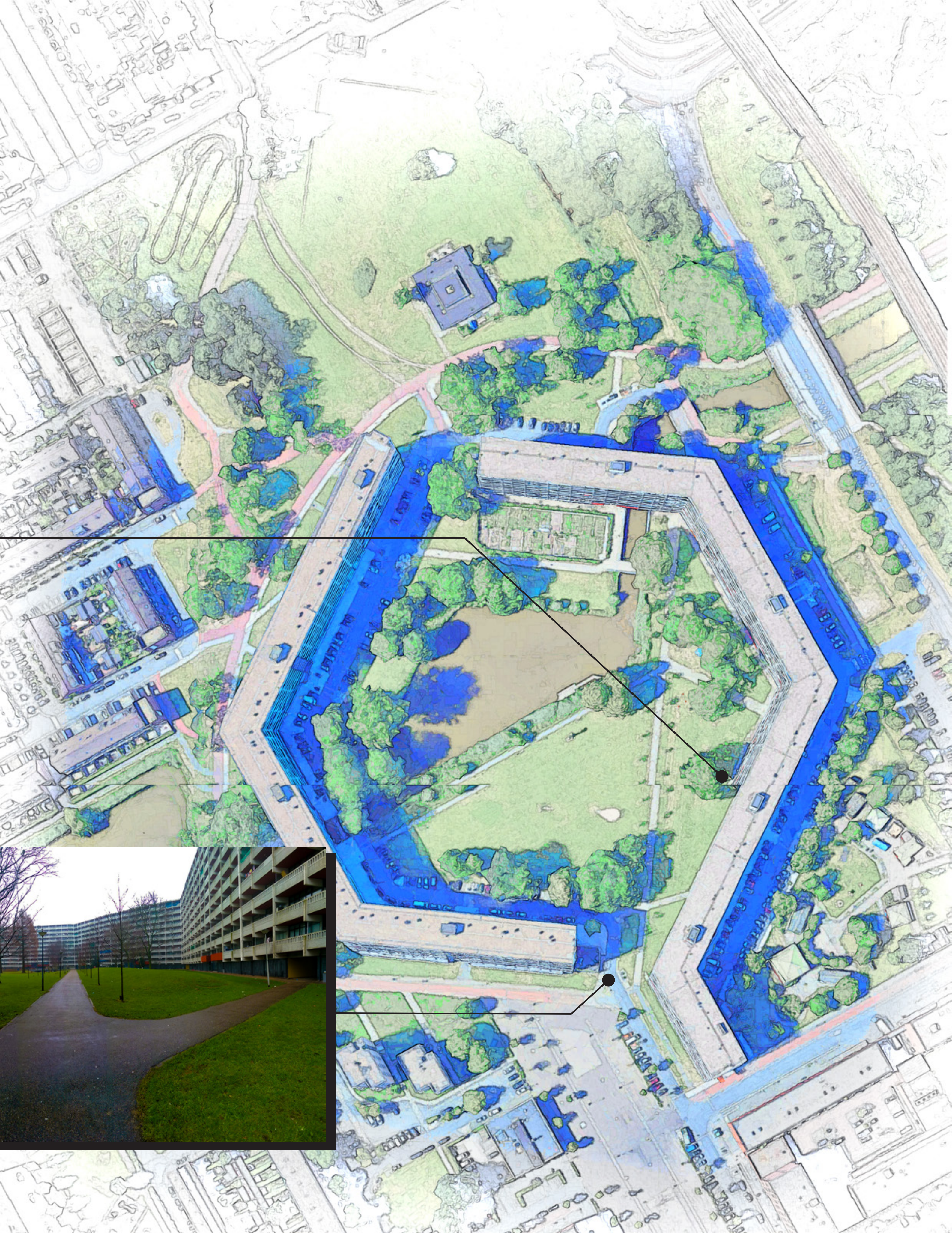
11.5 High rise, waste collection included in architecture

Another legacy from the post war modernist period are the high rise buildings in the south east of Amsterdam. The high rise from the modernistic period do have the same characteristics compared to the five story flats discussed in the previous chapter. Here, these older high rise buildings are discussed, however, the in the end given proposals are recommendations for newly build high rise as well.

Since the spatial characteristics of these types of neighbourhoods are quite similar to the previous discussed, the same principles can be applied. However, since the building blocks are larger, there are options to integrate all the proposed waste collection inside the building. In this way the waste collection is completely removed from the public space. This will result in less waste nuisance and it becomes possible to monitor the exact waste generation of one building block. How this waste collection infrastructure can be integrated in the building will be discussed on the next page. As a case study area, the neighbourhood Gravestein will be used situated in the south east of Amsterdam (figure 81).

▶ *Continuing page 130*

Figure 81
Gravestein, Amsterdam
(Map: Image by author, based on Google Earth; Photo's: Twan Cortenraede)



11
Urban integration of waste collection infrastructure

Proposal

In the case of high rise buildings, possibilities arise to integrate waste collection infrastructure within the building. High rise buildings result in a spatial concentration of waste, which means this more expensive integrated collection infrastructure in the building can still be profitable.

There is of course a difference in already existing high rise buildings and ones that still need to be build. Within newly constructed buildings the waste collection infrastructure can be integrated within the construction of the building. When it concerns an already existing building, adjustments to the building structure will be expensive and hard to realize. That is why two proposals will be discussed (figure 82.) The first one relates to the already existing modernist high rise present in Amsterdam. These modernist high rise buildings have the same structure compared to the previous discussed five story flats. The high rise are characterized by the garage boxes situated on the ground floor. Because of these garage boxes, the ground floor has not a lively character and the building detaches itself from its surroundings. These garage boxes can as well be used for waste collection following the principles from the previous chapter. However, since we are talking here about a big mass and more available space, the complete waste collection could be integrated within the building. In this way, the high rise can be compartmentalized and next to the entrances, waste collection stations can be integrated within the building.

Another option is a more expensive and technological driven proposal. Systems are already created which make it possible to dispose waste within a building via a network of pipes. In this way, the building can be compartmentalised per floor and waste can be disposed without the need to go to the ground floor. This proposal is more favourable for newly build high rise, since it can be taken into account during the design process. However, there are examples where this system is implemented within already existing buildings. In Singapore, a 40 block high rise neighbourhood is transformed into a green neighbourhood. Different projects, including collection systems in buildings will transform the neighbourhood in a sustainable way (Yo, 2015, July 5).

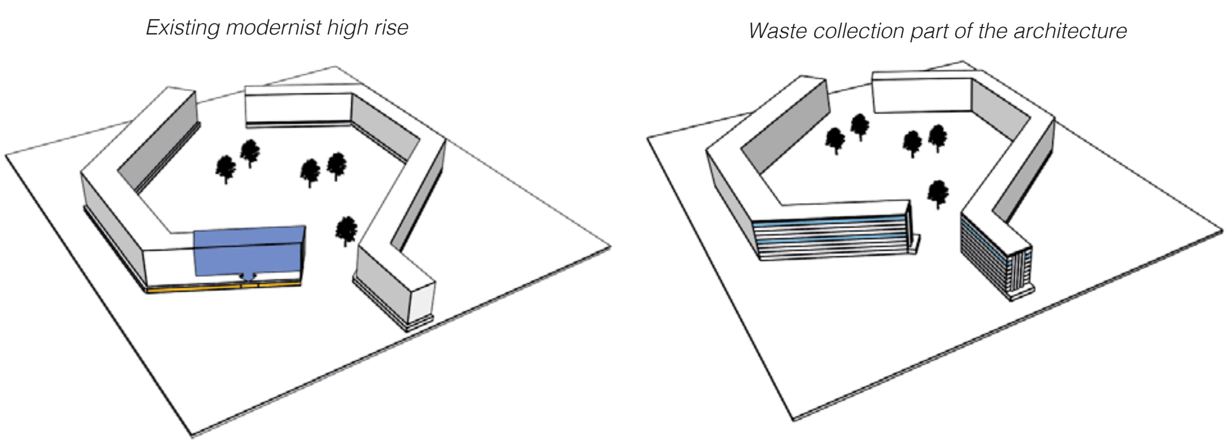
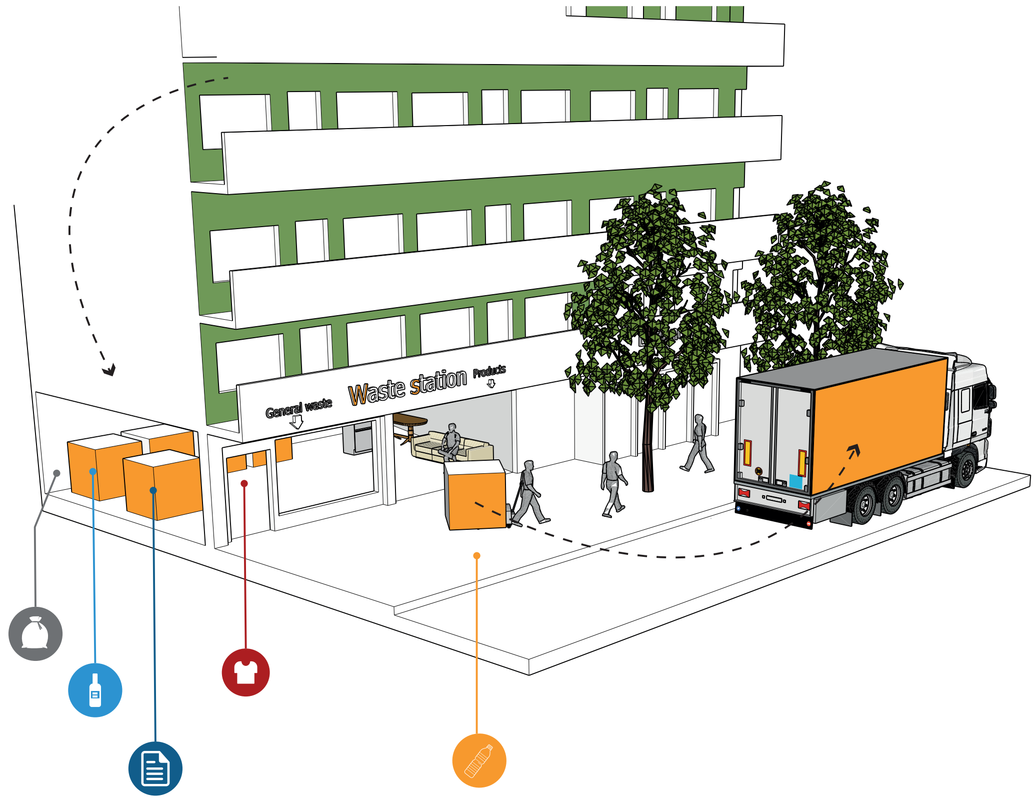


Figure 82
Two proposals for the integration of waste collection in buildings
Image by author)

Figure 83
Waste collection points, fully integrated within buildings
(Image by author)



Design and functioning
The focus of this thesis, is the integration of waste collection infrastructure in the existing build environment. For this reason, there is a preference for proposal one, since it connects to the current spatial characteristics (figure 83).

At the same time, is this probably a less expensive solution since it can be integrated within a building quite easily. With this proposal, not only daily disposed waste flows can be collected, it also makes the collection of bulky waste and products possible in the same way discussed in the previous chapter. The new waste collection stations are a addition to the neighbourhood and brings liveliness and activity to the ground floor. These waste collection points can be expanded ass well. They can become locations where products are being shared and where residents can help each other with repair and refurbishment of furniture and electronic appliances. Such a physical and clearly present point where waste related activities take place will help to increase awareness and change the residents behaviour.

This collection in clusters creates possibilities to monitor waste disposal quite precisely. Data of improving collection rates and reducing waste can be reported back to the residents of such a cluster. This will show their improvements and it will further stimulate them. A rewarding system can be connected to honor the changing behaviour. The rewarding system should focus on rewarding the clusters as a whole, by making investments which contribute to the community. Examples could be to offer financial means to organise a summer party for the neighbourhood, or by investing in the public space, listening to the needs of the residents. In this way, a rewarding system related to waste disposal can be of use to improve liveliness and social circumstances in the neighbourhood.

6

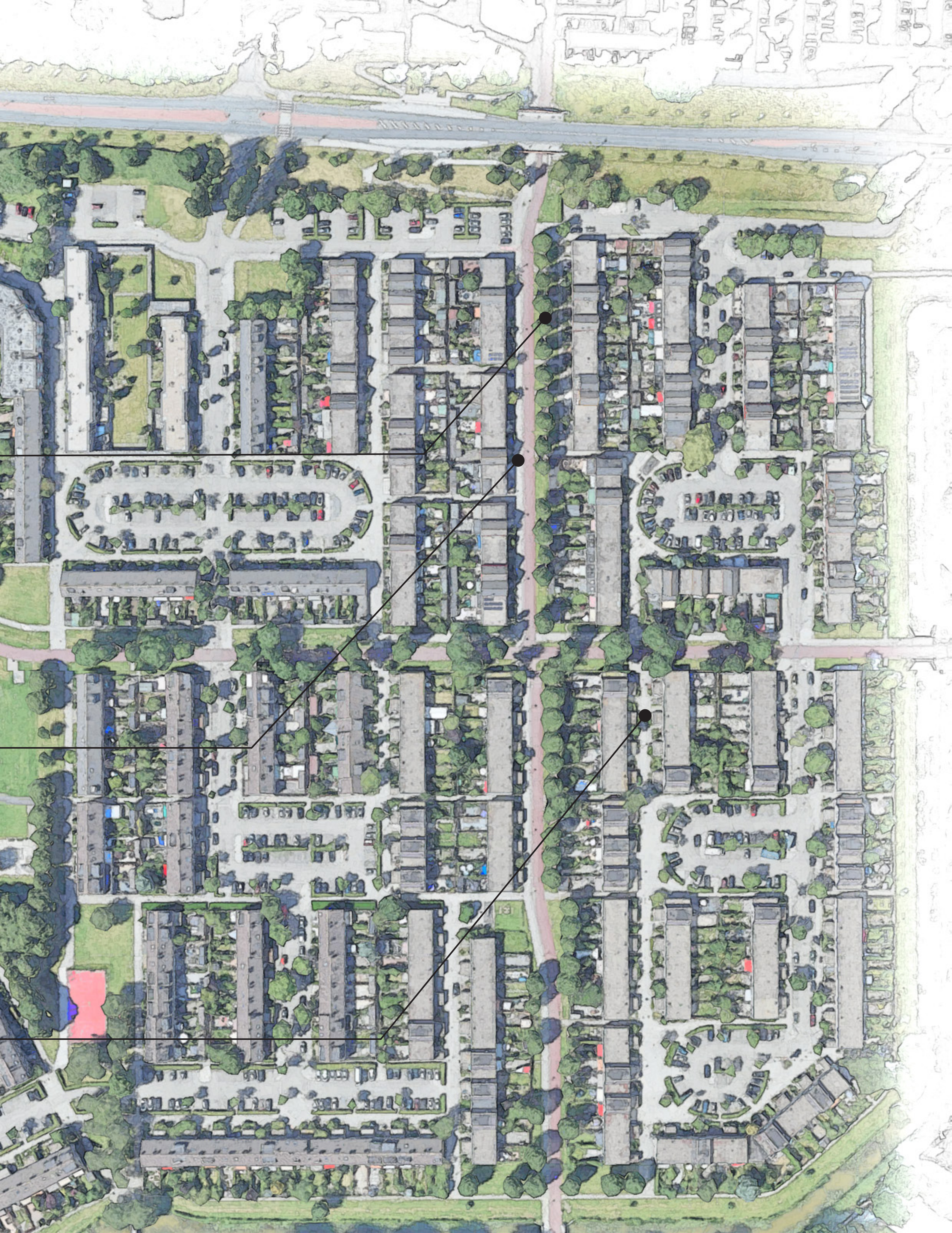
11.6 Terraced housing, mini-containers

Outside the A10 high way ring, a lot of terraced housing neighbourhoods can be found. The neighbourhoods still differ a lot in density, however, they have one characteristic in common. The houses have gardens and more space to collect and separate waste at their residence. To explain possible improvements to the collection system, the neighbourhood Rijgersbos Zuid in the south east of Amsterdam will be analysed (figure 84).

The neighbourhood consist of all terraced houses accompanied by gardens with cycling roads as main infrastructural lines. These infrastructure lines are the quickest way to the north where all the daily functions are situated. At the moment, residents are only in possession of a mini-container for residual waste. Another crucial fact is that most of the residents place their mini-container in their front yard instead of the garden. This positioning creates a bitty messy image. Street containers for the other homogeneous waste flows are can be found at some of the parking places. These locations are not alongside the most important infrastructural lines or at central locations in the neighbourhood. As stated in the collection principles section, these residents should get a mini-container at their home for paper, plastics and fruit, vegetable and garden waste. However. This neighbourhood has an open structure with lots of green spaces. These green space could be used for local treatment of biowaste. Local composting can reduce the amount of driven kilometres by waste trucks, since less waste has to be collected. The decision to provide these kind of local bio

▶ *Continuing page 135*

Figure 84
Rijgersbos zuid, Amsterdam
(Map: Image by author, based on Google Earth; Photo's: Twan Cortenraede)

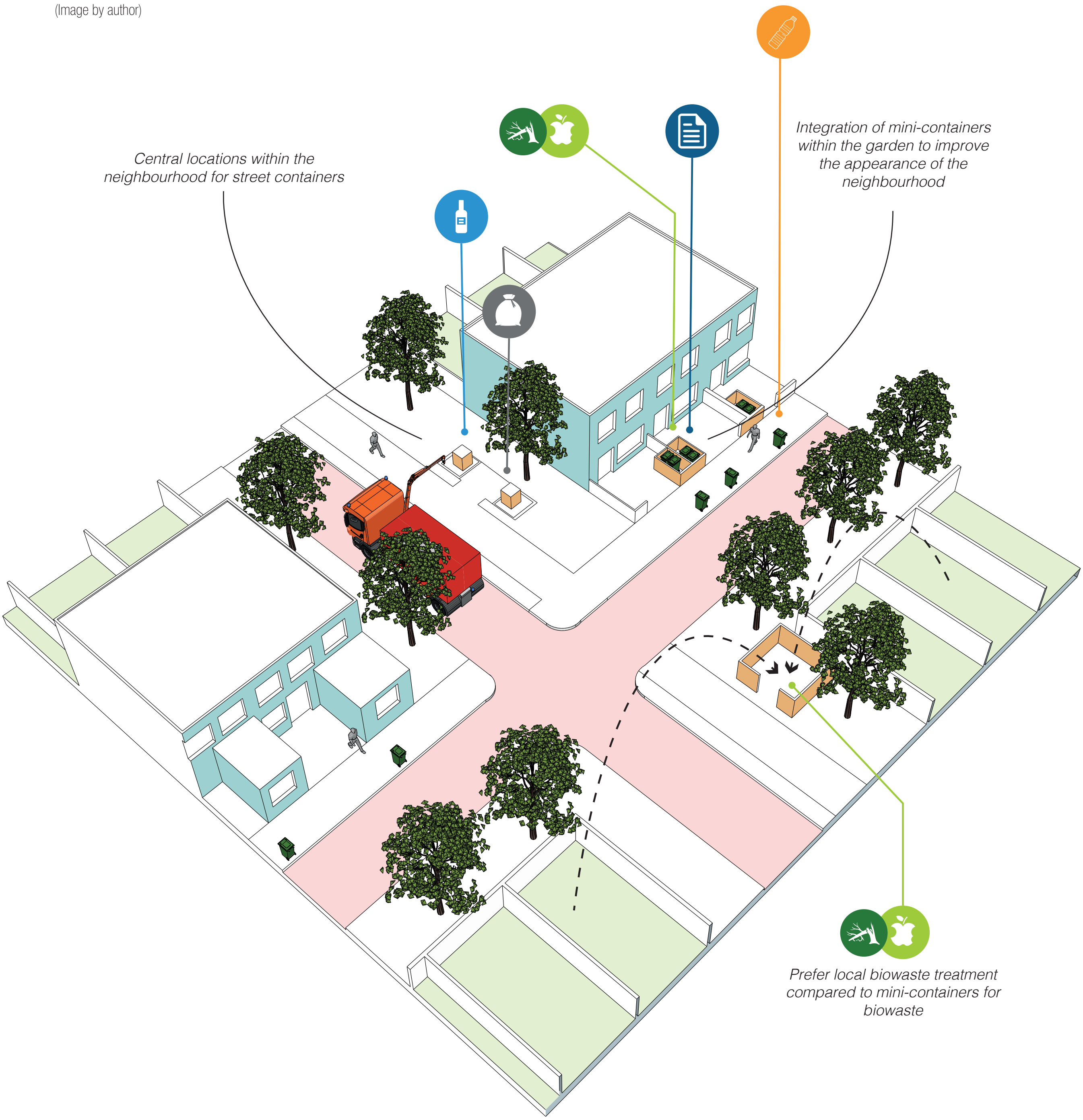


11
Urban integration of waste collection infrastructure

Figure 85

Rijgersbos zuid, Amsterdam with mini-containers and central waste stations.

(Image by author)



waste treatment facilities should not only be based on the spatial characteristics. The use of these facilities requires some kind of dedication and willingness of the residents themselves. When implementing this way of collection and treatment, the project should be developed in collaboration with the residents to increase their involvement and awareness. To expand these biowaste treatment points throughout the city, the municipality should take an active role and support and co-start local initiatives.

In Amsterdam, already a local initiative has started which tries to increase the local composting of biowaste within the neighbourhood. The ‘Wormen Hotel’ is a small composting facility which can be placed within the neighbourhood. Worms facilitate the process of composting and fertilizer is the end product. This initiative started as a collaboration between residents. A bottom up approach like this is needed to make sure the whole neighbourhood participates in the project and more biowaste is removed from the residual waste (Buurtcompost n.d.). Expanding this initiative to other neighbourhoods would be a great step forward. Not only the worm hotel could be a solution, already many forms of local composting of garden waste can be found around the Netherlands.

Residual waste containers and packaging glass containers should be positioned at central locations, where residents pass by every day (figure 85).

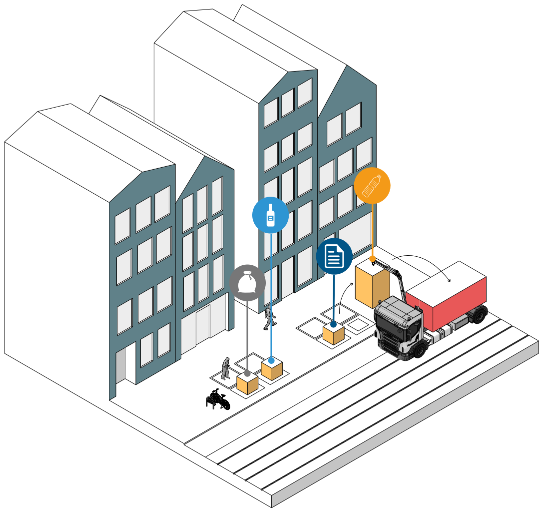
When integrating this system, more should be done instead of just delivering the different mini-containers. To avoid the neighbourhood become a place where containers are just scattered everywhere, a plan has to be made how these containers can be placed at every residency without making the neighbourhood ugly and visually appealing. Here again, thinking about waste collection during the architectural processes, could already lead to better integration.

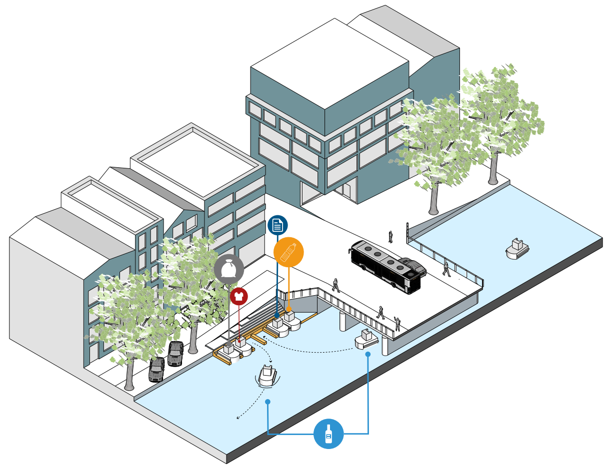
Conclusion: 6 neighbourhoods, 6 proposals

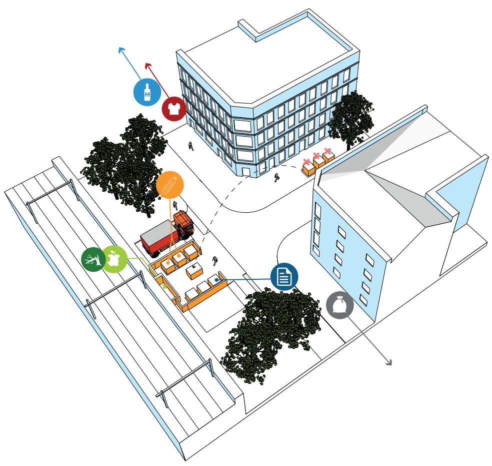
Six proposals have been made for six different types of neighbourhoods. The proposals are a spatial translation of the proposed principles in chapter 9. The proposals show possibilities how the collection of residential waste can be improved in the whole of Amsterdam. It is important to understand that these proposals are just one of the many options to improve the system. They focus on increasing the possibilities to dispose waste flows, or improve the current possibilities.

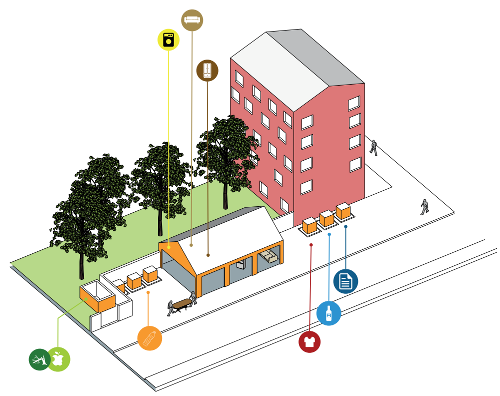
The proposals are based on certain characteristics which were found in the case study areas. These stated characteristics, can be found in all the neighbourhoods related to the category. However, some characteristics can also be found in other neighbourhoods of another category. An example is the water waste station. The proposal was based on the canal district where the canals were seen as a possible infrastructural feature to collect waste. This water waste station proposal, can be applied to all the neighbourhoods which have this feature of water. A lot of new housing development areas are for instance situated along side the water.

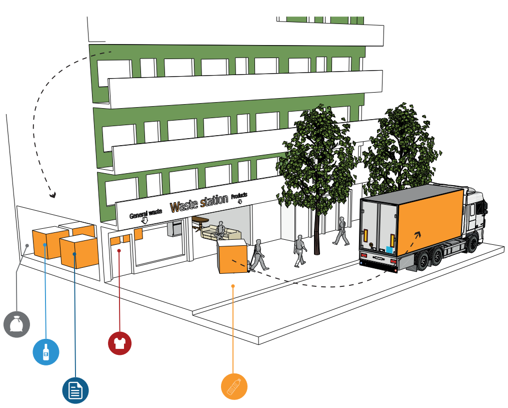
In this way, these proposals are of great use to derive overall recommendations for Amsterdam. The implementation process learned us a lot of possibilities for urban integration, relations to other urban systems and understanding of residential waste on a local scale within the neighbourhood. In chapter 13, the main conclusions of this integration process and related recommendations will be stated. They will help the municipality to improve their future visions and translate this vision to actual implementation.

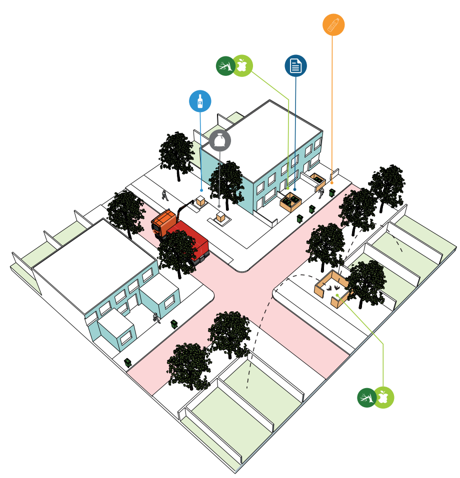












(Images by author)

12

Circular waste treatment implemented within Amsterdam

In chapter 8, a new circular waste treatment systems have been created including a spatial translation. This resulted in three different waste groups with different positions within an urban environment. In chapter 12, these different waste treatment groups will be allocated and integrated within Amsterdam. Together with the implementation of the collection system, a wide range of integration proposals is made, which can inspire policy makers and designers.

There are three different waste treatment groups with two different positions within an urban system (chapter 8.2). First the waste treatment system of treatment group 1 and 3 (paper/cardboard, packaging plastics, garden waste, fruit and vegetable waste, residual waste and gross solid waste) will be allocated within Amsterdam. The second part will be about integrating waste treatment group 2. Especially here, the focus will be on trying to link the waste treatment system to other urban systems and propose implementations adjusted to the spatial, economic and social characteristics of Amsterdam. This implementation proposals will help to define crucial recommendations for the municipality. These recommendations will help continuing and fasten up the circular economy transition.

12.1 Material reuse in the Port of Amsterdam

Within the municipality of Amsterdam, large waste treatment facilities are already present or contracts with other treatment companies have been made. For waste treatment group 1 and 3, no large new facilities are needed. As concluded in chapter 8.3 the facilities should be placed in areas where housing is not nearby since of the negative environmental effects. Besides that, large scale transport facilities and infrastructure should be nearby. The current facilities can already be found on this types of locations which are most of the time industrial areas.

At the moment, the municipality have contracts with Maltha in Heiningen, Reparco in Renkum and Coolrec in Eindhoven for the treatment of packaging glass, paper/cardboard and electronic appliances (figure 87). Since The municipality decides which companies (not necessary in Amsterdam) it is important to anticipate on moving waste through the Netherlands or even globally. A waste transfer station within the port, where multiple transport modes and infrastructure come together is essential. This will make sure that the most sustainable form of transport is always available. However, the municipality could also create a vision on attracting waste treatment companies to their territory. This economic strategy can make the area an economic region where waste treatment is one of the key economic activities. Amsterdam does already have an ideal location to facilitate these types of activities.

The other waste flows are treated within the Port of Amsterdam (figure 87). The Port of Amsterdam is an ideal location since of the transport possibilities, even on global scale. Next to that is the port already in a transition to become a biobased port, focussing on the manufacturing of biobased products and resources. However, as discussed before, the port is under some spatial treats. Housing development is pushing the port to the west and port area in the east is redeveloped for housing. This means that a restructuring of the Port is needed to combine these housing and economic activities. It also brings the possibility to create a strong waste oriented cluster where circular principles are used to create a port specialised in circular waste treatment and circular resources. This includes the current waste

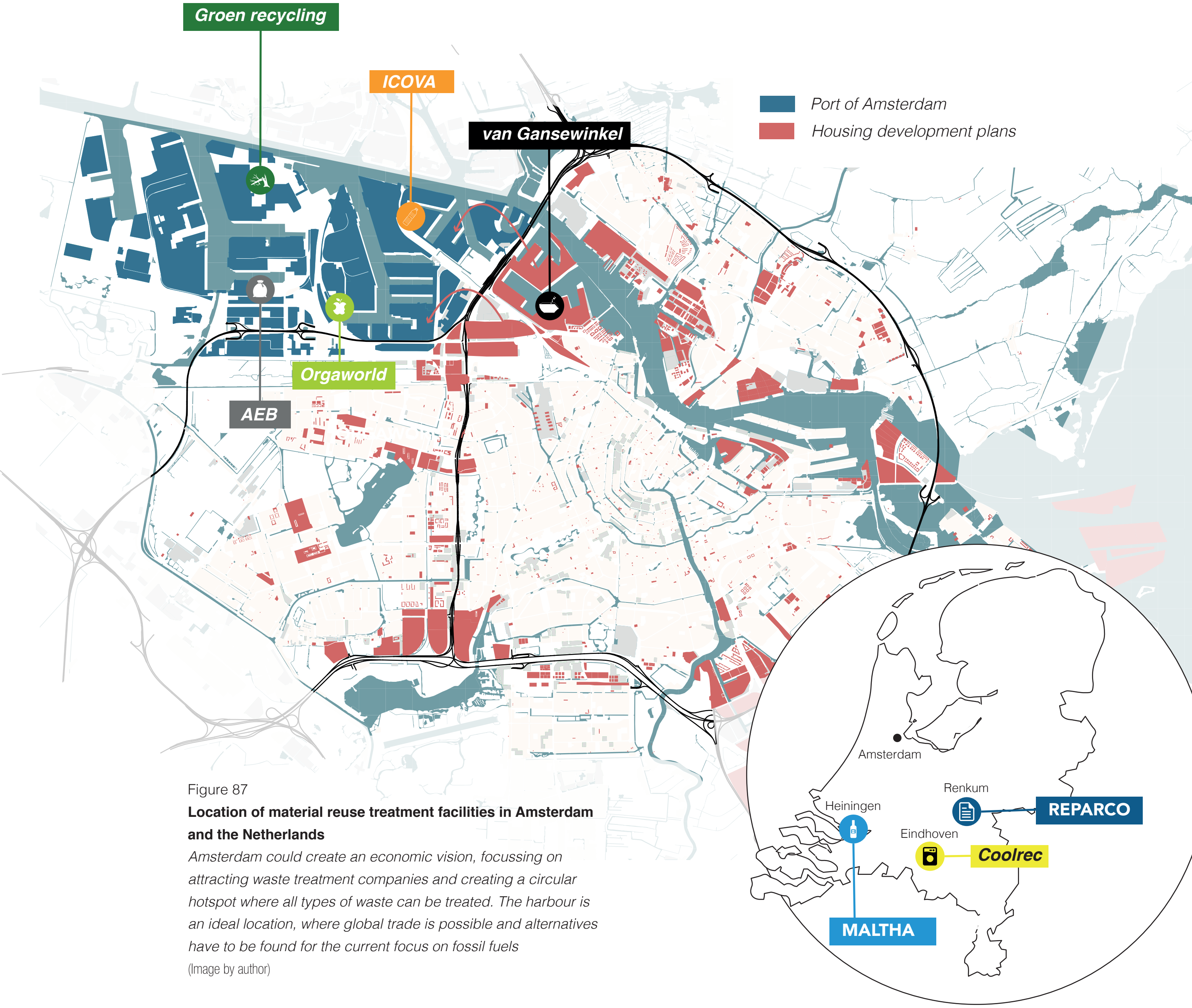


Figure 87

Location of material reuse treatment facilities in Amsterdam and the Netherlands

Amsterdam could create an economic vision, focussing on attracting waste treatment companies and creating a circular hotspot where all types of waste can be treated. The harbour is an ideal location, where global trade is possible and alternatives have to be found for the current focus on fossil fuels

(Image by author)

treatment activities and attracting new activities to have a circular hotspot where all types of waste can be treated and returned into the economic as a valuable resource. As already explained before, waste can become a world market. Textile and dry biowaste are already shipped around the world. The port of Amsterdam is originally a fossil fuel oriented port. A transition towards these new circular waste activities could replace the original activities.

Within the port area already a link is made with other systems. Amsterdam is expanding its heath network and multiple waste treatment companies are connected to this system. Heath generated during the waste treatment process is used to heat up multiple neighbourhoods in Amsterdam. These sustainable connections should be made continuously.

When such a new cluster can be formed within the port of Amsterdam, the location becomes increasingly interesting for the profession of industrial ecology. Industrial ecologist can design the most efficient processes and especially valuable technical links between companies within the industrial area and between industrial areas and the city. The Port of Amsterdam could become one of the leading ports if it comes to circular waste treatment which is a good alternative for the current activities focussed on depleting natural resources.

12.2 Waste treatment within residential areas

A larger challenge is the integration of waste treatment group number 2 within residential areas. The goals is to bring waste treatment and collection (in the form of waste points) closer to the people. This system should be part of the urban systems we use in our daily lives to create more awareness about waste, and make it easy for people to live in a more circular way. Waste can as well contribute to the urban environment, by bringing new activities, and sustainable integration.

Within this final design and integration chapter, three possibilities are proposed which show how waste can be connected to existing urban systems. Three different systems will be shown which tackle different social, economic or spatial challenges but also make use of opportunities. By combining different social and economic layers and integrating them spatially by making use of the variety of Amsterdam urban forms, three integrated systems can be created.

These three systems are just a few options which can be made. However, the main point is to show how by linking layers and urban systems to waste treatment, a totally new perception of waste treatment can be created and show that it will work within urban environments for certain types of waste.

Three different concepts

The first treatment point will be large scale waste point within the urban environment (chapter 12.2.1). They will be positioned at industrial areas which are selected for housing development. Flows will come together at these stations and multiple modes of transports can be used. The waste station will have a commercial character and will serve as showcase areas for the circular economy.

The second treatment group will be on a much lower and more local scale. It will focus on communities and how waste could be treated and collected by communities. Linking the waste treatment to already local systems, residents are more likely to make use of the system and they can experience how valuable waste can be (chapter 12.2.2).

The third and final proposal will focus on the finding of the ideal locations to expand the network of waste points even further (chapter 12.3). Two possible connections to already existing activities will be explained.

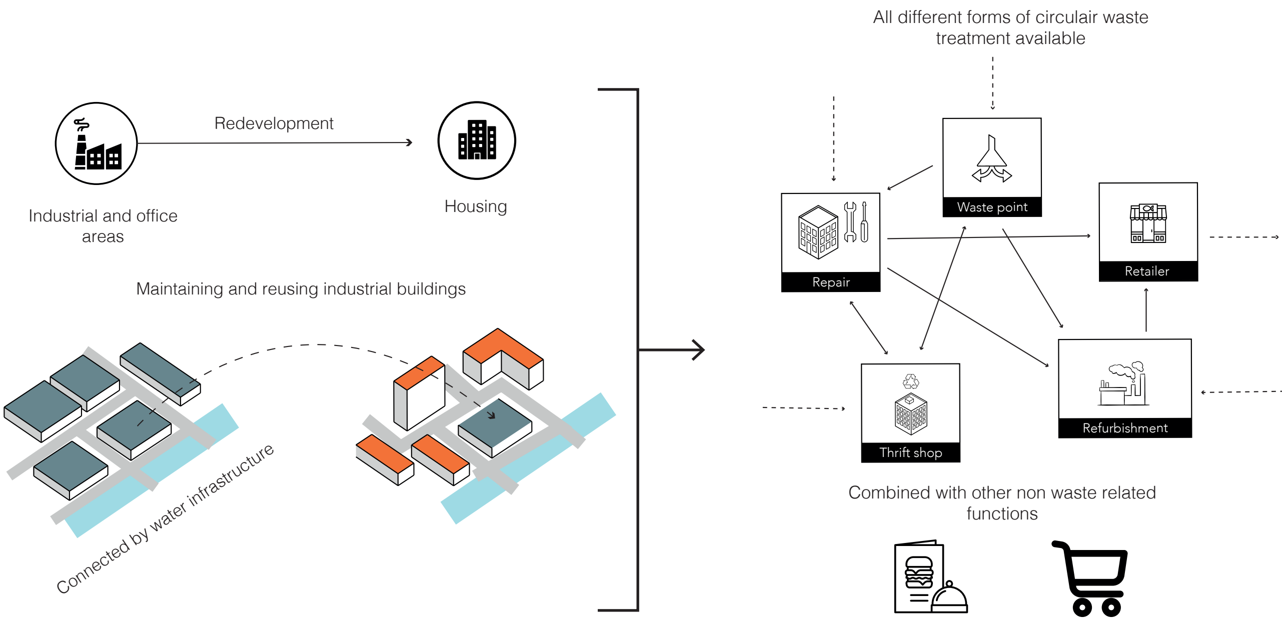
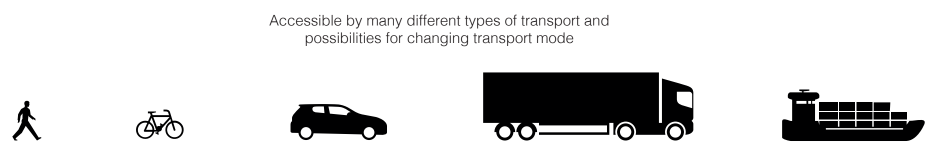


Figure 88
Concept of urban waste centres
(Image by author)



12.2.1 Urban waste centres

As discussed before, Amsterdam is in the need of new housing. Because of that reason, industrial sides within the A10 high way ring are being redeveloped into residential areas. Beside the fact that industry is leaving the city, current waste points are under pressure because of these developments. The question has been raised by the municipality what should happen with these waste points.

Because of the coming transformations, opportunities arise to integrate waste collection and treatment facilities within these new areas (figure 88). Old industrial buildings could be reused to facilitate these new activities. Since the value of these areas is quiet high because of their location and giving up housing for waste treatment is not the most valuable option, these new type of waste points should offer more instead of just collecting waste. The facilities should have a more commercial character and money should be made out of waste. The multifunctional buildings should operate like a sort of waste marketplace where the value of the handed in products is determined. The products can be resold again, repaired or refurbished by companies situated in the building, or even companies from elsewhere should be able to buy the goods they think still have value. In this way a dynamic environment is created where a physical market is created where flows of waste are constantly flowing in and out. The waste points should be reachable by multiple modes of transport as well. Larger trucks should be able to transport the unused

Continuing page 143

12
Circular waste treatment implemented within Amsterdam

Figure 89

Industrial areas within the A10 high way ring which are selected for redevelopment in housing districts

These areas have opportunities to integrate waste collection and treatment within residential areas.

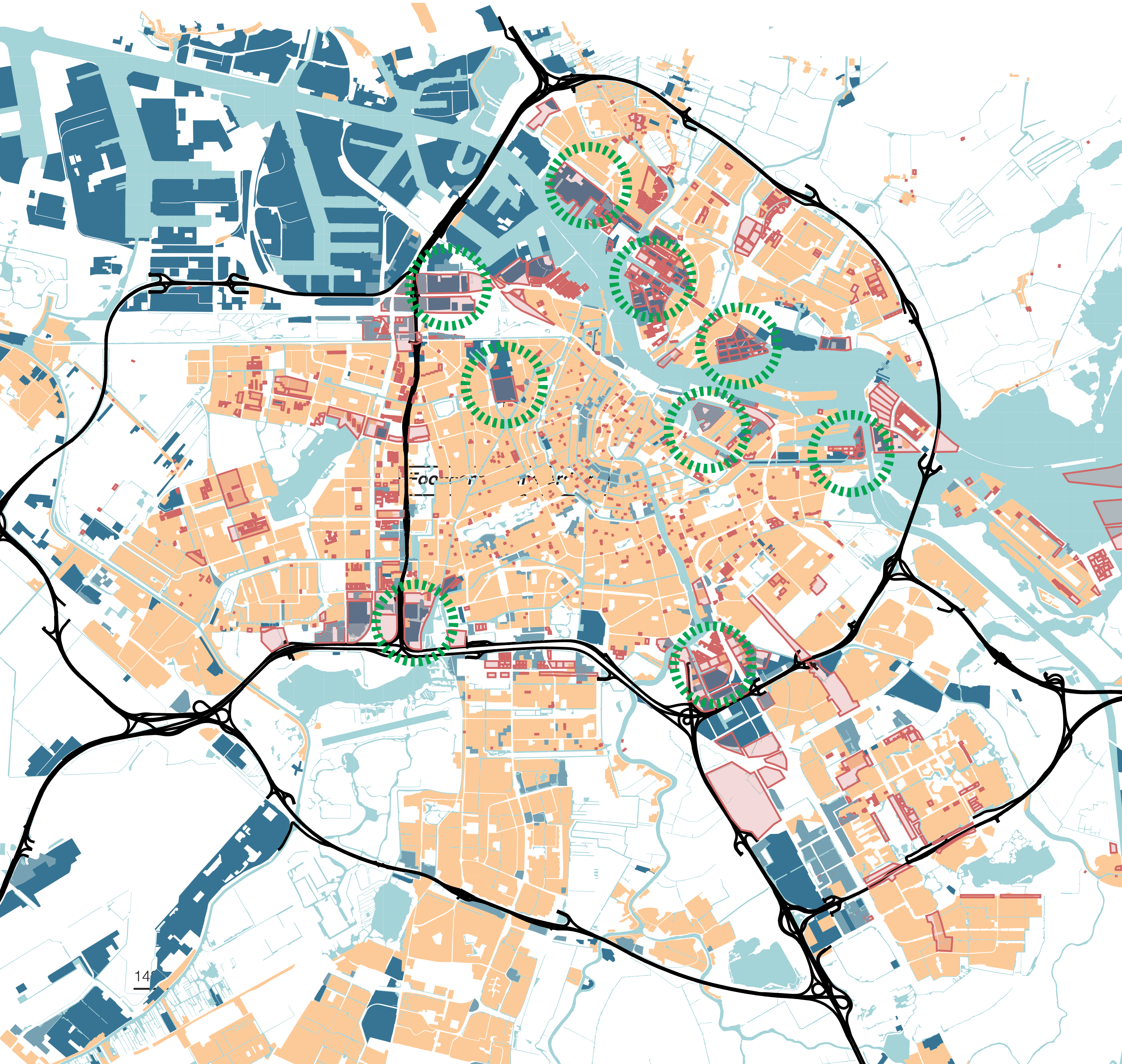
(Image by author)

Industrial and office areas

Residential areas

Housing development plans

Possible location urban waste centres



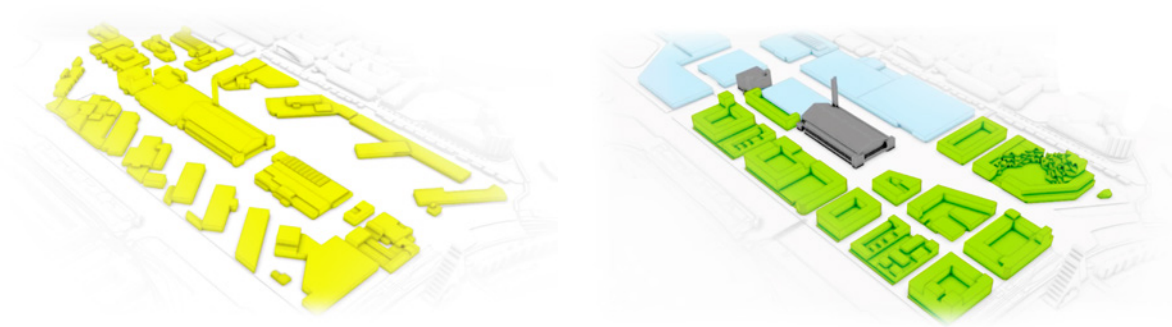


Figure 90
Redevelopment Food Centre Amsterdam
Transforming 50% of an industrial area into housing
(Images by Volkerwessels Vastgoed/Ballast Nedam)

waste to the larger treatment facilities in the harbour. Boats can transport purchased goods into the city centre or pick up used goods at the same time. Residents should be able to drop of their waste by car, bike or walking. In this way the waste point becomes a vibrant area where all sorts of activities come together.

Not only waste related activities should situated within the building or area. By making a mix with other activities, like restaurants or just a supermarket, residents come more into contact with the circular treatment of waste and can experience the whole process by just walking trough the building and see how a product is delivered, refurbished and sold again, all in the same building. The companies that provide the circular activities should be a mix of small local companies and even larger world wide known brands. A local furniture maker could be situated right next to for instance G-star, which recycles their jeans. The whole waste point will become a vibrant place where the core of circular economy is visible. It can be experienced and used as a showcase area for circular companies.

This forms the idea of these waste points right within the urban areas . Within Amsterdam there are multiple locations where old industrial areas, housing development and multiple infrastructures (water) come together. These possible locations are shown within figure 89. To show how such a waste point can look like and how it functions within the urban environment, one location has been picked out. The Food Centre of Amsterdam will be used on the following pages as a case study to show how this idea can be implemented and integrated.

Food Centre Amsterdam

In 1934, the central market in Amsterdam was build. It started as a market for fruit and vegetables, but eventually it became a food centre for all types of daily provisions. The food centre expanded and currently around 100 different companies are situated within this area. Because of its central location within Amsterdam west, and the need for new housing, a new plan for restructuring the area was presented in 2013 (figure 90). On the southern part of the area, 1500 new houses will be developed. In the northern part, new large sustainable industrial halls will arise, which will keep functioning as the Amsterdam food centre. In the middle, the original and iconic market building will be restored and reused. So far, it is not clear yet what the new function is going to be, however, the building should be opened up for the public. The first designs of the new area have been made, and it is expected to be fully developed by 2034 (Gemeente Amsterdam, n.d.).

The area has been dynamic and vibrant for many years. The current and historic activities have been the inspiration for a new design where waste collection and treatment is integrated within the new development. The new design makes use of the current buildings and creates a place where waste becomes a resource and circular economy can be experienced. The main idea behind this new waste point is a reinterpretation of the food market, where waste is traded, its value is being determined and products are being repaired, refurbished and eventually sold again.

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Circular waste treatment implemented within Amsterdam

A new concept

Within the current plans, the area will be split up in two parts (figure 91). In the northern part, new, sustainable industrial halls will rise which will keep on functioning as the food centre of Amsterdam. In the southern part, around 1500 new houses will be developed. Between both areas a strong border is created and no connection between the two areas is been made. Large industrial halls are directly next to the new apartments and the connection between the two areas is fenced off. The only connection between the two areas is made through the old market building. However, the new function of this building is still unclear.

Both areas could be more connected to each-other and the strong borders could be reduced. This brings is us to a new conceptual idea for the area, where waste will be the connecting factor (figure 92). By preserving more old buildings and connecting them via a central waste point/waste market, an area is created where all types of flows come together. The preserved buildings will all get a different function, related to the central market squire. This central area can be reached by all different modes of transport. From the north, through the industrial part, cars and trucks can drop of waste and goods. From the southern part, residents can enter the area via bike or as a pedestrian. Reconnecting the place to the water and the

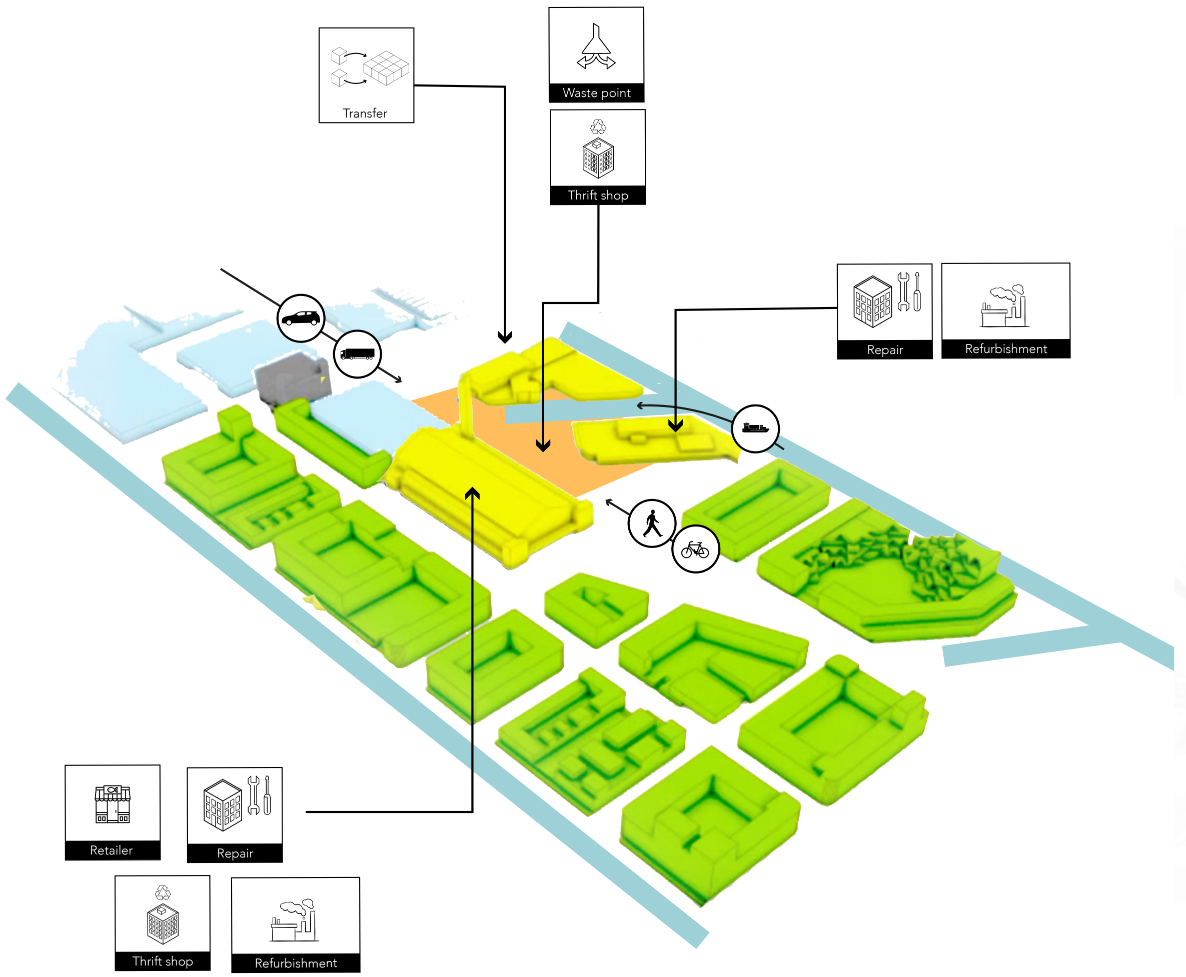
▶ *Continuing page 145*

Southern, residential part of the food centre
(VolkerWessels Vastgoed/Ballast Nedam)

Northern, industrial part of the food centre
(VolkerWessels Vastgoed/Ballast Nedam)

The clear border between the two areas
(VolkerWessels Vastgoed/Ballast Nedam)

Figure 91
Current redevelopment plans Food centre Amsterdam,
A clear divided area with strict borders.
(Image edited from Volkerwessels Vastgoed/Ballast Nedam)



canal system of Amsterdam, transport via autonomous vessels becomes possible as well. By preserving more of the old buildings, and putting new functions in them, the border between industrial and residential will become more vague. The old food centre buildings will preserve the historic value of the area and creates an area where residents of Amsterdam can identify themselves with.

In figure 93, on the next page, an impression is given on how such an area could look like. On the pages which follow, the functioning and integration of the different aspects of the design will be explained.

Figure 92

New concept for Food centre Amsterdam

A transition area where multiple flows of people and goods come together. A central area will connect the different buildings which each other which will host waste treatment related functions.

(Image edited from Volkerwessels Vastgoed/Ballast Nedam)

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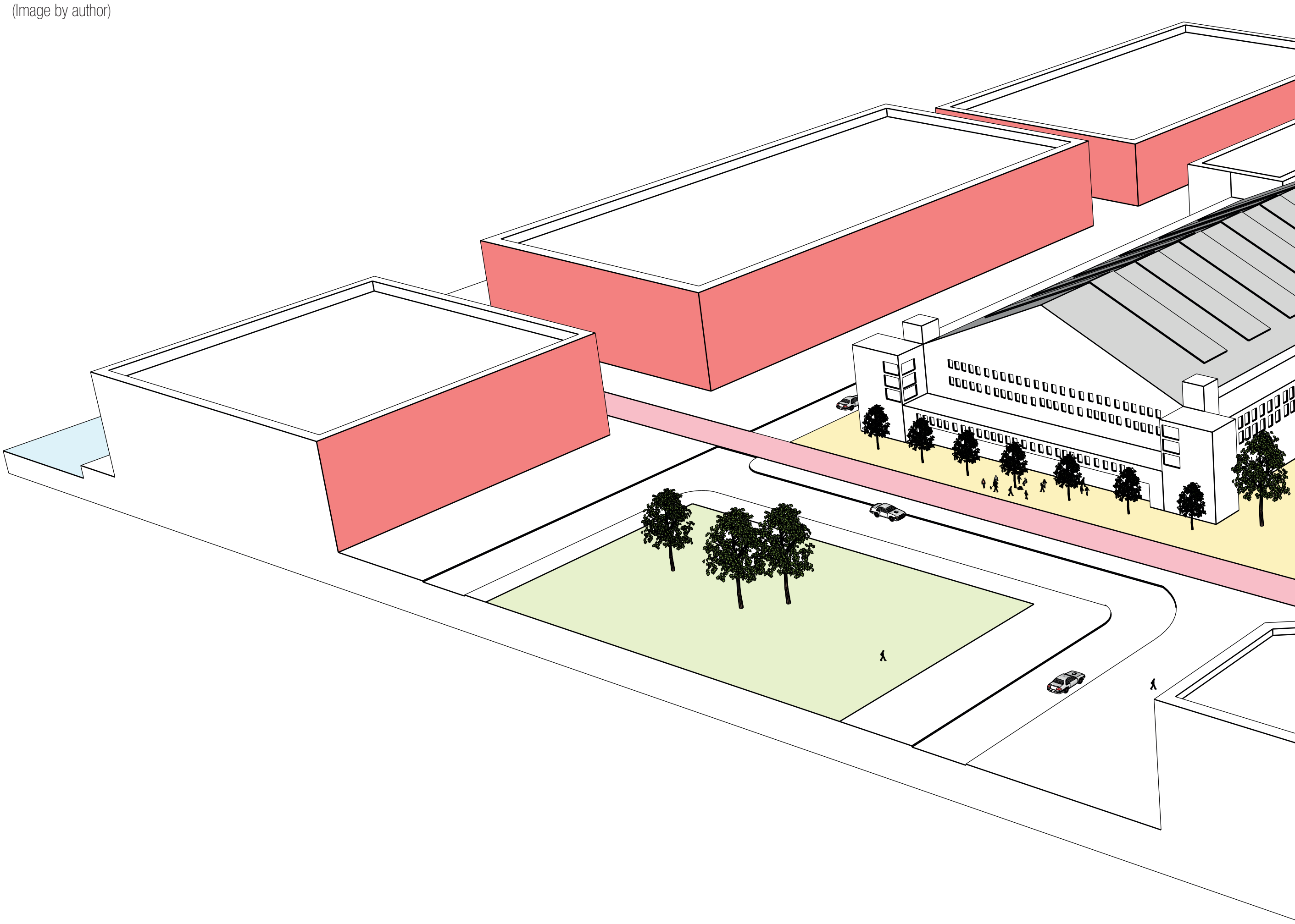
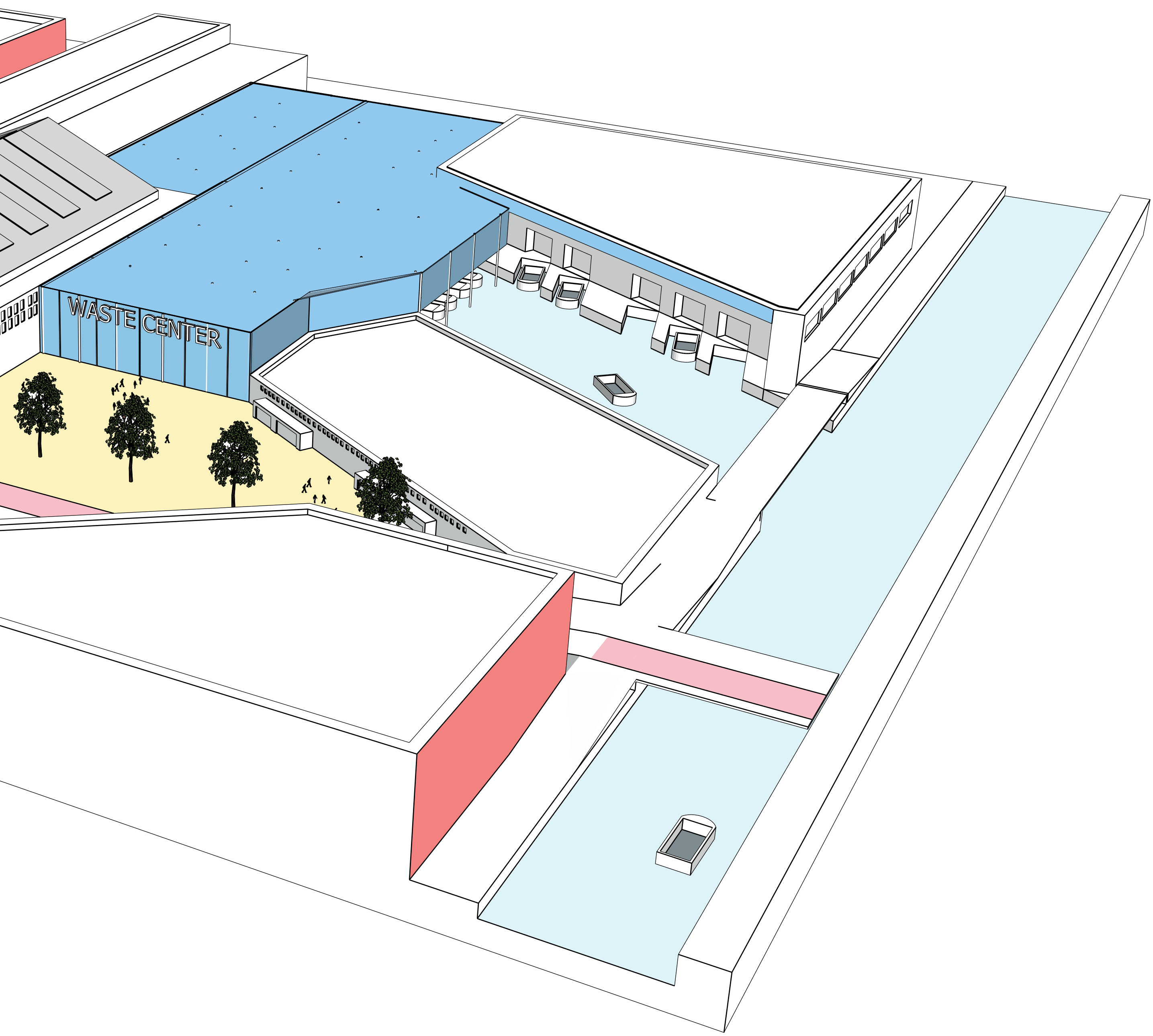
Circular waste treatment implemented within Amsterdam

Figure 93
Urban waste centre replacing the food centre

(Image by author)




WASTE CENTER

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Circular waste treatment implemented within Amsterdam

Traditional waste point
(AEB Amsterdam)

Historic use as a food auction
(Gemeente Amsterdam)

Figure 94
The central waste market hall

(Image by author)

The central waste market hall

The large indoor hall connects the three buildings and forms the centre of the circular waste station (figure 94). The large hall will be a combination between a traditional waste point and the concept of a food auction, related to the historical use. Like a traditional waste point, residents can drive with their car into the large hall on an elevated platform (see picture). Different types of waste can be dropped of at different locations. In the northern part of the hall, waste which is transported via road by containers can be dropped off. Waste which is treated in the Port of Amsterdam can be dropped off in the southern part at the automated vessels. In the centre, large spaces are reserved where different product related waste flows can be dropped of. This concept is derived from a traditional food auction. The products are displayed and can be bought by everyone who comes into the central hall. Residents can come through the front entrance and stroll through the hall like it is an enormous thrift shop. Repair and refurbishment companies can look at the same time for valuable products which can be up-cycled and sold again. A clear management structure makes sure products will not remain too long within the building, when no-one is interested in a certain product it will be disposed via the containers and room will be made for new incoming products.

Within the hall there will be mix of residents, bargain hunters and repair/ refurbishment shop owners. Repair shops which are situated within the building can buy the products or even people from elsewhere in the city or other parts of the region can come here to look for valuable waste. A open structure, which can easily be adjusted to changing circumstances, where a wide variety of waste flows and people come together to work on a circular economy

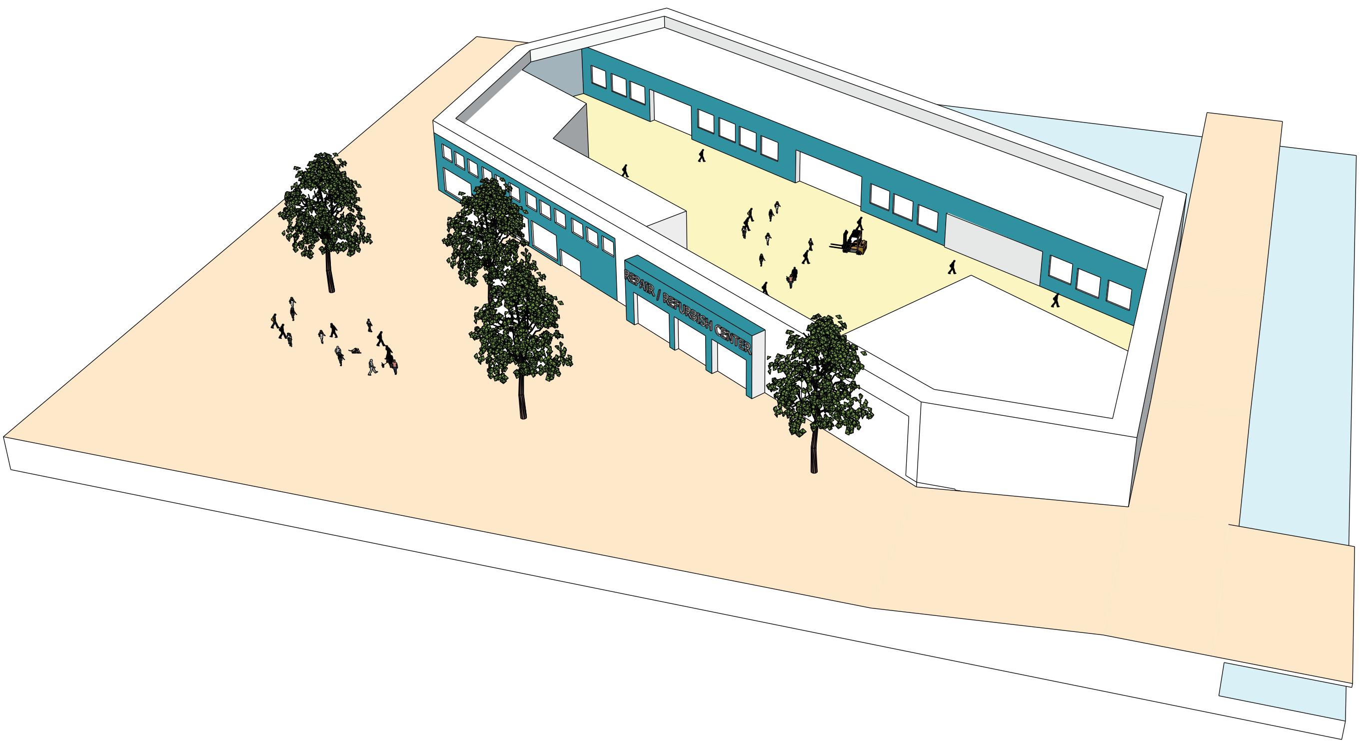

Figure 95
The workshop

(Image by author)

The workshop

In one of the former industrial buildings of the food market, a workshop will be created. In this building repair and refurbishment companies from Amsterdam can fabricate and sell products made from Amsterdam's waste. In the workshop, the more loudly activities will take place. Old furniture can be picked up at the central hall and transformed into new vintage furniture ready to be sold again to the visiting residents. The building should have an open structure, where everyone can walk in and see the activities take place. A creative building with a structure similar to the NDSM warf in Amsterdam North, will create a lively atmosphere (see picture).

The workshop owners are close-by the actual waste drop of point and can look everyday for new and valuable products which they think are worthy to be recycled.

NDSM Werf, Amsterdam. An industrial composition of creative industries, op to the public
(NDSM)

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Circular waste treatment implemented within Amsterdam

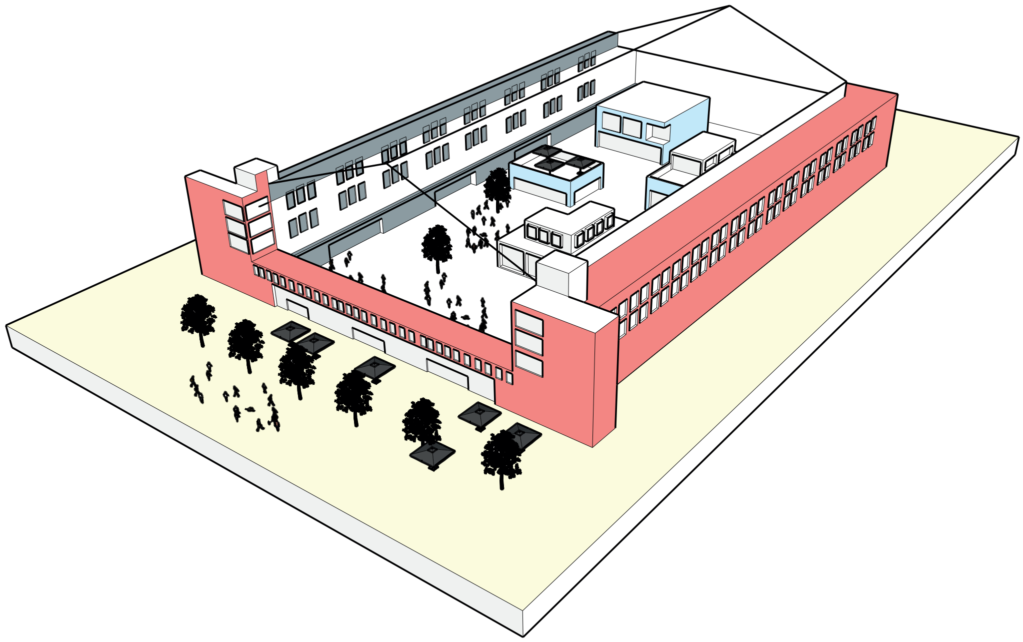
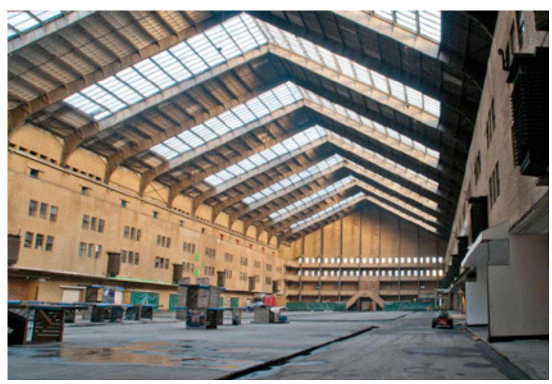


Figure 96
Mixed use circular centre

(Image by author)

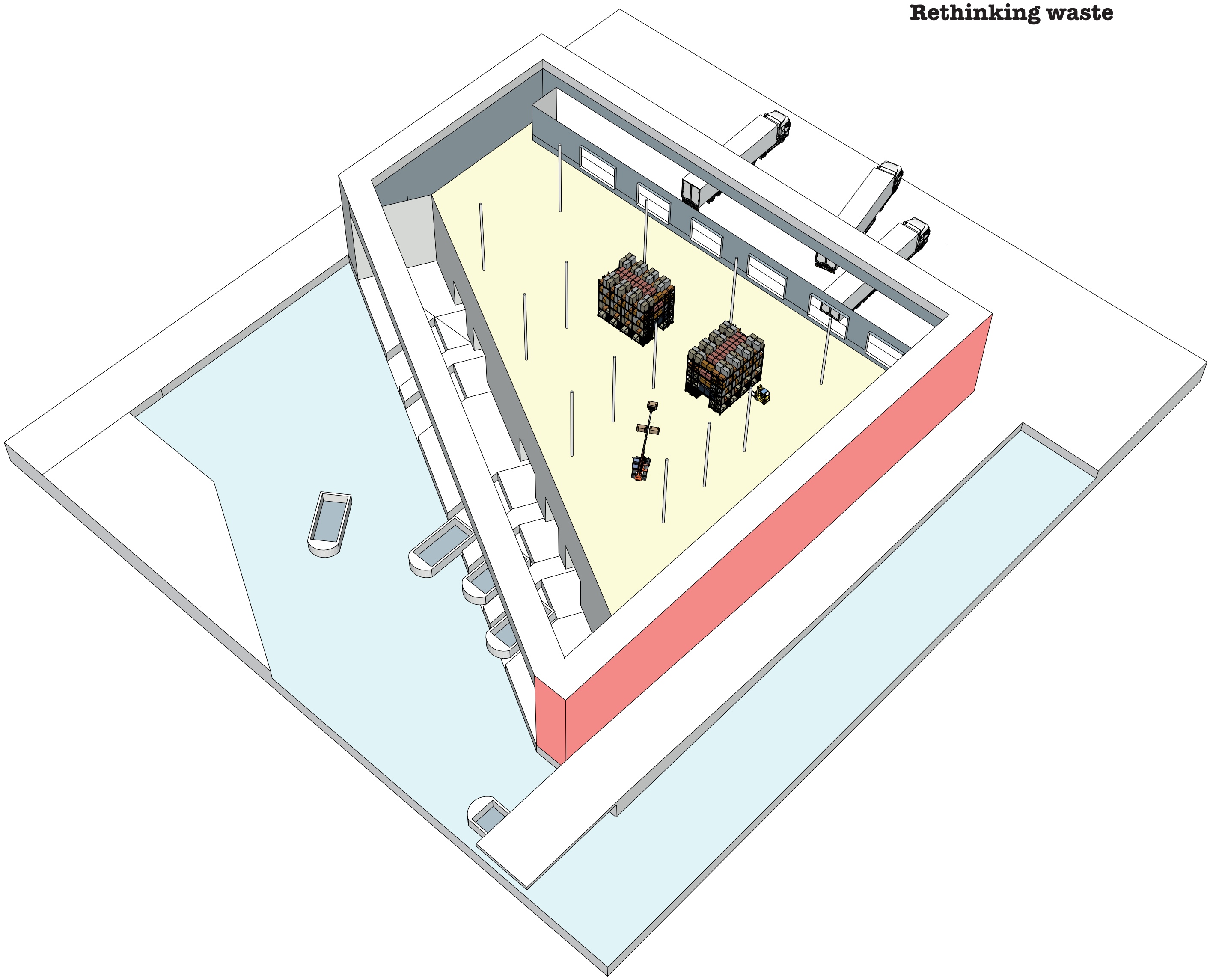


Food centre Amsterdam
(Nul20)

Mixed use circular centre

The historic food market will be restored and preserved, becoming a mixed use building where all kinds of circular activities take place (figure 96). Within this building the less heavy repair and refurbishment companies will be situated. People can have their clothes repaired and second hand clothes can be bought. Smaller electronic appliances like mobile phones are getting a new live within this building. Next to the smaller companies, large brands can use this space to showcase their circular ambitions and activities. G-Star raw for instance will sell their jeans based on plastic pick up from the ocean, or the Dutch railway company shows how new products are made from materials retrieved from old trains (G-star, n.d.; NS; n.d.). In this way the building becomes a building where the possibilities of circular economy can be experienced.

By combining the circular activities with other 'normal' retail and bars and restaurants, the area will attract more people. Open space within the building can be used for all types of markets or other cultural activities (see picture). By adding other types of use, more people will be attracted to the waste station and more will get in touch with the concept of circular economy and the value of it.



Sustainable city distribution

Figure 97
Sustainable city distribution

(Image by author)

One of the key concepts of this waste station, is the possibility to reach it by a wide variety of transport modes. Different types of transport are used to move the waste or products through Amsterdam. This distribution function could be used for more purposes. Large mail delivery companies could use the already in place infrastructures to move around all types of goods through Amsterdam. Online ordered products can be transported to the city centre via vessels. By combining the waste transportation and distribution system to other delivery system, the area gets multiple functions and more value. Even when less waste is being transported, the system is being used. Combining different systems and combining private and public functions will make it more likely this waste point will be effective, efficient and profitable (figure 97).

12.2.2 Communal waste treatment

The previous discussed waste point focussed on the large scale and commercial side of circular economy. The concept of the second waste point will be based on much smaller processes and integration within the suburbs of Amsterdam.

Circular economy is a concept which can operate on various scales. It can already by started by sharing between neighbours or helping each-other repairing a bike. Al the activities which involve repairing, reusing or refurbishing are forms of circular economy and can occur in every neighbourhood. The second waste type of waste point is focused on this more low scale communal waste treatment which can integrated within the neighbourhood.

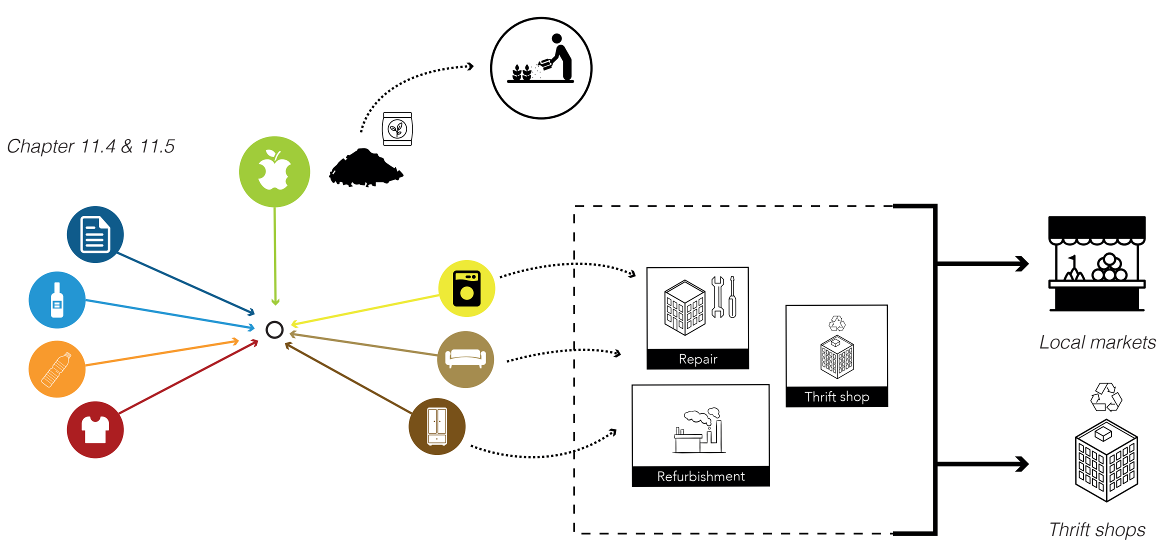
This waste point tries to connect to the communities that live in the suburbs of Amsterdam. By creating at strategic locations workshops where residents together can create value out of waste or prevention of disposing, a community will be created based on waste (figure 98 & 99). The concept will be related to the demographics and spatial characteristics of certain neighbourhoods. The old modernist neighbourhoods (described within chapter 11.4 & 11.5) are the areas where the percentage of unemployment is the highest and most of the people have non Dutch ethnic backgrounds. These areas are most of the time labelled as problematic. Next to the demographics characteristics, do these areas have certain spatial characteristics which make it possible to have such waste points integrated within the area. As described in chapter 11.4, do these areas have lot of unused green spaces where more activity can take place.

Figure 99 →
Location of neighbourhoods described in chapter 11.4 & 11.5 and their connection to local markets

(Image by author)

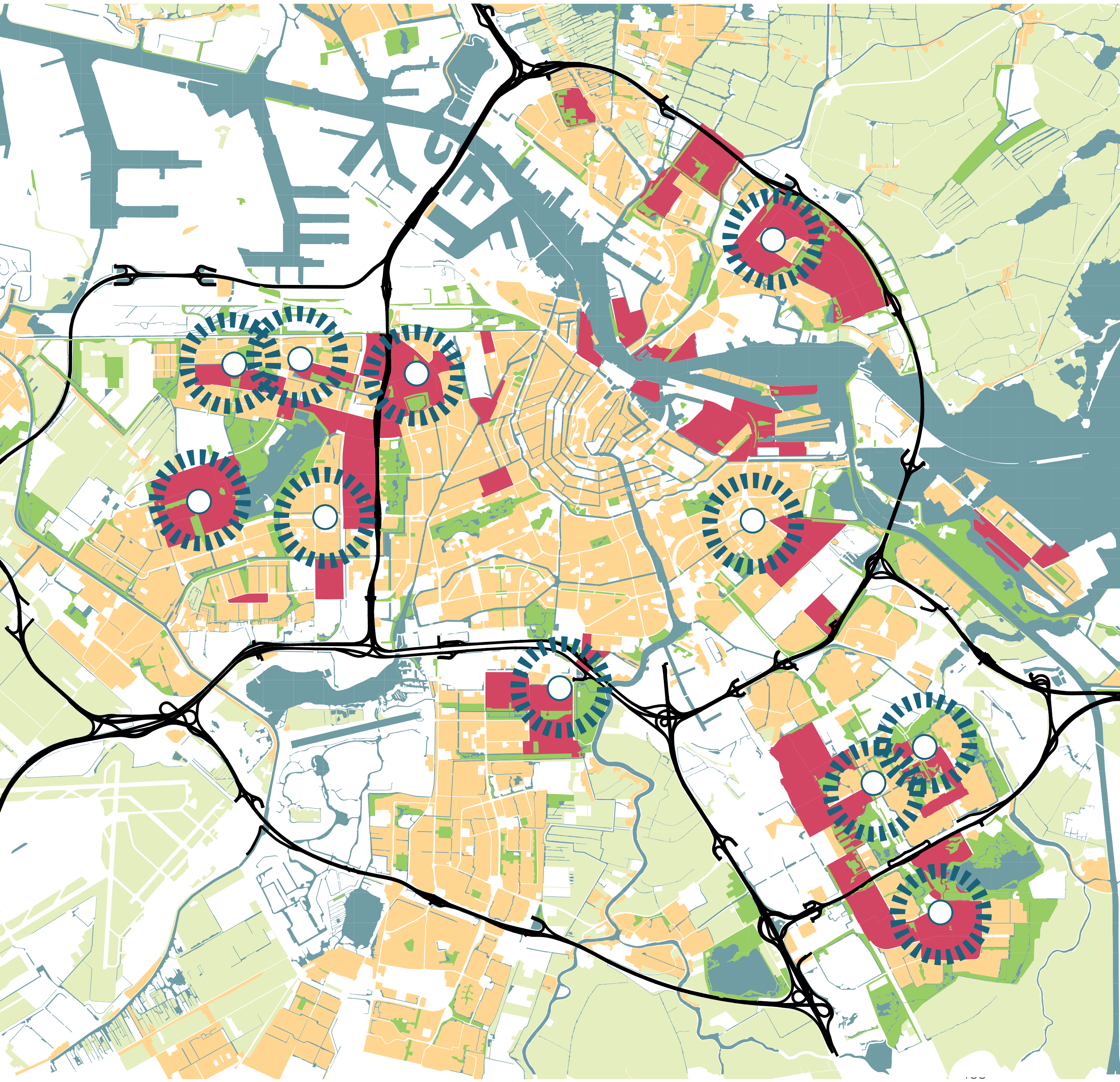
Figure 98
Concept communal waste points

(Image by author)



Local markets

Described neighbourhoods in chapter 11.4 & 11.5



12
Circular waste treatment implemented within Amsterdam

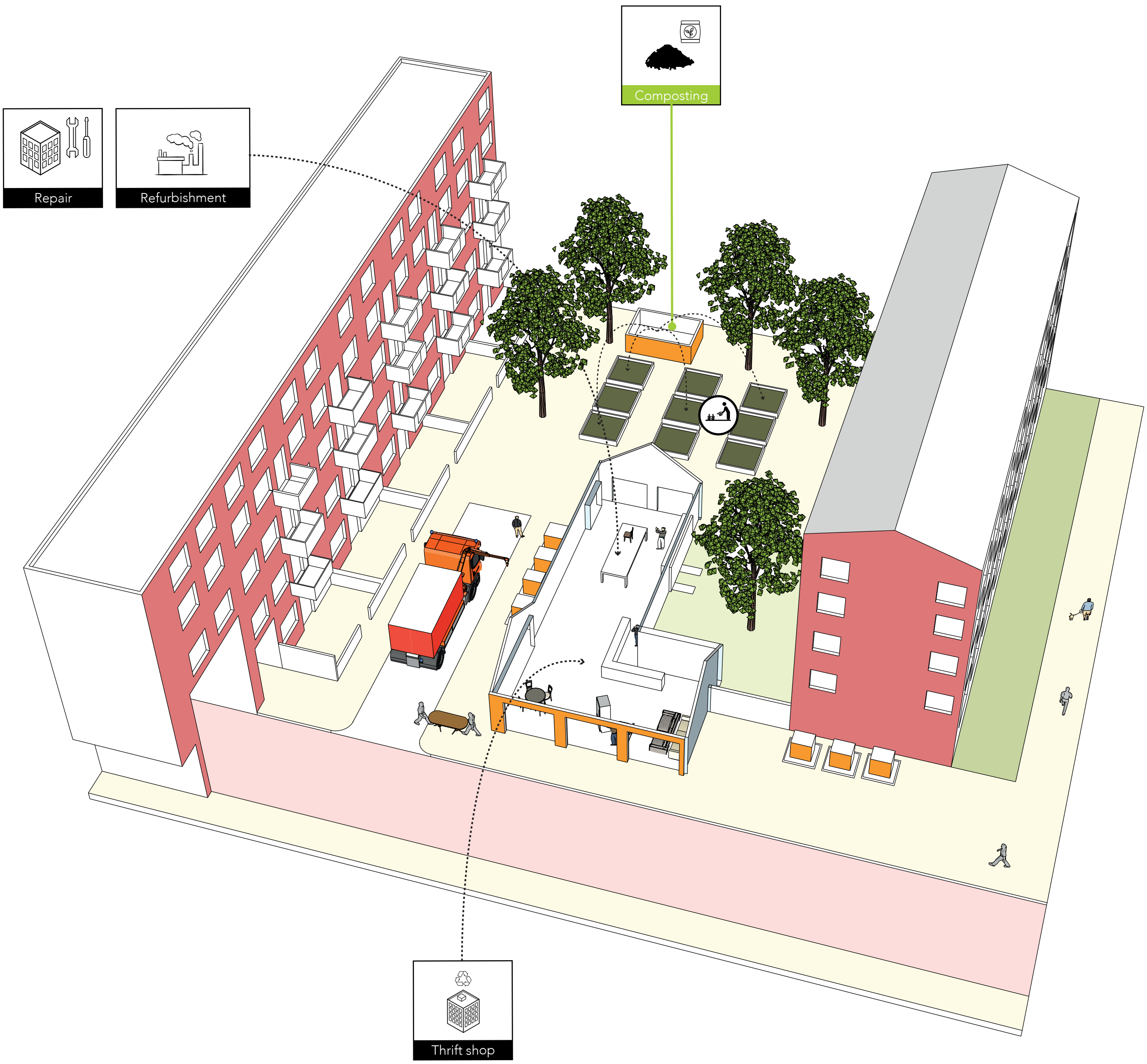


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Figure 100
Communal waste treatment
The design shows an expansion of the proposed waste collection point in chapter 11.4. Circular activities can be added to create a circular environment in the currently unused green spaces. Rewarding mechanism can be used to help residents further develop their circular treatment centre by providing funds to add activities. These activities can be related to circular economy, or they help strengthen the community within these types of neighbourhoods.

(Image by author)

The goal of these waste point is to help to form a strong community, which helps each other and implement circular principles on the lowest scales. Connections can be made to other activities in the neighbourhood which also strengthen the community feeling. For instance street markets can be used for selling the refurbished or repaired products. Or vice versa when products are collected at the market. Another option would the connection to the sport fields. Parents watch there children every Saturday or Sunday playing sports. This periodically event is perfect to relate to waste treatment and collection. The waste types described within this chapter are the ones which are not disposed every day. Creating communal activities, accompanied by sport clubs and residents, making together there neighbourhood a better place and thinking more sustainable about their waste (chapter 12.3).

Linking circular economy to the local markets is based on an initiative active in Amsterdam west. Cirkel markt, links circular thinking to the local market to increase the relevance, profitability and attractiveness of the local market. Waste from the market is treated locally and products manufactured from the waste are sold again on the market or in their store in the neighbourhood (cirkelmarkt, n.d.).

Again, this is a great example of how circular economy can be coupled to other urban systems. This integration makes it more easy to create new circular systems in Amsterdam. These local connections based on waste create value for other activities and make use of already existing urban system. The use of these existing system makes it possible to expand circular thinking in the neighbourhood without the need for high investments. In this example, the local street markets and nearby already existing thrift shops provide a perfect system to collect and sell products.

In the neighbourhood itself, the proposed waste collection stations in chapter 11.4 and 11.5 can be expanded to create workshops where products can be repaired and refurbished (figure 100). The treatment facility should be developed in collaboration with the residents. Through rewarding mechanisms, the residents cna be provided with funds to further develop their own circular location. For instance, vegetable gardens can be added where the local composted biowaste comes to use. Other options are to invest the rewarded funds in improving the condition of the public space or the organisation of community strengthening activities, like a summer party, or providing Dutch language courses to help the residents with a ethnic background to integrate within the Amsterdam community.

12.3 Increasing number of waste stations

To expand the network of waste collection points even further another proposals are made. These two proposals are focussing on determining locations where new drop off points could be placed. The allocation is based on making connections to already existing urban system (figure 101). The first proposal is the connection of waste stations to sport fields and their related activities. The second type of location is the synergies that can be made with the educational system. Making these connections will help to integrate waste even further into our daily lives. Waste becomes in this way valuable in multiple ways.

Relating waste to sport activities

Sport clubs form most of the time close communities. Residents from the surrounding neighbourhoods come together every weekend to play games for themselves or cheer for their children. It would be an ideal location to make a waste collection point since sport fields are most of the time just outside of the urban environment and can easily be reached. Linking waste to sport clubs is not something new. In the Netherlands it is quite common for sports clubs to collect for instance paper in a container, which can be sold and used as a profit to sustain or expand the sports activities. Linking a waste collection station to a sport club, who will maintain it, can profit the sports club. Residents will deliver their waste at that location when they know the benefits will be for the sports fun of their children. The facility could also include a workshop where residents can help each-other fixing their products, or people can perform their hobby and refurbish products which can be sold again.

This is a great example of how waste could or even should be linked to already existing structures. The existing structures maintain the functioning of the system and the community can profit from the waste related activities. When residents can experience how their change in waste disposal behaviour can benefit the community, it is more likely they keep on changing their behaviour in a positive way.

Waste for educational use

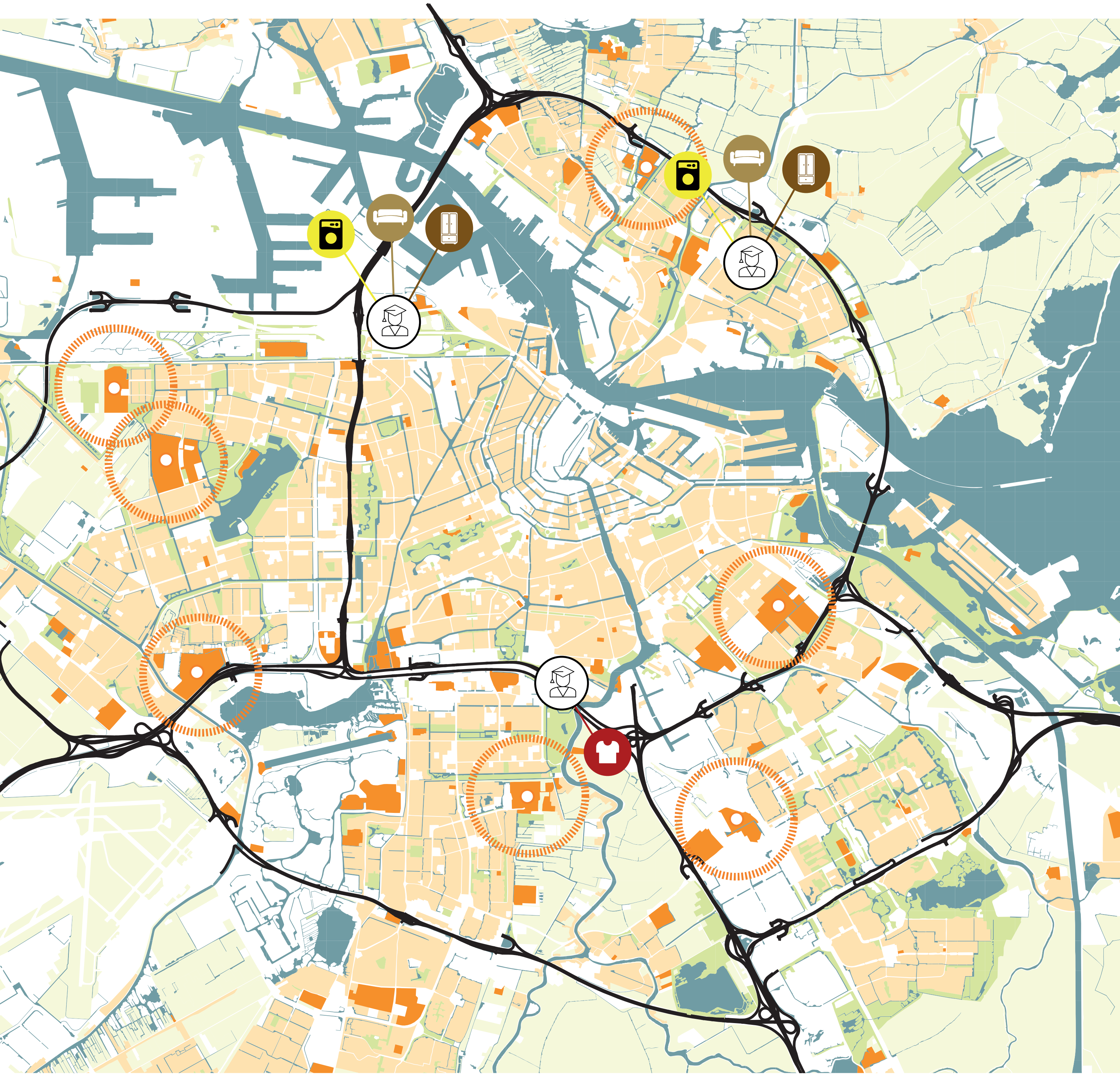
The second proposal is linking waste treatment to education. In the Netherlands, it is expected that there will be a shortage of people with manufacturing skills (Telegraaf, 2017, December 4). For a circular economy to function it is important to have enough people with knowledge about materials, products and especially their value. More people need to be educated to make sure in the future there are enough professionals which can repair and refurbish our products. Linking waste stations to already existing education in electro-engineering and furniture making brings possibilities to teach these students about circular economy. The students can use the waste as a resource for their school projects, can get education about materials and can be taught how value of waste can be determined. Students can operate the waste station and apply their gained knowledge in practice.

Figure 101
Possible locations for waste points in Amsterdam
Related to the connection to sport activities and the educational system.
(Image by author)

Sportfields

Waste points attached to sportfields

Waste points attached to educational facilites and the related eduaction in waste flows



13 Conclusions: recommendations for Amsterdam

The goal of this thesis was to propose a new integrated system for improving the collection and treatment of residential waste in Amsterdam. The new systems are based on circular principles and create a scientific link between the conceptual circular economy and practical profession of urban design. By looking back at the defined problem statement and set objectives, this chapter discusses the outcomes of the research. Conclusions will be drawn on a scientific level and recommendations for the city of Amsterdam will be outlined. This way, the conclusions of this thesis can be used within the further developed of Amsterdam as a circular city. In chapter 14, a reflection is given on the executed research and design proposals. This reflection results in recommendations for further research.

13.1 Contribution to scientific discussion

As described in the theoretical framework, knowledge is absent on the translation of circular concepts into spatial systems that are able to integrate in urban environments. The goal was to create a link between circular economy theories and urban design to better understand the spatial impact of the circular transition. The well known circular framework of the Ellen Macarthur foundation was used to develop a framework to evaluate the level of circularity of the waste treatment in Amsterdam. This framework contributed to defining potential enhancements. New circular diagrams of innovative waste treatment systems could be made which showed improved forms of treatment to create improved circular systems.

The next step was to translate these new concepts into a spatial system. By looking at the necessary facilities for these new ways of treatment, spatial elements were developed. These facilities weere described as the nodes of the new system where waste is compiled or treated. This translation made it possible to investigate where links to other urban systems and environments could be made. The characteristics of the different facilities were described and for some facilities the potential for integration within the urban environment was determined.

The question in the end is if a new valuable method is created. The method is based on a very simplified version of a waste treatment system of a city. Besides that, does the method make use of a world wide well known model of circular economy, developed by the Ellen MacArthur foundation. This makes the method easy to understand and explains how circular economy can influence other urban systems. The method eventually shown is especially useful for the policy and decision-makers, as they get an improved understanding of the spatial consequences and opportunities a circular economy brings.

13.2 Design outcomes and recommendations for Amsterdam

The goal related to this research objective was to show how the developed systems could be integrated within an urban environment. Amsterdam was the case study area where an improvement for the residential waste system was needed.

Amsterdam is highly ambitious and wants to be among the leading circular cities of Europe. By experimenting and conducting detailed research on waste flows, the municipality tries to find circular solutions in facilitating urban development. In 2020, 65% of the residential waste flow should be collected in separate homogeneous waste flows. This goal has definitely not been reached. Amsterdam faces multiple spatial challenges concerning the integration of waste collection infrastructure. In the city centre, no waste collection infrastructure is available and waste points throughout the city are under pressure by housing development projects. Besides the lack of collection possibilities, the treatment of some waste flows can still be improved and made more circular.

For that reason, this thesis presented proposals on how more collection options in Amsterdam could be created and how waste treatment can be made more circular and integrated within the city. These proposals provide a wide range of possibilities and some crucial recommendations for the municipality can be drawn. These recommendations can be used when further developing the residential waste system of Amsterdam and should lead to a more diverse and better anchored system within the society. Links with other urban systems have to be made to create a real progressive circular city, which is ready for the future and a global example on how residential waste systems can be enhanced in terms of circularity. The conclusion of this thesis is in this way in line with the statements by Murray et al. (2017). Real sustainability can only be achieved when making changes within the three pillars of our society: social, economic and environmental. These pillars should be the core of every circular urban solution that aspires to create a society dedicated to sustainability. From the proposals the following main recommendations can be derived:

The value of local treatment

Research has made clear that circular economy and new circular treatment methods have economic value. However, this value is most of the time expressed in money and related to larger scale treatment facilities. A major conclusion that can be drawn form the proposed solutions is the creation of value in different ways than just monetary value. The creation of a more sustainable and circular society is maybe more important compared to the economic benefits. Small scale and local treatment of waste may not have the highest economic benefits but has high value in creating awareness and showing the benefits on a societal and environmental level. By investing in local treatment methods, residents are able to experience circular economy and they will see the value of reusing and recycling waste. Bringing these processes closer to the people will contribute to the creation of a more sustainable society. Changing the daily habits of the citizens will support the transition and will result in a complete circular city. When the whole city is in support of this transition n and together progression is made, a real circular and sustainable city is created. A balance has to be found between profits and benefits, nevertheless, the municipality should also consider other values apart from economic benefits.

Investment in infrastructure

The municipality recognizes the importance of waste collection infrastructure which is available for all the residents of Amsterdam. In some areas of Amsterdam, access to these infrastructures is lacking. Within this

▶ *Continuing page 160*

13
Conclusions: recommendations for Amsterdam

thesis, multiple options are shown how collection infrastructure could be integrated in areas with limited space. By looking to other possibilities compared to the conventional street containers, options arise to make waste collection infrastructure accessible for all the residents. In the city centre of Amsterdam, high investments are needed to facilitate this. However, by making these investments and by making connections to ongoing research projects like Roboat, these new infrastructures show the serious ambitions the city has. These investments do not only make collection infrastructure available everywhere in Amsterdam, it also shows the capacity to find smart urban solutions. These investments will make sure Amsterdam stays one of the leading cities in the world in the circular transition and it will become an example to cities around the world. By doing a serious one-time investment, Amsterdam can show in this way the real eager and progressiveness of the city.

These investments also include the expansion of waste collection points to make it more easier for residents to dispose their waste. When the network of drop off points is expanded, less waste has to be picked up, which will reduce the amount of waste transportation in the city. Multiple options for increasing the number of waste points are given within this thesis. There are multiple options on different scales, with different objectives and profits. These proposals can be of inspiration when looking for new implementing solutions. They definitely make clear that certain forms of residential waste treatment can happen within the city borders. Waste is not inextricably linked to industrial areas and it can be valuable for the city.

Motivating residents by rewarding

Within the future plans concerning the improvement of waste collection, the municipality speaks of the possibility to reward residents when less residual waste is being disposed. Rewarding residents can be a great motivation to foster the awareness onsustainability and increase the separated collection of residential waste. When creating the proposals for a better collection system these ideas also popped up. Experiments should start where the disposal of waste is being monitored. Especially in areas where waste collection can be organized on a housing block level, it becomes possible to monitor the disposal habits of residents. By organising this system per housing block it becomes possible to reward this group at the same time. The forming of communities may occur, in which residents encourage to separate collection of waste and reduce the generation of waste. The municipality itself proposes a system where residents have to pay less for the waste disposal when improvements are being made. However, this rewarding could better be done on a communal level. By rewarding a whole housing block by offering money to improve the public space in their area or to organize a street party during summer, the rewarding also contributes to the creation of a stronger community. In this way, waste becomes not only a resource in a material way, but also a resource for strengthening communities.

Linking waste to existing urban systems

The contribution of waste collection to the creation of stronger communities may occur in multiple ways. As mentioned before, waste treatment on a local scale can have more value than just economic. By making the connection to already existing communal system throughout the city, a more vibrant treatment is created and communities can experience this value. Within this thesis, proposals were made for connecting local treatment of waste to already existing urban systems. Making links to education, local markets and sport accommodations can strengthen communities. The community can experience the value of waste, make a contribution to the community by improving their disposal habits and participate in circular treatment activities. A new waste treatment system should not be an isolated system, controlled by the municipality. It should be part of the society and integrate within the current urban systems that make the city. In this way waste treatment contributes to the city in an economic, social and environmental way, which are the three pillars of true sustainability.

New management structures for waste systems

The connection to existing urban systems also creates new possibilities for organizing and managing waste treatment. Communities can be in charge of their waste disposal to a certain level. By making communities on a lower scale responsible for their own waste disposing and by implementing reward systems, local waste collection and treatment can be organized by the residents themselves. In doing so, costs can be reduced and profits for residents increased.

Supporting local initiatives

The local treatment of waste and the supporting of local communities is not to be directed completely top down. To make this processes reality, there should be a certain initiative form the residents themselves. The municipality already states within their future waste collection vision that local initiatives should be supported more. This should not stay at the level of just supporting. The municipality can create initiatives together with residents. By combining rewarding mechanisms with initiatives, residents can be stimulated to continue their enhanced waste collection efforts. Local resident groups should be able to create a collection plan adjusted to their needs and with their own ambitions. This can include local biowaste treatment, or the need for more or better placed waste containers. By talking to residents and asking what kind of improvements they would see could be the key to success. This way, waste collection and treatment is adjusted to the circumstances in every neighbourhood and also rewarding can be adjusted to the needs of the residents.

Reversed collection of residential waste

Preference should be given to the desired homogenious waste flows compared to residual waste. Residual waste will not be eridicatd completely. When positioning waste collection infrastructure, or applying new collection methods, this principle should be taken into account when allocating the needed infrastructures. In this way, residents are motivated and in some way forced to separate their waste.

Port of Amsterdam as a circular cluster

The municipality of Amsterdam should try to attract new circular waste treatment companies to the Port of Amsterdam. In this way, sustainable economic activities are attracted and all waste produced within the city can be treated within the region.

These recommendations contribute to achieving the set goals and create more value on multiple scales. Some recommendations require large investments and probably long term planning. Nevertheless, some recommendations can already be applied on a short term. Small scale local initiatives and the promotion of these initiatives in Amsterdam do not require high investments or long term planning. On a small scale, first steps towards a more circular city and society can already be made. However,, for these future steps, more search needs to be conducted on different topics. In the next chapter some crucial recommendations for further research will be given. This total list of recommendations creates a solid future plan on how circular waste treatment and collection actually can be improved.

14 Reflection

Within this final chapter a reflection is given on this thesis. The reflection will consist of a critical view towards the conducted research and the eventual design proposals. Within the first part the expected scientific relevance and design proposals will be discussed. This will include limitations of this thesis and the resulting recommendations for further research. The second part will be a personal reflection on how this thesis connects to the chosen research group, its methods and how I personally developed this thesis within the chosen research group.

14.1 Reflection on the conducted research and design proposals

The goal of this thesis, from a scientific perspective, was to create a method which translates conceptual circular thinking into spatial systems. By doing this, the spatial effects of circular economy would become more visible and integration possibilities within urban environments easier to find.

In my opinion, I did contribute to this scientific discussion. By creating a simple method which translates conceptual systems into physical nodes, a link between circular economy and urban design has been made. However, this was just one of the first steps in creating a solid method. Because of the high complexity of urban systems and a wide variety in types of waste, it was difficult to formulate a method which applies to all cases. During the processes, the different systems needed to be simplified to make the research possible within the time frame. By choosing for a wide scope and addressing multiple waste flows, details in the research got lost. However, in my opinion, choosing for a wide scope created a nunderstanding of the complexity of the systems and still created an understandable method which shows multiple solutions and improvements. By translating the known concept of circular economy by the Ellen MacArthur foundation, I think I especially created a method which can be understood by a big audience. It shows the essence of linking circular economy to urban environments and urban design. In my opinion does this thesis particularly increase the understanding of spatial effects of circular economy. In this way it forms a good base for policy makers and researchers to analyse these effects in more detail. This thesis shows that a link between circular economy and urban design can be made. Circular economy concepts can be input for sustainable urban designs and urban design can implement circular concepts. Even though a link has been made, I think this method should be applied more to get a better understanding of the links between both professions. By doing, most can be learned.

From a societal perspective does this thesis contribute to questions raised by city concerning sustainable urban growth. The question remains if these proposals for Amsterdam would really work, and that question remains unanswered. In the research the actual effects of the different proposals on the waste system remain unclear. In my opinion it is especially a story that could inspire policy makers at the municipality to rethink the use of waste and think in other systems. It could also help to make policy makers familiar with systemic thinking and how different flows can be combined and synergies can be created. The proposals led to more general recommendations for Amsterdam. These recommendations can be used in further development of policies and vision concerning waste treatment and collection. In this way, the main message is not the created proposals and the need to execute them. The main message of this thesis are now these recommendations which will help to continue and speed up the transition of Amsterdam This thesis could lead to more awareness on what the different options are to recycle waste. They can get inspired by the idea of maintaining the most value of the product of material before disposing it. For the design of actual solutions and how they could be implemented, more research is needed, especially on the actual contribution to the problem in the form of data and figures which suggest improvement.

A total re-configuration of the treatment system is in my opinion unrealistic. However, some aspects could be translated to the city and maybe it can be of inspiration for making Amsterdam more sustainable and circular. Solving in this way a part of the problems around depleting resources.

Recommendations for further research

The research conducted in this thesis had a wide scope and for this reasons for a lot of parts limitations arise. Within this thesis, the problem was approached from a systemic perspective. Due to this perspective, other important aspects of creating a circular city have not been addressed. However, during the process of creating proposals and implementing the systemic designs, interesting recommendations could be created (chapter 13). These recommendations include proposals on a social, economic and environmental level. To be able to continue with this recommendations in Amsterdam, I propose the following recommendations for further research:

The value of circular economy

As explained within the theoretical framework, circular economy is at the moment mainly a sustainable business model. This results in the fact that profits for larger business and companies are quite clear. In the recommendations for Amsterdam comes forward how important the value of circular economy is on a lower scale, related to residents. When the value can be experienced by the residents itself, circular solutions have a higher chance of success and can contribute to a more circular society. For that reason, methods should be developed on how residents can experience the value of this economy directly. By looking into rewarding and monitoring systems, residents can be motivated and persuaded to change their behaviour regarding waste collection and treatment. In other words, I recommend the further investigation of how the value of circular economy can be translated to the residents and how they can experience the value to persuade and motivate them. Experimenting with rewarding and monitoring systems could lead to valuable information on how residents can be motivated

▶ *Continuing page 164*

14
Reflection

Adapted waste treatment and collection

At the moment, a unilateral waste system is applied to Amsterdam. Street containers are the norm and is seen as one of the main options. However, experimenting and supporting local initiatives already made clear that a lot of improvement can be made when the waste system is adjusted to the needs of the residents. Local composting of biowaste is one of those examples. Amsterdam knows a lot of different types of neighbourhoods, with a wide diversity of residents. Not only the spatial characteristics of the neighbourhood determine the possibilities for integration waste collection infrastructure. The motivational reasons or restrictions experienced by the residents should be taken into account. Hence, I recommend the continuation of research on resident's motives for potential adhering to separating waste or not. In this way, local initiatives can be created with the support of the municipality to create waste systems adjusted to the needs of the residents. A tailored waste system (within a certain bandwidth) will contribute to a changing society. These adjustments can be combined with new forms of rewarding the residents for improvement.

Monitoring, calculating and predicting

Amsterdam has been experimenting with circular solutions and local initiatives for many years. As stated in the recommendations larger investments are needed to make an actual change. More research is needed on the actual effects of these large investments. Estimations should be calculated on what kind of improvement is to be expected. With this crucial information, Amsterdam can stop experimenting and start investing in the future. New methods should be created on how the impact of circular solutions can be determined as a burden of proof for implementation and justification of the costs.

This new method also includes the development of more advanced monitoring systems which can also provide feedback to the residents directly. In this way, residents gain insight in their waste generation and directly see any progression made.

Linking to other professions

This thesis tries to make a link between circular economy and urban design. The proposals are created from an urban design perspective, thinking mostly about integration within the public space. However, waste collection and treatment systems are not limited to the available outdoor space. Waste separation starts within the residency itself. This requires solutions on an architectural and interior design level to create possibilities for separating and storing waste easier within the building itself. This will require a connection between urban design, architecture and interior design to create one system dealing with challenges on different scales and in different domains. Research on finding residential waste solutions should be done by a combination of professions, trying to improve the complete waste 'production' line from generating till treatment. This also include industrial process to reduce the production of waste and industrial ecology to create circularity between treatment facilities and making connections to the city. The challenge of reducing and recycling residential waste needs an approach supported by a wide range of professions. Urban design alone is not able to solve all outlined issues.

14.2 Personal reflection on work process

This part of the reflection consists of a more personal reflection on the provided work and the process over the last year. It reflects on the relation to the chosen research group and how a contribution has been given.

Relation between research and design

The combination of performing research and making spatial translations through design is according to me the most important goal of writing a thesis within the master track urbanism. Within my thesis I tried to translate theoretical concepts, like circular economy, to spatial interventions and its integration within urban environments. The ultimate goal was to provide a method to turn a more economic and technological driven theory in a spatial challenge. Research played a big role in understanding the characteristics of circular economy, getting the right data to make implementation possible and finding simple methods to translate a systemic theory in spatial interventions. At first I did not really believe in the concept of research by design and design by research, since everyone is just using this term without even being possible to explain what it exactly means. However, I think I got a better understanding on how design can contribute to research. In the end I even think I had to use a design thinking even more within the research process. Design is a great tool to test your findings from research or created methods based on theoretical information. The feedback you get by implementing and designing the method can enrich your method since you get more knowledge on integration of the method and the aligning with the bigger urban system. It eventually led to interesting recommendations which are not related to systemic design but relate to other more social subjects.

My personal reflection on combing research and design is that I should have used it more. The alteration process was present within my thesis, but because of the complexity of understanding the whole system at once, it would have been more valuable to integrate design processes within the research in an earlier stage. My biggest pitfall was trying to understand the complete circular economy system at once. It was hard to create a complete new system at a conceptual level. Probably, in between steps where I would have tried to implement the system within the city of Amsterdam and used the feedback I got from the implementation, would have helped to understand the system.

So, one of the biggest things I learned from this thesis that it is almost impossible to understand a whole complex system at once. In between reflections and connections to the real world are necessary to get valuable input. However, I think I made a good attempt to connect theoretical perspectives and research to spatial challenges and design. Eventually, it resulted in a thesis which has a more research and conceptual character, instead of ready to use design workout in detail.

The connection, and contribution of this thesis to the Smart Cities and Urban Metabolism research group

Originally, my motivation to graduate at the research group of Smart Cities and Urban Metabolism was based on my personal interest in the concept of circular economy. My interest within this subject started by running an internship at the municipality of Amsterdam where I was part of a team which investigated the potentials of circular economy on a regional scale. This project, called Westas, introduced me to this for me unknown concept. During my internship I was given the opportunity to experience the way policy makers approach such new concepts and what the challenges from practice are.

14
Reflection

Within my thesis I aimed to deal with these challenges derived from my experience in practice. I commenced with a research proposal which tried to deal with these challenges, which were mainly about industrial processes and governance structures. After a long period of trying to find my focus and limiting the scope of my thesis the realisation came that I was leaving my field of expertise (urbanism). The thesis had little spatial relevance and became a research proposal which suited more the field of industrial ecology.

A more intensive collaboration with the chosen research group helped me to redefine my project, where my knowledge gained within the master of urbanism was present again. Presentations I gave in front of the whole research group and especially a stronger involvement within the REPAiR research helped to reconnect to the chosen research group. By being involved within the REPAiR research I got (re)inspired by used methods like geo-design and systemic design. During a trip to Naples and helping out with their contribution to the landscape triennial and other REPAiR related workshops I had the chance to practice these methods and learn how they could benefit my own thesis project. Since REPAiR is performing their research on Amsterdam (one of six case studies), my stronger involvement helped to understand Amsterdam better in relation to my thesis.

Because of this stronger involvement, I think my thesis got a stronger connection to the focus of the research group. I had a refocus on the translation of circular economy in a spatial way, which is strongly related to combining urban metabolism and urban design which is a focus point of this research group and previous graduation projects within this graduation lab.

Used methods and the relation to the research group

As explained in the previous part, I gained a lot of knowledge about different methods used and researched by the research group of Smart Cities and Urban Metabolism. This applies the most to designing in a systemic way and applying the system in a context through geo-design and integration through urban design. I got to know this knowledge by participating in the elective *'Geo-design for a Circular Economy in Urban Region'* organised by my graduation mentors. Eventually, this became the cornerstone of my graduation project.

Final personal remark

At last it is time to give an overall personal reflection on my work and process. I think I addressed an interesting and relevant topic, where I reduced the gap between research and practice a bit smaller. However, for a master thesis it would have been better to try to limit the scope even further. By spending almost half a year on finding the right focus, I think I eventually did not succeed in limiting the scope enough for a master thesis. My enthusiasm and drive to try to understand the circular economy as a whole and trying to create a complete city model, caused in my opinion a thesis which lacks a bit of detail.

Nevertheless, I think when people read this thesis, they will be inspired, or at least rethink their use of waste. In this sense I think I contributed something to society, and makes me happy with the end result.

'Only if societal needs are defined and included in the basic formulation, can we hope to build on all three pillars of sustainability. This needs urgent attention in the Circular Economy conceptual framework'

(Murray et al., 2017)

References

Agentschap NL (2012) Rapportage Green deal duurzaamheid vaste biomassa. Den Haag: ministerie van infrastructuur en milieu

AMS (n.d). AMS Roboat. Retrieved from http://www.ams-institute.org/roboat/

Ayres, R. U., Ayres, L. (2002). A Handbook of Industrial Ecology. Edward Elgar Publishing.

Barles, S. (2010). Society, energy and materials: the contribution of urban metabolism studies to sustainable urban development issues. Journal of Environmental Planning and Management, 53(4), 439-455.

Bastein, T., Rietveld, E. (2016) Circulaire potentie voor Utrecht. Den Haag: TNO

BBC (2011) Global resources stock check. Retrieved from: http://www.bbc.com/future/story/20120618-global-resources-stock-check

Berghauser Pont, M., Haupt, P., & Camp, D. (2010). Spacematrix : Space, density and urban form. Rotterdam: Nai.

Blok, K., Hoogzaad, J., Ramkumar, S., Ridley, A., Srivastov, P. Tan, I., Terlouw, W., Wit, M. de, (2016) Implementing circular economy globally makes paris agreements achievable. Circle Economy & Ecofys.

Bueren, van E.M (2012). Introduction. In E.M. van Bueren (ED) Sustainable urban environments: An ecosystem approach (pp. 1-13). Dordrecht: Springer.

Boulding, K. E. (1966). The economics of coming spaceship earth. In H. Jarret (Ed.), Environmental quality in a growing economy. Baltimore, MD: John Hopkins University Press

Buurtcompost (n.d.) Wormenhotel Amsterdam. retrived from http://buurtcompost.nl/

CBS (2016) Winning, invoer en uitvoer van materialen naar soort; nationale rekeningen. Retrieved from www.statline.cbs.nl

Centraal Planbureau (2017) Meer plastic inzamelen levert beperkte milieuwinst: innovaties geboden. Retrieved from https://www.cpb.nl/persbericht/meer-plastic-inzamelen-levert-beperkte-milieuwinst-innovaties-geboden

Circle Economy (2017) Circulair Noord-Holland. Amsterdam: Circle Economy

Cirkelmarkt (n.d.) Cirkelmarkt. Retrieved from cirkelmarkt.nl

Commoner, B. (1971). The Closing Circle: Nature, Man, and Technology. New York: Random House.

Conticelli, E., & Tondelli, S. (2014). Eco- Industrial Parks and Sustainable Spatial Planning: A Possible Contradiction? Administrative Sciences, 4(3), 331–349. https://doi.org/10.3390/admsci4030331

Ellen MacArthur Foundation (n.d.) Circular Economy System Diagram. Retrieved from https://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram

Ellen MacArthur Foundation (2012) Towards the circular economy: Economic and business rationale for an accelerated transition. Retrieved from: www.ellenmacarthurfoundation.org

European Commision (2014) Towards a circular economy: A zero waste programme for Europe. Brussel: European Comission.

European Commision (2015) Closing the loop - An EU action plan for the Circular Economy. Brussel: Europen Commision

Feng, Z. 2004. Circular economy overview (in Chinese). Beijing, China: People's Publishing House.

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? Journal of Cleaner Production, 143(Supplement C), 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Gemeente Amsterdam (2015a) Duurzaamheidsagenda. Retrieved from https://www.amsterdam.nl/bestuur-organisatie/volg-beleid/agenda-duurzaamheid/

Gemeente Amsterdam (2015b) Amsterdam circulair: een visie en routekaart voor de stad en region. Amsterdam: Circle Economy, TNO & Fabric

Gemeente Amsterdam (2015c) Afvalketen in beeld, grondstoffen uit Amsterdam. Amsterdam: Gemeente Amsterdam

Gemeente Amsterdam (2016a) Circulair innovatieprogramma 2016-2018 met doorkijk naar 2025. Retrieved from https://www.amsterdam.nl/wonen-leefomgeving/duurzaam-amsterdam/publicaties-duurzaam/circulair/

Gemeente Amsterdam (2016b) Uitvoeringsplan afval. Retrived from www.amsterdam.nl/afval

Gemeente Amsterdam (2017a) Roadmap circulaire gronduitgifte. Retrieved from https://www.amsterdam.nl/wonen-leefomgeving/duurzaam-amsterdam/publicaties-duurzaam/roadmap-circulaire/

Gemeente Amsterdam (2017b) Meerjarenplan fiets 2017-2022. Retrieved from www. amsterdam.nl

Gemeente Amsterdam (2017c) Kerncijfers buurten, 1 januari 2017. Retrieved from https://www.ois.amsterdam.nl/feiten-en-cijfers/

Gemeente Amsterdam (2017d) Gebiedsanalyse 2017, 6. Geuzenveld-Slotermeer-Sloterdijken, Stadsdeel Nieuw-West. Retrieved from https://www.ois.amsterdam.nl/feiten-en-cijfers/

Gemeente Amsterdam (n.d.) Food centre, herstructurering. retrieved from https://www.amsterdam.nl/projecten/food-center/

Gemeente Den Haag (2015) Den Haag duurzaam agenda 2015-2020. Den haag: Gemeente Den Haag.

Gemeente Rotterdam (2015) Duurzaam dichterbij de Rotterdammer. Rotterdam: Gemeente Rotterdam

Gemeente Rotterdam (2017) Rotterdam gaat voor circulair; visie en aanpak voor 2017. Retrieved from https://www.rotterdam.nl/wonen-leven/circulaire-economie/

Girardet, H. (1990). The metabolism of cities. In Cadman, D., Payne, G. (Ed), The Living City: Towards a Sustainable Future. Routledge (pp. 170-180) London, Engeland: Routledge

G-Star (n.d.) RAW responsibility. Retrieved from https://www.g-star.com/nl_nl/about-us/responsibility/sustainable-product

References

Hoornweg, D., & Bhada-Tata, P. (2012). What A Waste, A Global Review of Solid Waste Management. Washington: World Bank.

Hoornweg, D., Bhada-Tata, P., & Kennedy, C. (2013). Environment: Waste production must peak this century. Nature News, 502(7473), 615. https://doi.org/10.1038/502615a

IPCC (n.d.) Reports. Retrieved from http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml

Kennedy, C., Cuddihy, J. and Engel-Yan, J. (2007), The Changing Metabolism of Cities. Journal of Industrial Ecology, 11, 43–59. doi:10.1162/jie.2007.1107

Kennedy, C., Pincetl, S., Bunje, P. (2010) The study of urban metabolism and its application to urban design and planning. Environmental Pollution, 159(8-9), 1965-1973.

Lancaster, M. (2002). Principles of sustainable and green chemistry. In J. Clark & D. Macquarrie (Eds.), Handbook of green chemistry and technology (pp. 10–27). Oxford: Blackwell.

Lansink, A., Vries, H. de (2010) De kracht van de kringloop. Geschiedenis en toekomst van de ladder van Lansink. Druten: BnM uitgevers.

Leer, J.G.G. van der (2016) Zero waste Buiksloterham: an integrated approach to circular cities (master's thesis). TU Delft, Netherlands

Lyle, J.T. (1994). Regenerative Design for Sustainable Development. John Wiley & Sons. New York: Chichester.

McDonough, W., Braungart, M. (2002). Cradle to Cradle: Remaking the Way We Make Things, first ed. New York: North Point Press

Mathews, J. A., & Tan, H. (2011). Progress towards a circular economy in China: The drivers (and inhibitors) of eco-industrial initiative. Journal of Industrial Ecology, 15, 435–457.

Meadows, D.H., Meadows, D.L., Randers, J. (1972) Limits to growth: a global challenge. New York: Universe books

Meershoek, P. (2017, June 28) Amsterdam gaat in 2034 door grens 1 miljoen inwoners. Het Parool. Retrieved from www.parool.nl

Metabolic (2014) Circulair Buiksloterham. Retrieved from https://www.metabolic.nl/projects/circular-buiksloterham/

Metropoolregio Amsterdam (2016) Ruimtelijke economische actieagenda 2016-2020. Retrieved from https://metropoolregioamsterdam.nl/pagina/20170226-mra-agenda

Metropoolregio Rotterdam Den Haag (2016) Roadmap Next Economy. Retrieved from www.mrdh.nl

Murray, A., Skene, K., & Haynes, K. (2017). The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. Journal of Business Ethics, 140(3), 369–380. https://doi.org/10.1007/s10551-015-2693-2

Newman, P.W.G. (1999). Sustainability and cities: extending the metabolism model. Landscape and Urban Planning, 44 (4), 219–226.

NOS (2018) ‘Is het echt nodig om 250 verschillende soorten plastic te gebruiken?’. Retrieved from www.nos.nl

NS (n.d.) Upcycleproducten. Retrieved from https://www.ns.nl/over-ns/duurzaamheid/recycling/upcycleproducten.html

Oswald, F., Baccini, P., Michaeli, M. (2003) Netzstadt: Desigining the Urban. Basel: Birkhauser Verlag AG

Pauli, G.A. (2010). The Blue Economy: 10 Years, 100 Innovations, 100 Million Jobs. Paradigm Publications, Taos, NM.

het Parool (2017, January 9) Amsterdam is de snelst groeiende stad van Nederland. Het Parool. Retrieved from www.parool.nl

Het Parool (2017, September 30) Klimaatverandering bedrijgt Amsterdam en Rotterdam. Het Parool. Retrieved from www.parool.nl

Poel, van der R., Boon, L. (2015) Kuddedieren; over het toerisme in de hoofdstad. Retrieved from www.nrc.nl

Peters, N. (2016) De Westas als ruimtelijke werkplaats: groeicijfers en ruimtelijke effecten (unpublished). Rotterdam: ECORYS

Port of Amsterdam (n.d.) Biomassa. Retrieved from https://www.portofamsterdam.com/nl/business/vestigen-en-ladingstromen/biomassa

Port of Amsterdam (2017) Plan haven stad op gespannen voet met belangen haven. Retrieved from www.portofamsterdam.com

UN Habitat (n.d.) Energy. Retrieved from https://unhabitat.org/urbanthemes/energy/

ROVA (n.d) Wat is omgekeerd inzamelen? Retrieved from https://www.rova.nl/over-rova/pagina/3838/wat-is-omgekeerd-inzamelen

Ruz, C. (2011) The six natural resources most drained by our 7 billion people. The guardian. Retrieved from https://www.theguardian.com/environment/blog/2011/oct/31/six-natural-resourcespopulation

Raad van State (2013) Uitspraak 201206132/1/A4. Retrieved from www.raadvanstate.nl

Rijksoverheid (2016) Nederland ciruclair in 2050. Den Haag: Minestry of infrastucture and environement, Economic affaires, Foreign affaires and Home affaires & Kingdom relations.

Royalhaskoning (2014) Marktverkenning Biobased Economy in de GFT-sector. Retrieved from https://www.royalhaskoningdhv.com/en-gb/projects

Simmonds, P. L. (1862). Undeveloped substances: or, hints for enterprise in neglected fields. London: Robert Hardwicke.

Smol, M., Kulczycka, J., & Avdiushchenko, A. (2017). Circular economy indicators in relation to eco-innovation in European regions. Clean Technologies and Environmental Policy, 19(3), 669–678. https://doi.org/10.1007/s10098-016-1323-8

Stahel, W.R. (2010). The Performance Economy, second ed. Palgrave Macmillan. New York: Basingstoke.

Stahel, W. R. (2015) The business angle of a circular economy—higher competitiveness, higher resource security and material efficiency. www.slideshare.net/CircularEconomy/articl e-walter-stahel-oncircular-economy. Accessed 24 Jan 2016

References

Telegraaf (2017, December 4) Werkgevers: tekort vakmensen is acute bedreiging. De Telegraaf. Retrieved from https://www.telegraaf.nl/financieel/1388818/werkgevers-tekort-vakmensen-is-acute-bedreiging

Tjallingii, S.P. (1995). Ecopolis: Strategies for Ecologically Sound Urban Development. Leiden, Netherlands: Backhuys.

Tooms, B. (2017) Recyclen plastic afval heeft weinig effect op milieu. Retrieved from www.nrc.nl

VNG (2009) Handreiking bedrijven en milieuzonering. Den Haag, SdU uitgevers

van Gansewinkel (n.d.) Hergebruik en recycling. Retrieved from https://www.vangansewinkel.nl/afval-bestaat-niet/hergebruik-en-recycling

Westas (2015) Manifest: de Westas, daar draait het om. Amsterdam: Amsterdam Logistics Board

Wolman, A. (1965) The Metabolism of Cities. Scientific American, 213, 179-190

Zhang, Y., Yang, Z & Yu, X. (2009) Ecological network and emergy analysis of urban metabolic systems: Model development, and a case study of four Chinese cities. Ecological Modelling, 220 (11), 1431-1442.

Zhang, Y. (2013). Urban metabolism: A review of research methodologies. Environmental Pollution (barking, Essex : 1987), 178, 463-73. doi:10.1016/j.envpol.2013.03.052

Zhang, Y., Yang, Z., & Yu, X. (2015). Urban Metabolism: A Review of Current Knowledge and Directions for Future Study. Environmental Science & Technology, 49(19), 11247–11263. DOI: 10.1021/acs.est.5b03060

Yo, Y.S. (2015, July 5) Teck Ghee estate to get $38m 'green' makeover. Retrived from http://www.straitstimes.com/singapore/housing/teck-ghee-estate-to-get-38m-green-makeover

Yuan, Z., Bi, J., Moriguichi, Y. (2006) The circular economy: A new development Strategy in China. Journal of Industrial Ecology, v. 10 (1-2), Camebridge: Massachusetts Institute of Technology and Yale University.

Data for creating maps and GIS analyses

GEO data base municipality of Amsterdam:
Gemeente Amsterdam (n.d.) Interactieve kaarten. Retrieved from maps.amsterdam.nl

BAG 3D Building data:
Kadaster (2017) 3D gebouwhoogte NL. Retreived from www.kadaster.nl

Figure source material

Google Earth
Google (2018) Google Earth. Retrieved from google.nl/earth

Icons by the Nounproject (paid license)
Nounproject (n.d.) Icons for everything. Retrieved from www.thenounproject.com

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