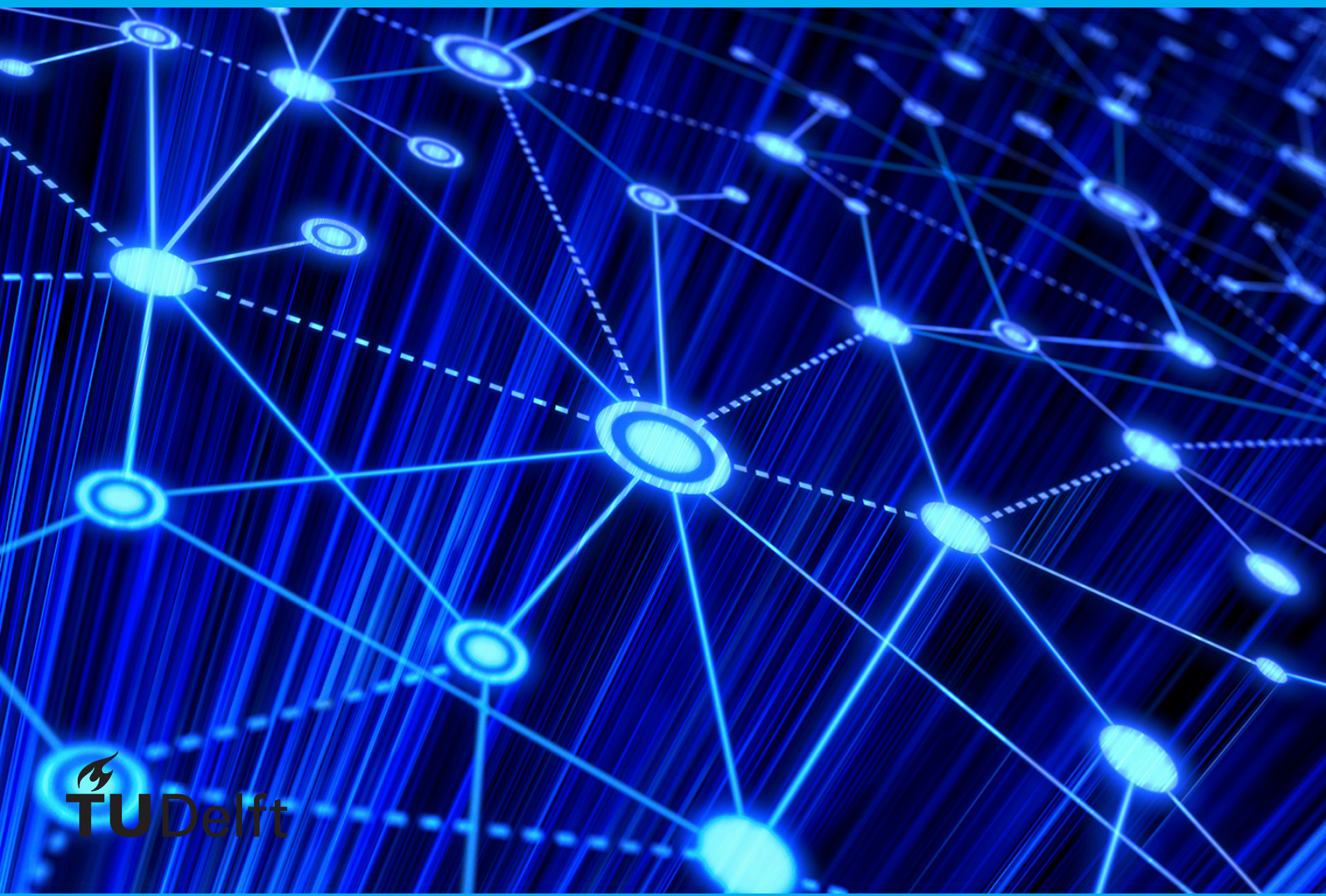
Property Rights for decentralized organic waste processing

An agent-based approach

Rudri Mankad



TU Delft

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by

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TU Delft

Preface

Dear Reader,

This thesis marks the end of my Master's in Complex Systems Engineering and Management. Although this is the formal end of my academic learning, my experience over the two years has shown that as long as one possesses the will to learn, it never really stops. Each day at the University was a new experience, and I will truly cherish the time I spent here. Sadly, the physical presence at the University was cut short due to the pandemic. In the midst of embracing the 'new normal' was my time to work on the thesis. It would have been more challenging than it was, had I not received the support from my thesis committee, family and friends.

This thesis was the most challenging academic experience of my life, and I am thankful to have received your guidance throughout this journey. I would like to thank Dr Rolf Künneke, the Chair of my committee for willing to be a part of it. Your help and guidance at the crucial junctures has been greatly beneficial to me, especially when I was feeling slightly lost. I am also grateful that Dr Amineh Ghorbani was my first supervisor. Thank you for your help with the critical comments, they pushed me to think further and truly helped me in my work. Thank you also for your immense support in the thesis formalities. Ir. Kasper, my daily supervisor, had been there to help whenever I required it, even if it was for the silliest of doubts. I really appreciate your willingness to help, and thank you for all the advice you gave. That too pushed me and gave me new perspectives for my work. I also thank the case study participants for their time and help in addressing that queries that I had with respect to it.

Thanks to all my friends in Delft for your help and company when I needed it. I will cherish these times always. Thanks also to my friends outside of Delft for your unwavering support. Finally, I would like to thank my parents and my brother for being there and looking after me, even when I am away from home. I will always be grateful to you.

Thank you!

Delft, September 2020

Summary

The increase in consumption of resources has led to more waste being generated, which then needs to be managed at the end of their life-cycle as waste. Current practices of waste management are not efficient as they lead to a release of emissions and a loss of value that is present in the resource, which is discarded as waste. New legislation for efficient waste management practices has been established, however, adopting them is hampered by factors, one of which is the high cost of these solutions. However, incentive-based approaches can be used to address this problem. This research explores the role of institutional incentives in the form of property rights bundles for such cases.

Property rights are a set of formal and informal rules that define how resource allocation is done, while property rights bundles are the set of one or more property rights tied together. As per academic literature, a clear allocation of property rights leads to an economically efficient distribution of costs, benefits, risks and responsibilities associated with a resource. Based on these aspects, this research explores the influence of property rights bundles in the case of collective ownership of waste processing infrastructure by companies. Through collective ownership of the infrastructure, the investment cost would be distributed among those using the resource, thereby reducing the share of investment per company and addressing the challenge of high investment costs. Furthermore, in this situation of collective ownership, property rights need to be defined clearly so that there are no conflicts among the participants at later stages.

The research is based on a case study of a few companies in Amsterdam, who are attempting to set up an initiative to improve the waste management practice in the region. For this purpose, they plan to invest collectively in a waste-processing infrastructure. This research thus explores the role of property rights in this regard.

The literature on property rights forms the theoretical foundation of the research, along with the Theory of Planned Behaviour, which is the behavioural theory chosen to analyse the decision-making of the companies. The case study was analysed using the Institutional Analysis and Development framework. An agent-based model was built based on the insights obtained from these concepts to capture the interaction between the property rights and the characteristics of the companies, such as the amount of waste generated by them, the amount of budget they hold, etc. The influence of property rights bundles was analysed using the attributes of property rights: robustness, strength, duration and excludability.

The results obtained were analysed using the defined Key Performance Indicators: Joining Ratio, Number of Participants and Number of times the initiative is started. It was found that for the case of the Amsterdam Zuidoost initiative, providing property rights bundles of claimants and proprietors as incentives leads to an increase in the number of participants that join the initiative. However, due to lack of statistical significance between the distributions, we cannot determine which of the two has a higher influence. Furthermore, the influence of the other property rights bundle could not be verified due to lack of statistical significance in the distribution.

From the perspective of general results, it was concluded that maximum participants join when incentive 3 (property rights bundle of Proprietors) is provided, followed by when all incentives (all property rights bundles in an increasing order) are provided, and finally when property rights bundle of Claimants is provided. The influence of property rights bundle of Authorised Users could not be verified. However, the influence of property rights bundles for the selected model and agent parameters is unknown, and more research is required to determine this relationship.

One of the foremost recommendations comes from the model outcomes that more research is required to explore the influence of property rights bundles with respect to the model parameters considered. This research does not take into account the property rights bundle of owners and it is recommended that future research includes this bundle to understand the influence of this bundle from a quantitative perspective. Furthermore, as property rights have not been studied from a quantitative perspective before, alternative approaches could be used to obtain more insights of this concept.

Contents

List of Figures

List of Tables

1

Introduction

This chapter begins by providing a background of the research problem in section 1.1. Following this, the research problem is discussed in section 1.2, and the research gap associated with it in section 1.3. The research objective and research questions are then specified (section 1.4) The approach taken for the research is presented in section 1.5, after which an overview of the report structure is given (section 1.6).

1.1. Background

Through the years, the world's demand for resources obtained from the natural ecosystems has increased. Humans are now consuming more resources than it is possible for the Earth's ecosystems to produce (Global Footprint Network, 2019a, 2019b). Consequently, there has been an increase in the volume of waste generated, which is projected to increase further (Kaza, Yao, Bhada-Tata, & Van Woerden, 2018). This has led to a search for more efficient ways of waste disposal. Conventional waste disposal methods such as land-filling are not favourable in the current situation as they lead to an increase in carbon emissions and prevent the recovery of value out of products at the end of their life (Kosseva, 2013). New forms of waste disposal such as incineration, anaerobic digestion and gasification provide means for energy recovery from waste (Ng, Yang, & Yakovleva, 2019; Panepinto & Zanetti, 2018).

There is an increased awareness on the potential of using waste as a resource (Pfaltzgraff, De Bruyn, Cooper, Budarin, & Clark, 2013; Rezzadori, Benedetti, & Amante, 2012) and this is reflected in the change in waste management practices globally, which encourages disposing of waste in a responsible manner. For example, in the European Union, the Directive 2008/98/EC has made it mandatory to collect waste separately where possible (European Parliament and Council, 2008). Following which, in the city of Amsterdam, the household waste and commercial waste is treated separately. The local municipality is responsible for handling the household waste, and proving separate collection containers for each waste type. However, the same is not true for commercial waste; as requirements for waste separation are not specified, and policies for waste collection are at a macro level (City of Amsterdam, 2020). This insufficient redressing of sustainability in policies for commercial waste management provides scope for further research, which is discussed in greater detail in the next section.

1.2. Research Problem

The existing policies for commercial waste management in Amsterdam are inadequate to address the sustainability aspects of waste management. Firstly, specifications regarding waste separation are not defined. Secondly, for private companies, waste management has been left to the market. This has allowed them to enter into independent contracts with waste collectors (City of Amsterdam, 2020). As a result, multiple waste collectors operate in the same region, leading to an increased congestion caused by waste collecting trucks and an increased carbon emissions due to redundant kilometres travelled (Amsterdam Zuidoost, 2016).

An alternative to the current centralised waste management is decentralised waste management. Some initiatives related to organic waste management include composting and waste recycling that are used in urban agriculture and small-scale decentralised energy generation (Cofie, Cofie, & Bradford, n.d.; Karagiannidis, Wittmaier, Langer, Bilitewski, & Malamakis, 2009; Voegeli & Zurbrugg, 2008). While decentralized waste management has advantages such as reduced emissions in waste transportation and in waste valorization (Ng et al., 2019), despite this, the initiatives for decentralised waste management remain limited to households. Existing research shows that an incentive-based model for waste management in the case of households improves waste management practices (Karkanias, Perkoulidis, & Moussiopoulos, 2016; Leigland, 2006). It is therefore of interest to see the applicability of incentive-based models to the case of commercial waste management.

In this research, an initiative by a small group of companies in the Amsterdam Zuidoost provides this opportunity for research. The objective of the initiative is to improve the inefficiencies in the current waste management arrangement, by installing a decentralised waste processing plant in the region. The organic waste stream from the neighbouring companies would be sent to the plant, which would be processed to give by-products, and sold in the market.

One of the attributes of decentralisation is localised ownership (Mangoyana & Smith, 2011), and this also applies to the case of the initiative. The waste processing plant would be collectively owned and managed by the companies participating in the initiative. As a result, financial resources would be required from these companies participating in the initiative for operating and maintenance of the plant. The investment required for this is significantly higher as compared to the current waste management fees paid to the waste collectors. Furthermore, the costs would have to be borne as an additional expense along with the operational fee of waste management. Although revenue would be obtained from the sale of by-products generated, this is unlikely to be of the same magnitude. The economic feasibility of similar decentralised waste management techniques has been a challenge (Domingues, Borges, & Garces Junior, 2012; Fuess & Zaiat, 2018).

Given the collective ownership structure of the waste processing plant, it is worthwhile to explore the possibility of institutional incentives in the form of property rights to this case. Efficient allocation of property rights has been associated with economic gains, and hence it would be interesting to explore them and their impact in this scenario.

1.3. Research Gap

Property rights define the actions that individuals can take with respect to a particular good or service (McGinnis, 2011). The concept of property rights has been discussed in literature due to its importance from an economics perspective. Property rights are necessary for the efficient allocation of scarce resources, and defining them is important from an economic perspective as this governs the economic behaviour and the result that emerges due to this behaviour (Coase, 1960; Pejovich, 1982, 1995 as

cited in Kim, 2005).

Although the initiative for decentralised organic waste processing in the case of Amsterdam Zuidoost is built on socially beneficial reasons and hence economic efficiency is not the primary objective, property rights are important to this case as well. This is because property rights can help determine the actions that can be taken with respect to resource use (North, 1986) and prevent conflicts that can arise due to unclear allocation of responsibilities when attempting to achieve a common objective. Property rights also affect technology adoption, as studied by (McCulloch, Meinzen-Dick, & Hazell, 1998). They consider the case of farmers failing to adopt technology that can result in alleviation of the problems faced by the farmers. One of the reasons for this failure is the absence of property rights and collective action. As per the authors, to increase the chances for technology adoption by farmers, incentives for adoption must be built into property rights and collective action institutions, information related to the technology must be provided and transaction costs for coordination and enforcement must be reduced (McCulloch et al., 1998).

The importance of property rights has been heavily discussed in common-pool resources literature. Allocation of adequate property rights to the communities can serve as an impetus to manage natural common-pool resources, as seen in the case of fisheries by (Schlager & Ostrom, 1992). Through existing literature, it is known that providing a more complete set of rights leads to greater involvement in the management of resources and also provides an incentive to invest in the resources (Schlager & Ostrom, 1992). This is true for the case of collective action in the case of management of common-pool resources, such as, forests, fisheries, etc. to avoid the tragedy of the commons (Agrawal & Gupta, 2005; Schlager & Ostrom, 1992; William, Brockington, Dyson, & Vira, 2003; Yan, 1991). This is also true in the case of management of other types of resources, such as land (Musole, 2009).

Considering their importance in collective activities, it would be interesting to see how property rights can be applied to other cases where their concepts can be deemed suitable. Furthermore, they have been explored from the perspective of provision of economic benefits, however they have not been explored from the perspective when economic benefit is not of priority. The case study of collectively-owned waste infrastructure, which requires investment from multiple parties provides such an example. The ownership of waste processing infrastructure from this perspective has not been examined yet and would form the focus of this research.

1.4. Research Questions

In order to address the knowledge gap, the focus of the research will be on understanding the role of property rights for the collective ownership of infrastructure. Although the initiative has a not-for-profit inclination, the economic aspects will be involved as participants are expected to contribute towards investment in the infrastructure. The profits derived from it will be determined by the distribution of property rights. Thus, the research objective is to understand whether property rights can incentivise participation of companies in decentralised initiatives. The incentive mechanisms considered are the different bundles of property rights, which will be institutional by definition. By providing these different bundles to the participating companies, their intent to participate and invest in the initiative will be studied. The research questions that can help address the research objective are provided in the next section.

To address the research objective, the main research question that will be answered is:

What is the influence of different bundles of property rights on the participation of companies in initiatives for organic waste processing?

This question is broken down into sub-questions, each of which is addressed through the course of the research to answer the main question.

1. What are property rights and how can they be formalised in the context of waste processing initiatives by companies?
2. How can we gain insights into the interaction and decision-making among actors to engage in initiatives for decentralised organic waste processing by companies?
3. How can we measure the effects of property rights in initiatives for decentralised organic waste processing by companies?
4. Which factors determine the effect of property rights on the initiative by companies for organic waste processing in the case of Amsterdam Zuidoost?

1.5. Research Approach

The theoretical concepts on which the research is based are first obtained. This includes property rights and the factors that influence the decision-making of companies, especially with respect to initiatives. The interaction among these aspects are of interest, as they could lead to outcomes which can help understand the role of property rights in the case when achieving economic benefits is not of primary importance. The insights obtained from the interaction are captured using an agent-based model. This method or approach is suitable here as it helps to study the interaction among various components, and the patterns that emerge as a result of the interaction (van Dam, Nikolic, & Lukszo, 2013). The insights obtained from the model are measured using the Key Performance Indicators, which are then discussed specifically with respect to the case study. The overall approach is depicted in figure 1.1.

1.6. Thesis Structure

The rest of the thesis report is structured as follows. Chapter 2 discusses the methodology followed and includes how each method is applied to this research. Next, Chapter 3 provides the theoretical foundation, including all the theoretical concepts used in the research. Chapter 4 aligns the theoretical concepts to a case study of Amsterdam Zuidoost. Chapter 5 describes the system and the conceptual model. This is followed by chapter 6 wherein the results of model verification and sensitivity analysis are presented. Chapter 7 contains information on the experiments carried out to generate data for the hypotheses. Chapter 8 presents the results of the data analysis of the model and validation. Chapter 9 includes a discussion on the model and the system modelled. Finally, chapter 10 concludes the report by summarising the answers to the research questions and providing suitable recommendations. A discussion on the relevance of research and its results to CoSEM program, and its contribution to the society and the scientific community is highlighted. Figure 1.1 depicts the research flow and the research questions discussed in each chapter.

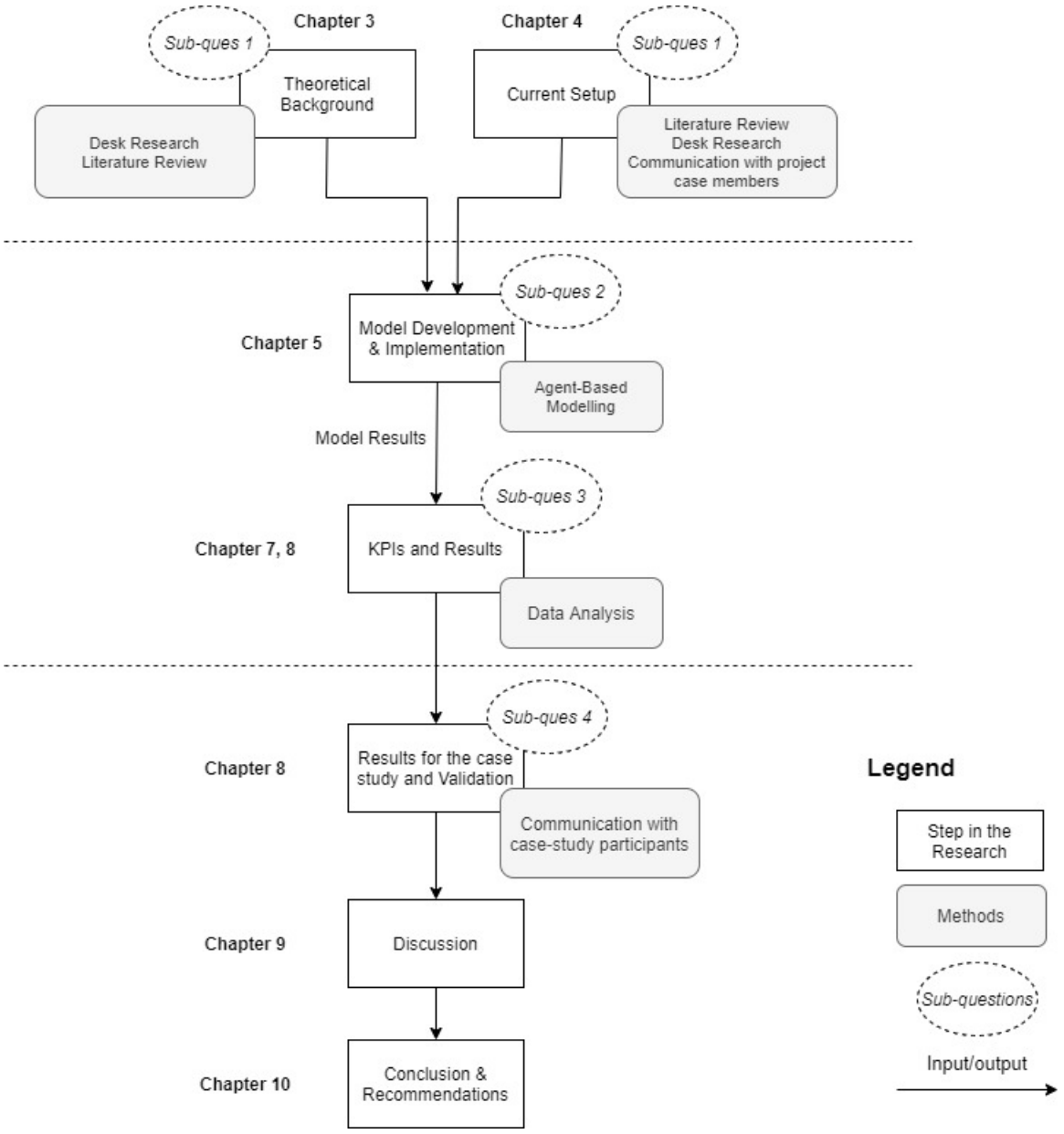


Figure 1.1: Thesis Report Flow

2

Methodology

This chapter provides information on the methodology followed in the research to answer the research questions. The use of literature review as a method is discussed in section 2.1, followed by the use of desk research is section 2.2. Agent-based modelling and its role in the research is discussed in section 2.3. Section 2.4 focuses on the case study used in the research.

2.1. Literature Review

A literature review was conducted to identify the existing research on property rights and their application in the case of collectively-owned infrastructures. The literature study was also helpful to identify how the components in the Theory of Planned Behaviour are applicable to the context of this research.

2.2. Desk Research

Desk research was conducted to obtain academic literature in the form of journal articles and reports on which to identify the knowledge gap, position the research in literature, identify the theoretical concepts applicable to the research and to connect them to develop the research.

Desk research was also used to obtain information on the case study and to build the model: such as the waste management policies applicable in Amsterdam, facts and figures on the amount of waste produced by companies in Amsterdam, the price range of the by-products from waste processing and quantity of by-products produced, etc. These values are discussed in Chapter 5, Model Formalisation.

2.3. Agent-Based Modelling

Agent-Based Modelling forms the core of the research, as it provides insights into the interaction among the model variables, which can lead to model outcomes interesting for the research. Agent-based modelling serves as a tool to better understand a system, its components and the interaction among them. It provides an opportunity to understand the functioning of the system ”in-silico”, by allowing us to consider a wide range of system properties and values which can prove to be inefficient and expensive in the real-world. It is a representation of a real-world system, with agents representing the social, autonomous entities that possess certain states and behaviours. Through the interaction among these

agents with differing properties at the independent level, macro-level patterns emerge which provide insights into the overall functioning of the system (Janssen, 2005).

In their work on agent-based modelling of socio-technical systems, van Dam et al. (2013) provide a guideline of ten steps to be followed in order to arrive at the outcomes. These steps were applied to the context of the research. Starting with formulating the exact problem to be addressed, the system boundaries were decided and actors relevant to it were identified. Based on the discussion and information obtained from interviews and desk research, a conceptual model was created. This model was then implemented in Netlogo (version 6.1.1), following which it was verified to ensure that it was functioning as required. Experiments that were designed to test the hypotheses were then run, and the data obtained from these was analysed to identify patterns and outcomes of interest. The results were validated with a few of the case study stakeholders. Data analysis was done in Python.

2.4. Case Study

To provide a realistic context for the research, a case-study was used. The initiative being undertaken by a few of the companies in the region of Amsterdam Zuidoost provides the case upon which the agent-based model was built. The initiative is being developed as a means to improve the waste collection and disposal practices for businesses in Amsterdam. It is explained in further detail in Section 4.1.

2.4.1. Interviews and Questionnaire

Interviews were held with the objective of obtaining information on the case study. Semi-structured interviews were held with a representative of the organisations participating in the initiative and the project leader of the initiative to obtain general information related to the initiative. For specific questions applicable to the companies in the initiative, questionnaires were sent out. Responses were received from one of the companies, and this information was used to validate the results obtained in the research.

2.5. Summary

This chapter discussed the methods which are used in this research. The research objective will be addressed by employing a literature review and desk research and will use information from the case study to develop the agent-based model.

3

Theoretical Background

This chapter sets the theoretical context for the research by explaining the main concepts that will be used to answer sub-question 1: What are property rights and how can they be formalised in the context of waste processing initiatives by companies? Property rights and related concepts are discussed in section 3.1. After having obtained insights into one of the theoretical concepts of the research, the next sections discuss the framework and theory that will be applied to understand the theoretical aspects of the case study: in section 3.2 a framework is chosen that will help identify the actors and other components important to this research and section 3.3 sheds light on the theory that will be used to capture the decision-making of the actors identified.

3.1. Property Rights

In this section, the main findings from a literature review completed on property rights are provided. This is followed by a discussion on the application of property rights with respect to the initiative.

3.1.1. Property Rights as an institution

The concept of property rights has been central to economics and has been discussed under neoclassical economics, organisational economics as well as institutional economics (Kim & Mahoney, 2005; Schlager & Ostrom, 1992). Over the years various definitions and meanings have been provided for the concept in literature. Musole (2009) defines property rights as a set of formal or informal rules, as they structure the allocation and use of resources among individuals. Libecap (1989) adds that property rights associated with a resource determine how these resources are used to earn income and transfer or exchange them. This implies that how resources are allocated (or not) can affect how individuals carry out activities related to the use or maintenance of the resource, such as investment in the resource or leasing it out for other purposes (Besley & Ghatak, 2010).

Property rights are also defined as the actions that individuals can take with respect to the use of a particular good or service (McGinnis, 2011). This includes the rights and obligations with respect to the use and management of the resource, the rules of exchange or contract, rules related to use of a resource in case of conflict among the rights of individuals (North, 1986). These rights can determine who takes decisions with respect to resource use, and define the incentives individuals face when they

hold claims against these resources (North, 1986). A key feature of private property rights is that of exclusion, i.e. users that are unauthorised are unable to access or use the resource (Besley & Ghatak, 2010). Thus, these rights can also restrict the rights of an individual or a group with respect to a resource or an asset (Mascia & Claus, 2009; Meinzen-Dick & Mwangi, 2009).

3.1.2. Why are property rights important?

As stated previously, property rights are directly related to economic gains, costs, risks, responsibilities, etc. If these rights are not clearly defined and allocated to specific individuals/groups, it could impact how these gains are allocated in the system. Lack of clarity could lead to positive transaction costs in assigning the resources and benefits, which could impact the economic productivity of the system (Teraji, 2008). As the goal of an efficient economic system is to reduce the costs, the property rights should be well-assigned and well-defined. In the case when multiple stakeholders are involved and the property rights are shared among them, it is even more crucial that these rights are allocated without any ambiguity so that benefits are allocated efficiently. This occurs also in the case of collective action, which as defined by Wade is the action by more than one individual, to achieve a common goal or to satisfy a common interest. Essentially, the goal or interest cannot be achieved by an individual acting alone (Wade, 1987). Property rights possess different components (discussed further in section 3.1.4) which give rise to the notion of shared ownership: these multiple components indicate that multiple individuals/groups can possess different components of rights to a resource (Kim & Mahoney, 2005), as in the case of collective action.

In addition, property rights are necessary for the efficient allocation of scarce resources, and defining them is important from an economic perspective as this governs the economic behaviour and the result that emerges due to this behaviour (Coase, 1960; Pejovich, 1982, 1995; as cited in Kim and Mahoney, 2005).

Jaffee and Louziotis (1996) in their work on property rights and economic efficiency explain that strong property rights reduce the uncertainty and risk related with the resource use in the long term. This, thus creates incentive for economic efficiency (Musole, 2009).

In Amsterdam Zuidoost, multiple companies are participating in the initiative to process organic waste in a decentralised manner. A waste processing infrastructure will be installed at the site, and all companies that collectively invest in the infrastructure can utilise it for their waste processing. Property rights are applicable in this situation wherein multiple parties are involved, and there could be a conflict among parties/actors with respect to resource use, thereby affecting the economic allocation of costs, benefits, risks and responsibilities (North, 1986; Wade, 1987).In the case of the initiative, the primary objective is to address a societal and environmental inefficiency, caused by the current way of commercial waste management. The participants do not expect economic gain, however, other forms of economic aspects are involved for which well-defined property rights are required and these are listed below:

1. One of the scenarios is related to the distribution of benefits obtained through the sale of by-products obtained from waste processing in the waste processing infrastructure. In case property rights are not adequately allocated, companies that have invested in the initiative will not be entitled to receive the benefits, which can affect the motivation of other such companies to participate.

2. Property rights determine who the decision-making authorities are in an economic setting. Thus, another scenario is one in which actors who have invested in the infrastructure are not permitted

to participate in the decision-making for the operation of the initiative. This scenario may not affect all the participating companies equally.

3. There could also be a possibility that the non-commercial nature of the initiative can turn into a commercial enterprise in the future. In such a situation, it is necessary that the property rights are distributed sufficiently among the companies. From literature, it is also known that when the value of a resource increases, more actors express their interest in participation and for such a case, clear allocation of property rights are required (Musole, 2009).

3.1.3. Property Rights Components

Across literature, there has been agreement with the notion that property rights can be categorised or that multiple types of property rights exist. Based on the literature being referred to, this categorisation could be with respect to land, or for any asset, or for common-pool resources (Common-pool resources are those goods for which consumption cannot be restricted to limited number of users, and this poses a problem as their consumption leads to a reduction in its availability for others (Ostrom, 2010). Due to these characteristics, their management is essential).

In this section, a few of these categorisations and types are discussed and the classification that will be considered for the scope of this research will be selected. The objective of this discussion is to present that despite the differences of type of resource to which these are applied, these categories refer to how the resource is used.

1. Brandao & Feder (1995, as cited in Musole, 2009) differentiate among the following types of property rights for analytical purposes: open access, communal property, private property and state property. This categorisation is done with respect to the land resource.

    - Open access: Property rights are not strictly allocated to any individual or group of individuals. This implies that there are no rights to exclude individuals, which can result in free-rider problems and also provides no incentives for the users to invest in the management of the resource.
    - Communal (or common) property rights: Rights are assigned to a specific community who regulate the use and control of the resource. Incentive problems could exist in this case as well, as no member might want to invest in the resource. However, these investments can be viewed as a public good. They are considered inefficient due to rent dissipation.
    - Private property rights: Land is assigned to specific individuals or corporate entities. Exclusive rights are provided to the use of the resource, or obtaining benefits from it, or transferring whole or a part of the resource.
    - State property rights: The state possesses the property rights to the resource, and can transfer the rights to other users or communities.

    A similar such categorisation exists for common-pool resources, as stated in McGinnis (2011). However, the categories are described as property rights systems, and are defined for property rights bundles (multiple types of property rights held together). As the property rights system perspective is not considered in the research, this is not discussed further. Interested readers can refer to McGinnis (2011).

2. The earliest categorisation is as per Roman law, which states that complete ownership of an asset denotes that the following types of rights exist with respect to it (Pejovich, 1990; as cited in

Musole, 2009):

(a) Rights to use an asset, i.e. usus

(b) Rights to obtain benefits from the asset, i.e. usus fructus

(c) Right to change its form and substance, i.e. abusus

(d) Right to transfer some or all of the rights defined above at a fixed price agreeable to the parties involved

3. Schlager and Ostrom (1992) identify five types of rights that are applicable to common-pool resources. These are closely related to the categories as per Roman law, but are more specifically defined. These are described below (McGinnis, 2011; Ostrom, 2010)

(a) Access rights – The rights to enter an area and enjoy the benefits without extracting the resources

(b) Withdrawal rights – The rights to obtain products from a resource

(c) Management rights – The rights to regulate internal use patterns and transform the resource by making improvements; in other words, to define the withdrawal rights

(d) Exclusion rights – The rights to determine who will be authorised to access, withdraw from, or manage the resource

(e) Alienation rights – The rights to sell, transfer or lease any of the rights defined above

From the perspective of the research, the property right types as defined by Schlager and Ostrom (1992) will be used. This is because the distinction into the various categories provides the granularity using which the influence of property rights can be studied. The rest of the research will hence be focused on these rights.

3.1.4. Authorisations provided by Property Rights

Access rights and withdrawal rights are defined at the operational-choice level, i.e. users who hold these rights can take actions based on a set of rules. Management rights, exclusion rights or alienation rights are defined at the collective-choice level, i.e. users who hold these rights can participate in collective-choice actions, which means that they can participate in formulating operational-level rights as well as operational rules (Schlager & Ostrom, 1992).

Alienation rights and exclusion rights, possessed by owners, produce the maximum incentives to invest in resources for long-term. Proprietors, who hold exclusion rights, also face incentives to make investments in the resource (Schlager & Ostrom, 1992). This is because exclusion rights allow owners and proprietors to determine who can or cannot enter/access the resource, thereby allowing them to capture the benefits obtained from the investment (Schlager & Ostrom, 1992). The next highest incentives are faced by claimants, who can participate in determining which users can hold rights of withdrawal for the resource. However, due to the lack of exclusion rights, they may not always be allowed to exercise the rights of management, as this would be dependent upon whether they are in a set of circumstances which allows them to capture the benefits of coordinating their activities without holding the rights of exclusion (Schlager & Ostrom, 1992). Authorised users do not hold the authority to formulate the rights of access and withdrawal, and whether they face incentives to act in an efficient way depends upon the institutions devised by those with collective-choice rights (Schlager & Ostrom, 1992).

According to Schlager and Ostrom (1992), different bundles of property rights affect the incentives that individuals face, the actions they take and the outcomes that they achieve.

3.1.5. Bundles of Property Rights

A property rights system is a system of interconnected rights, as defined in a legal or institutional context (Ostrom, 2010). The rights associated with these systems are a combination of one or more of the fundamental types described by Schlager and Ostrom (1992), and this group of units is referred to as a bundle. These bundles of rights are allocated in an economically efficient way, i.e. they are assigned to the individual or the party that is expected to utilise the rights in the best possible way (Kim & Mahoney, 2005). The bundles consist of rights grouped together such that they form effective incentives for the respective parties to which they are assigned (Kim & Mahoney, 2005). From the perspective of this research as well, these bundles will be the incentives provided to companies to encourage participation.

The bundles of rights defined in literature and used in this research are (McGinnis, 2011; Ostrom, 2010; Schlager & Ostrom, 1992):

1. Authorized Entrant: User(s) or group(s) that possess access rights only
2. Authorized User: User(s) or group(s) that possess access rights and withdrawal rights
3. Claimant: User(s) or group(s) that possess access, withdrawal, and management rights
4. Proprietor: User(s) or group(s) that possess all rights except alienation rights
5. Owner: User(s) or group(s) that hold all the rights

3.1.6. Sources of rights

Property rights can be formally defined such as in the case of laws and regulations, or can also be informal as in the case of norms, social values, relationships, etc. Irrespective of the type, they are required to be recognised by an authority before they are considered legal (Sikor & Lund, 2009). The source of rights is important because if the right is legally recognised, it can allow the holder of the right to defend it in case of a conflict. Based on how they are assigned, these rights are divided into de jure/legal rights and de facto/economic rights (Musole, 2009; Schlager & Ostrom, 1992):

- De Jure or Legal rights – Rights are legally provided and enforced by the government to resource users. It has been acknowledged that although legal recognition is important, these are not the only defining institutions for property rights (Musole, 2009).
- De Facto or Economic rights – These rights represent the ability of the individuals to utilise the rights (Musole, 2009). Rights are mutually developed and assigned by the users themselves. They are not legitimate unless recognised by the government or a relevant authority, and hence are less secure than de jure rights, if challenged (Schlager & Ostrom, 1992). However, there is a possibility that these rights can be effectively defined under social or informal contracts as well (Musole, 2009).

3.1.7. Attributes of Property Rights

This section discusses the fundamental characteristics of property rights. The characteristics which are most applicable to this research are discussed here, and the rest are described in appendix A.

1. The first attribute that is discussed is the difference between ownership of the resource and the rights to use the resource (Alchian & Demsetz, 1973 as cited in Musole, 2009). According to this attribute, there is a difference between owning the resource and owning the right to use the resource. Thus, property rights are not one unit, but made up of multiple types. Musole (2009) states that this is consistent with the division of property rights into its components, according to Roman law, discussed in section 3.1.3. The property rights components used in this research are consistent with this attribute.

2. Property rights may be described by their divisibility, exclusivity, transferability, duration, quality of title and flexibility (Grafton, Squires, & Fox, 2000). Some of these aspects are discussed in this section due to the relevance with this research, the complete list is provided in appendix A:

   (a) Divisibility - this aspect can be related to the point mentioned above. Divisibility of property rights, indicates the ”extent to which the rights can be partitioned” (Grafton, Squires, & Fox, 2000, p.681). Property rights used in this research are divided into multiple components (section 3.1.3) and as a result, it can be said that the rights exhibit divisibility.

   (b) The transferability of property rights is the ability to exchange, gift or lease the rights. This is related to alienation rights, discussed in section 3.1.3.

   (c) The duration of property rights denotes the time period for which the rights are held. It also describes how long the rights are valid, i.e., whether they need to be renewed or are held permanently. This aspect is discussed further in section 3.1.7.

   (d) Quality of title denotes how specifically the property right is defined and basically refers to the source of property rights, i.e. de jure of de facto, as discussed in section 3.1.5

   (e) Flexibility of property rights denotes the ability to adapt to changes in resource and circumstances of the owners. This aspect is discussed in section 3.1.7 under ’robustness’.

3. Another attribute is the way in which a right is utilised, which depends upon the decision process determined by users, for example, majority voting (Musole, 2009). This attribute will be used in the context of the case study and will be specified in Chapter 5, where the conceptual model is detailed.

4. Property rights exhibit multiplicity with respect to the ownership of a resource(Musole, 2009), i.e. the rights to use the resource can be divided among more than one individual or group of people at the same time. The property rights used in this research exhibit multiplicity as more than one company owns the right to use the resource (waste processing infrastructure) at the same time.

3.1.8. Security of Tenure

Security of property rights, or tenure, has multiple definitions, as discussed in a literature review by Arnot, Luckert, and Boxall (2011). The significance of this concept is that it determines the certainty of holding rights to a resource. Much of the literature discusses it with respect to land, however it can also be applicable to other cases, as in the case of irrigation systems (Meinzen-Dick, 2014). The author discusses that along with the type and source of the rights, the security with which they are held is also important. Meinzen-Dick (2000) in her work on property rights focuses on the study the property rights of irrigation systems, stating that they have not received much attention previously but need to be addressed as they can shape incentives for management of the irrigation infrastructure. She states that property rights are important from the perspective of the irrigation infrastructure maintenance

because i) they offer incentives for management, ii) give the responsibility and required authorisation over the resource, and iii) property rights provide resources for maintenance. If the individuals are sure and have knowledge on whether they would be able to receive the benefits of investment, they would be incentivised to invest in the maintenance of the infrastructure. This attribute is composed of the following aspects: i) assurance, or strength of the rights, ii) robustness, iii) excludability, and iv) duration. These are defined below:

- Assurance / Strength: This is the degree to which these rights can be protected or defended in the case of a conflict. In the case of water resources, stronger rights apply even during periods of scarcity whereas weaker rights could be denied during such times (Meinzen-Dick, 2000; Meinzen-Dick & Mwangi, 2009).
- Robustness: Robustness of property rights is its ”ability to withstand challenges” (Meinzen-Dick, 2014, p28). These challenges could emanate from institutional circumstances (for example, when new participants join the initiative and as a result there is a change in the institution for the division of benefits/negative revenue) or physical circumstances (for example, when the maximum limit of the infrastructure is exceeded and it needs to be determined how the waste would be handled in such a case). This aspect is determined by the number and strength of the rights that are held (Meinzen-Dick, 2000). Thus, control rights, i.e. management, exclusion and alienation rights are more robust than use rights, i.e. access and withdrawal rights (Meinzen-Dick, 2000). This aspect can be related to the flexibility attribute of property rights, discussed in the previous section. This attribute refers to the ability to adapt to changes in resource and circumstances of the owners Grafton et al. (2000).
- Excludability: This aspect defines the capability to decide on who has the rights to access the resource (Meinzen-Dick, 2000).
- Duration: The expected duration of the rights (Meinzen-Dick, 2000). Rights that are held for a longer period are more secure than those with a limited duration. This aspect has been discussed as an attribute of property rights in section 3.1.6.

3.2. Institutional Frameworks

In order to understand the research problem better, a deeper examination is required of the aspects involved in it. The use of a framework can help in this regard. A framework is described as a tool that ”identifies, categorises and organises those factors deemed most relevant to understanding some phenomenon” (McGinnis, 2011, p. 170). For this research, as the objective is to explore the institutional arrangement in a situation involving collective action, we considered some frameworks that can help identify the components that should be used in the research.

A brief description of the three frameworks that were considered for the task is given below.

1. The Institutional Collective Action (ICA) framework is developed to study governance arrangements among institutional units by extending the theories of collective action among individuals to include institutional bodies such as cities and government agencies (Feiock, 2009). It is applied to study the problems that can arise when responsibilities are delegated to local governments and agencies, resulting in fragmentation and externalities. In the purview of this research, the focus is on companies and their decision to participate, as opposed to government agencies that formulate policies. This framework would thus be applicable in a scenario wherein government agencies are involved in decisions regarding the adoption and use of the waste processing infrastructure.

2. The Williamson model is used to analyse the institutions that are at play at each level of an institutional environment (Williamson, 2000). This framework is helpful to analyse the interaction among the institutions at each level, and how they might influence each other. It is depicted in figure 3.1. In this research as well, institutions that operate at each level are taken into account, however, as the focus is on property rights (which is Level 2 in the Williamson Model), the institutions at the other levels are considered to be static and non-influential for this research. Furthermore, this model provides a very broad view of the situation, whereas the requirement in this case is to take into account specific characteristics of the actors involved.

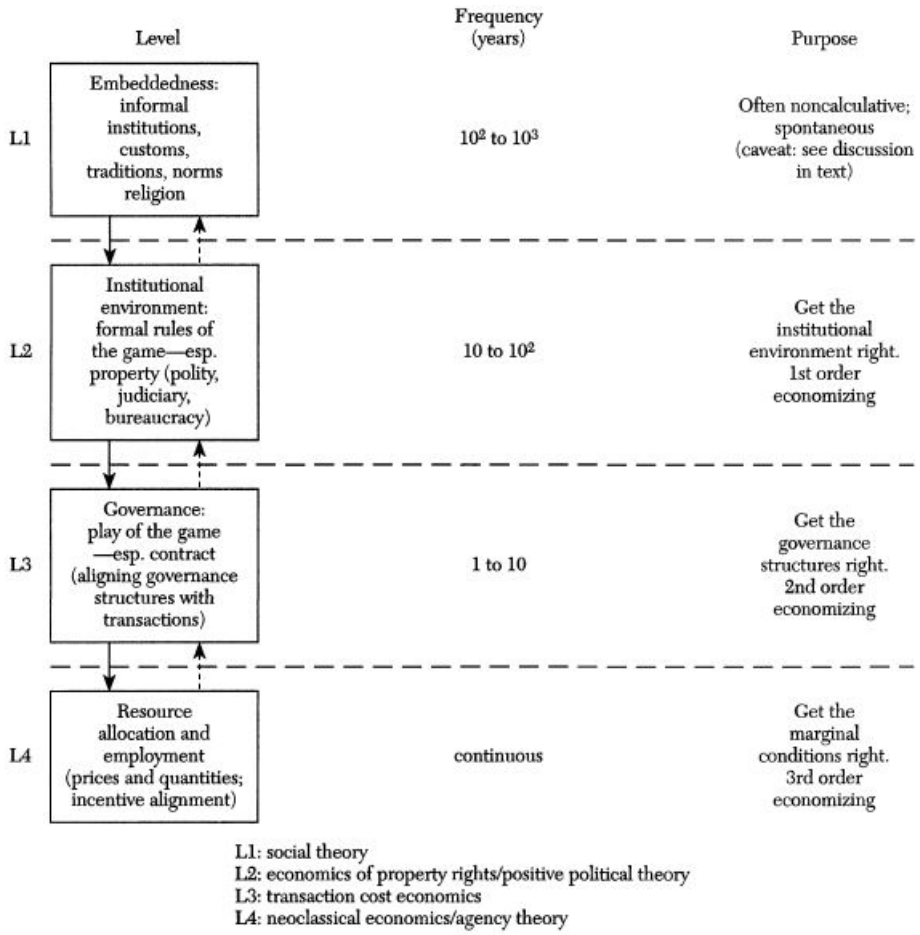


Figure 3.1: Economics of institutions by (Williamson, 2000)

3. The Institutional Analysis and Development (IAD) framework, developed by Ostrom (2009) identifies the components that are at play in the institutional arrangement being analysed. It organises the factors of an institutional arrangement, and is commonly used to study the evolution and development of institutions over time across various arrangements (Andersson, 2006; Coleman & Steed, 2009; Imperial & Yandle, 2005; Smajgl & Leitch, 2009).

   The framework consists of two parts: the action arena, which consists of the action situation and the actors, and is acted upon by external variables to produce patterns of outcomes and interaction that are evaluated against a criteria (Ostrom, 2010). The framework is illustrated in figure 3.2.

It was decided to use the Institutional Analysis and Development (IAD) framework as it considers

the entire context of the situation and includes all possible components that may be applicable to the context. By also providing an overview of the relations among these components, it helps to recognise the interactions and how they may affect each other. In a way, this also defines the scope of the situation to be analysed. For the scope of the research, the IAD framework was particularly applicable to the actor identification and system decomposition steps of the agent-based modelling process (discussed in chapter 5).

3.2.1. Institutional Analysis and Development (IAD) Framework

As stated by Ostrom (2007), the IAD framework is a ”multi-tier conceptual map” (p.27), wherein the action situation of the framework can be at one of the following levels (McGinnis, 2011):

1. Operational choice: At this level is the implementation of actions by individuals that have the permission to do so. These actions are taken based upon the collective choice rules that have been defined at the collective choice level.

2. Collective choice: At this level are the processes wherein institutions are created that determine how actions will be taken at the operational level.

3. Constitutional choice: At this level, the procedures at the collective choice are defined, including determining which actors can be involved in taking decisions at the collective choice level.

4. Meta-constitutional level of analysis: This level considers the effect of soft institutions and cultural factors, that are not immediately affected by the actors involved.

For the scope of the research, the action situation is at the operational choice level wherein actors face incentives to take actions within a pre-defined set of rules as well as at the collective choice level, wherein the institutions that determine the actions at the operational level are created.

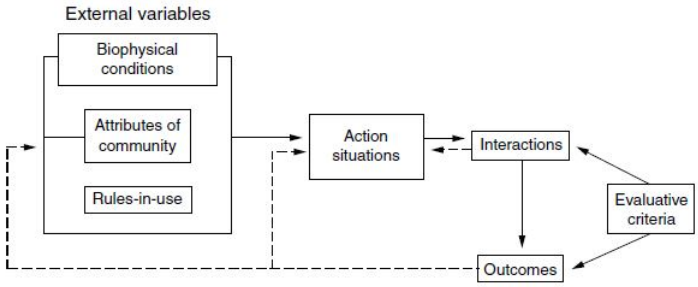


Figure 3.2: The IAD Framework (Ostrom, 2010)

The components of the IAD framework, as depicted in Figure 3.2 are described below:

1. The external variables of the IAD framework are the factors which set the context for the action situation (McGinnis, 2011). These include:

   (a) Biophysical conditions: The physical and material conditions within which the action situation is placed (Ostrom, 2010). This also includes the type and characteristics of the good that is involved.

   (b) Attributes of community: These are the social and cultural characteristics, shared among the actors in the action situation (McGinnis, 2011; Ostrom, 2010).

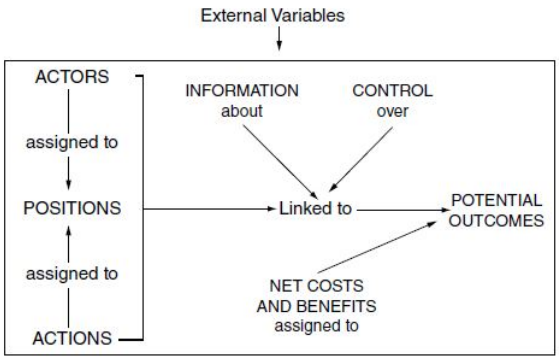


Figure 3.3: The action situation of the IAD framework (Ostrom, 2010)

(c) Rules-in-use: The institutions in the situation, which guide the actions that can/cannot be taken. These could evolve over time, in a collective-choice or constitutional-choice setting (McGinnis, 2011; Ostrom, 2010). These could be:

- The formal rules, as opposed to the rules that are used in practical settings (McGinnis, 2011)
- Shared norms, strategies and rules (McGinnis, 2011)
- Property rights, which determine how the resources are to be used (McGinnis, 2011)

2. The action situation is the core of the IAD framework, within which individuals and/or as representatives of organisations take in information and carry out actions based on their decision-making leading to outcomes (Ostrom, 2010). The components of the action situation are depicted in Figure 3.3. Based on the work by Ostrom (2010), these components are:

(a) Actors and their characteristics: This component represents the actors involved in the situation to be analysed, their characteristics and the decision-making theory that is used to analyse the decisions taken by the actors, which are the decision-makers in the situation.

(b) Positions: The positions are held by the actors, and these determine the actions that can be taken by them.

(c) Actions: All the possible actions that can be taken by the actors at decision-making nodes.

(d) Information: The amount of information available, which can be used by the actors to make decisions.

(e) Outcomes: The components discussed above, i.e. the actions that are taken by the actors with the information available to them leads to decisions taken by all the actors, giving rise to possible outcomes within the action situation.

(f) Costs and benefits: The costs and benefits are assigned to the actions and outcomes in the action situation.

3. The outcomes are generated by the interactions in the action situation and the external variables (McGinnis, 2011; Ostrom, 2010).

4. The evaluative criteria assess the outcomes generated and the overall system. These can help identify those aspects that are satisfactory, and those that need improvement (McGinnis, 2011)

5. The interactions that take place among the action situation, external variables, outcomes and the evaluative criteria, serve as feedback for the actors to change their actions (McGinnis, 2011).

3.3. Behavioural Theories

The objective of the research is to study the influence of property rights bundles on the decision of companies to participate in the initiative for organic waste processing. The decision-making is a part of the action situation in the IAD framework, as it would determine the actions taken in the situation. Thus, the factors that affect the decision-making of the companies are to be explored. Models of behaviour have been widely used in academic research to explore the factors that influence behaviour. Social-psychological models are used to explain the decision-making process as a behaviour. While it is possible that the business and the individuals have different motivations, the willingness of the companies to set up the initiative denotes that factors beyond cost/benefit calculation are at play here. Hence, the decision-making is studied from the perspective of these additional factors, captured through social-psychological models.

Darnton (2008) provides an overview of the various types of models of behaviour that can be applied to study human behaviour and the factors that influence behaviour. Based on the factors applicable to this research and discussed in appendix B, the Theory of Planned Behaviour by (Ajzen, 1991) was chosen for this research.

3.3.1. Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB) is a psychological model used to explain the behaviour of individuals (Ajzen, 1991). The TPB has been able to explain a wide range of human behaviour in different scenarios of pro-environmental behaviour for individuals as well as for companies (Botetzagias, Dima, & Malesios, 2015; Scalco, Ceschi, & Sartori, 2018). For example, prior research demonstrates that TPB can explain the intention to recycle, to reduce pollution and for better environmental management in the case of Small and Medium-Sized Enterprises (SMEs) and corporate management decisions (Sánchez-Medina, Romero-Quintero, & Sosa-Cabrera, 2014; Sawang & Kivits, 2014). According to this theory, the behaviour of an individual is directed towards a goal, and thus he/she would perform the action if there is an intention to do so (Botetzagias et al., 2015). The intention is based on the attitude towards the behaviour, the subjective norm and the perceived behavioural control (Ajzen, 1991, 2002; Scalco et al., 2018). Each of these aspects are described below, and the relation between the variables in the theory is shown in figure 3.4.

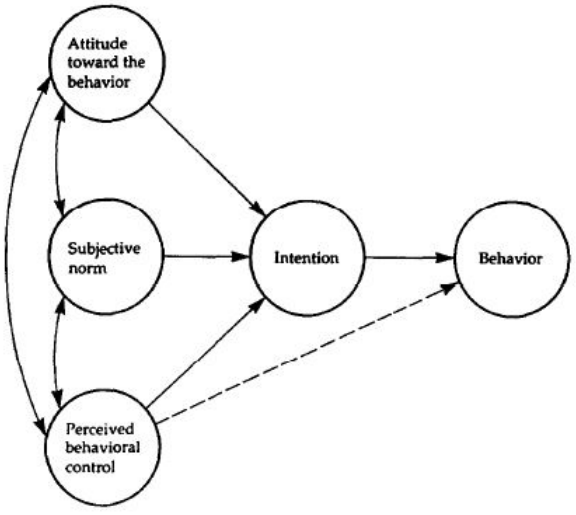


Figure 3.4: The relation between the variables in the Theory of Planned Behaviour Ajzen (1991)

3.3.2. Subjective Norm

The subjective norm is a social factor which refers to the ”perceived social pressure to perform or not perform the behaviour” (Ajzen, 1991, p.188). According to this factor, the individual's decision to take action is influenced by the approval of the people or group who he/she considers important (Scalco et al., 2018).

Subjective norm as a behavioural aspect is applicable to the case of collective action, as described by Ostrom in the Collective Action theory (2009). According to this theory, humans do not act out of self-interest in a situation that requires collective action. Norm-based, bounded rational theories are more applicable to explain how collective action takes place (Ostrom, 2009). In a collective action situation, the norms are shared by the participants, as the prevalence of norm among the participants starts to affect the behaviour of the others (Ostrom, 2009). This thus relates to the subjective norm construct in the TPB, according to which normative beliefs result in perceived social pressure, or subjective norm (Ajzen, 2002).

For the case of organisations or companies, norms are affected by internal and external stakeholders of the company. There have been a few studies that discuss this. The normative beliefs are influenced by the reference groups that are considered important by the company (Sánchez-Medina et al., 2014). This is closely related to the study undertaken by Sawang and Kivits (2014) on the decision of management to undertake green initiatives. The authors state that managers are affected by internal stakeholders such as customers, and external stakeholders such as government or industry while deciding whether or not to adopt an initiative. Furthermore, this variable is subjective, i.e. each company could be influenced by its internal and external stakeholders in different proportions. Thus, some companies might be more influenced by the stakeholders, whereas other companies might be influenced to a lesser extent.

3.3.3. Attitude

The attitude variable in the TPB is an aggregate value of the beliefs held by an individual about the likely consequences or other aspects of the behaviour (Ajzen, 2002). The variable is related to one's beliefs about the possible outcomes or consequences from engaging in a specific behaviour and whether these outcomes are positive or negative (Ajzen, 1991). In other words, it refers to how individuals evaluate the action or the behaviour (Ceschi, Dorofeeva, Sartori, Dickert, & Scalco, 2015).

As mentioned before, the attitude aspect of the TPB states that the intention of an individual to perform an action is based on his/her evaluation of the consequences of performing that action. In the case of participation in socially beneficial initiatives, prior research states that the factors that influence participation in such initiatives include both moral as well as materially tangible aspects. For example, Wehn and Almomani (2019) study the incentives and barriers for participation in community-based monitoring and use the theory of planned behaviour to guide their research. They identify personal tangible outcomes, personal intangible outcomes and societal/social tangible outcomes as the perceptions that guide the participation of citizens in these socially-inclined initiatives (Wehn & Almomani, 2019). Personal tangible outcomes are those related to actual gains or losses as a result of participation, whereas personal intangible outcomes are those related to inner satisfaction. Social/societal outcomes are those that affect the community or society at large, as a result of participation (Wehn & Almomani, 2019).

Brønn and Vidaver-Cohen (2009) in their research found that companies participate in initiatives based on their sustainability motives, profitability motives and legitimacy motives. They carried out the study to understand the motives for participation in social initiatives by Norwegian companies. They

found that their results are similar to the theoretical and empirical work done by other scholars, who state that the participation in social initiatives is based on moral as well as strategic perspectives, and due to intrinsic values as well as external requirements (Brønn & Vidaver-Cohen, 2009). The motives found in the work by Brønn and Vidaver-Cohen (2009) are:

- Sustainability motive: This is similar to the moral perspective, which is based on the idea that companies have a moral duty to contribute to society. 'Strengthening global networks', 'Sharing resources with society' and 'Concern for society's future' are a few of the aspects discussed under this. Out of these, the factor of 'Concern for society's future' is directly related to why companies have decided to participate in the Amsterdam Zuidoost initiative, as the initiative is their attempt to address the noise pollution, air pollution and traffic issues that occur due to the current waste management practices, and hence will be considered in the research.
- Profitability/Strategic motive: These are all the motives which specifically have monetary outcomes. They are related to the strategic perspective defined by other scholars referenced in the work by Brønn and Vidaver-Cohen (2009), who divide the strategic motives into:
  - Instrumental motives, which are based on the beliefs that engaging in initiatives can lead to long-term impact on business profitability and provide competitive advantage. It is known that one of the objectives of the Amsterdam Zuidoost initiative is to save costs on the current waste management practices, and this is reflected by the broader instrumental motive.
  - Institutional motives, which are the mandatory institutional requirements that cause companies to participate. As this is a voluntary undertaking, with no legal requirements to start it, this motive is not considered.

  In this research, the instrumental motive is taken into account, and is representative of the profitability motive. A list of factors have been found that fall under the broad category of profitability motives. Out of these, the factor of 'Create financial opportunity' is used in this research as a proxy for the profitability motive of why companies participate. This factor is chosen as it relates to the cost-saving objective of the initiative. Additionally, the revenue earned would be used to recover the investment in the infrastructure.
- Legitimacy motive: This motive is rooted in the assumption that the actions taken by an entity are acceptable within a social system of norms, beliefs, etc. (Brønn & Vidaver-Cohen, 2009). This has not been considered explicitly for this research as its effect has been captured using the subjective norm variable.

Based on the above discussion, we can formulate that behavioural beliefs regarding participation in a socially-beneficial initiative can be founded on sustainability, strategic and legitimacy reasons, out of which the sustainability and strategic motives will be taken into account in this research.

3.3.4. Perceived Behavioural Control (PBC)

This aspect of the TPB takes into account situations wherein the intent to action is dependent upon factors that are beyond the control of the participants (Ajzen, 2002).

According to the theory, when people think that they possess the resources, such as, time, money, cooperation by others, etc. and there would be few barriers or manageable barriers in carrying out the action, they would possess a higher value of PBC (Ajzen, 2002). As per Sawang and Kivits (2014), the value of Perceived Behavioural Control (PBC) is affected by factors such as 'financial readiness'

and ‘knowledge readiness’ which form a part of the concept of ‘organisational readiness’. As per their research, this is as an important factor in determining the behaviour of managers in adopting an initiative. It is considered to be composed of operational readiness, financial readiness, staffing readiness, technical readiness and knowledge readiness. Similarly, research by M. P. Singh, Chakraborty, and Roy (2018) consider the influence of technological capabilities, financial capabilities, human resource capabilities and infrastructural capacity to explain the perceived behavioural control of small firms.

In this research, the factors of financial readiness/financial capability and knowledge readiness that affect the PBC of an organisation or firm, will be taken into account.

3.3.5. Relation between Property Rights and the Theory of Planned Behaviour

The influence of property rights for the case of collective ownership of the waste processing infrastructure is yet to be determined. Although it is known that property rights and their allocation determine the economic behaviour of individuals, there is no definitive theory that provides details of the relation between property rights and behaviour.

In this research, the connection between these two aspects has been studied with the help of the TPB (Ajzen, 2002). From the behavioural aspects defined as part of the TPB, the influence of property rights is captured through the Perceived Behavioural Control (PBC) aspect. By definition, the PBC represents those factors which are beyond the control of the participants but can influence their intention. From literature, it is known that the kind of property rights possessed influences the decisions and behaviour of the participants, however, which type of rights are possessed by them is not in their control. Hence, property rights are considered to be related to the perceived behavioural control of the participants of the initiative. Furthermore, property rights and their bundles will be analysed from the perspective of knowledge readiness, as companies will be informed of the incentive/property rights bundle it is provided. This information will then be used to calculate the intention.

The variable of subjective norm that measures the social pressure to perform a behaviour is not dependent on the property rights possessed by the participants and hence property rights will not be examined through this aspect of the TPB. Similarly, the attitude aspect of the TPB is a measure of how individuals evaluate the behaviour or the consequences of the behaviour in question. In this case, the behaviour considered is of participation in the initiative, which can address the inefficiencies of the waste management. which is related to the sustainability motive and the profitability motive of participation. Although obtaining property rights is also a consequence of participation in the initiative, obtaining property rights is not the main reason for which the initiative is set up.

The Perceived Behavioural Control associated with each type of property rights bundle is examined through the security of tenure of the property rights in question. which is composed of the aspects of strength, robustness, duration and excludability of property rights, as discussed in section 3.1.7. These aspects, from the work by Meinzen-Dick (2000) will be considered in this research as they are applicable to the case of infrastructure, on which this research also focuses. Their application to the case study is discussed in the next chapter.

3.4. Summary

This chapter discussed the theoretical concepts which form the foundation of this research. The concept of property rights, their importance, property rights components, property rights bundles, their source, attributes and security of tenure are discussed. Following this, the frameworks that can be used in this research are discussed. Based on its relevance to the situation, the Institutional Analysis

and Development framework was selected. Similarly, out of various possible behaviour and decision-making models that could be applicable to the research, the Theory of Planned Behaviour (TPB) is chosen through which the decision-making of the companies is analysed. The influence of property rights will be studied through the Perceived Behavioural Control of the TPB, using the security of tenure provided by property rights.

4

Applying the Theoretical Concepts

This chapter discusses the case study in section 4.1 and in section 4.2 applies the IAD framework to the case study, through which the actors, their characteristics, institutions and the relationship among them is captured. In the same section, the Theory of Planned Behaviour is applied to understand the decision-making of the identified actors. Finally, in section 4.2.3 property rights and its related aspects are applied to the context of the initiative. This section thus helps to address the sub-question 1: What are property rights and how can they be formalised in the context of waste processing initiatives by companies?

4.1. Case Study - Context and Description

Before providing information on the case study, this section discusses waste management, focusing especially on decentralised waste management and the barriers faced in its implementation. This discussion is required to understand the context in which the case study is placed.

4.1.1. Waste Management - Present Challenges

Waste management is required to reduce or eliminate the effects that solid waste can create on public health and the environment. Centralised treatment plants, landfills and incineration have been the norm for waste management (Abdel-Shafy & Mansour, 2018; Särkilahti, Kinnunen, Kettunen, Jokinen, & Rintala, 2017). This leads to longer transportation distances, high energy and resource consumption (Särkilahti et al., 2017). Although centralised plants have performed the societal function of waste management by providing environmental and health benefits, they fall short of addressing the new sustainability challenges of waste management (Särkilahti et al., 2017). An alternative to this is decentralised waste management. A distinction can be made between centralised waste management and decentralised waste management based on a few factors, discussed in table 4.1 (Massoud et al., 2019).

Waste management can be termed as decentralised also when each community manages and processes its waste locally, thereby not sending it to a central waste processing facility or the landfill (SAAHAS, 2014). Taking into consideration these aspects, we can state that decentralised waste processing is the localised processing of waste, wherein the decisions regarding the processing and the respon-

sibility of the waste is taken by the members of the community themselves (Araya, 2018; Massoud et al., 2019).

	Centralised waste management	**Decentralised waste management**
Geographic location of waste management facility	Limited, large-scale facilities concentrated in a few regions	Large number of low-scale facilities scattered across the region
Decision-making authority and responsibility ownership	Main responsibility for services held by a few individuals with whom the power is rested	Dispersed among several bodies who are also responsible for the services

Table 4.1: Parameters and their possible values for the influence on minimum organic waste (Massoud et al., 2019)

Decentralised waste processing offers advantages in the environmental, economic and social aspects. Environmental benefits include reduced consumption of fuel, reduced air pollution, creation of less hazardous products, etc (Tchobanoglous, 2010 as cited in Araya, 2018). Economically, it helps improve the local economy and also leads to a lower cost of road maintenance and in terms of social aspects, it helps to create jobs and deliver quality products (Araya, 2018; Särkilahti et al., 2017; N. Singh, 2016). It is assumed to be favourable over centralised waste management due to the environmental benefits that are offered including the reduced amount of waste sent to landfill (Araya, 2018; Sinha, 2010).

One type of decentralised waste management is anaerobic digestion[1], which is the breakdown of organic matter by micro-organisms in the absence of oxygen to produce by-products in the form of gases and simpler compounds (Araya, 2018). Anaerobic digestion generates by-products which can be contribute to the renewable energy mix, enables nutrient recycling and aids to the local economy (Särkilahti et al., 2017). Despite the advantages provided by this solution, a few barriers also exist that hinder its adoption. For example, barriers such as social acceptability, the lack of legal support and governance aspects that prevent the recycling of nutrients obtained from waste exist (Särkilahti et al., 2017). However, the major barrier to the adoption of this technology is the high investment cost (Win et al., 2017, as cited in González et al. (2020)). The economic feasibility is a challenge for decentralised waste processing, as observed by Araya (2018), Domingues et al. (2012) and Fuess and Zaiat (2018).

This hindrance is also reflected in the case study, as despite the willingness of the participants to address the current inefficiencies, the high investment cost poses a barrier to its adoption. Hence, a possible option that is being considered is joint ownership of the infrastructure.

4.1.2. Case Study - Amsterdam Zuidoost

The case study is that of an initiative undertaken by a few companies in the Amsterdam Zuidoost region. The initiative is being developed as a pilot to improve the waste collection and disposal practices for businesses in Amsterdam. The current setup is a free market scenario, wherein each company can choose among the waste collecting and processing firms that offer waste management services and enter into a contract with one of these firms (City of Amsterdam, 2020). In cases wherein multiple companies are present in the same region, such an arrangement can lead to inefficiencies as the same task, i.e., of waste collection is carried out by multiple firms. This leads to redundancy with respect to the miles travelled by the waste collection trucks, while creating noise pollution, additional emissions causing air pollution, congestion and unsafe traffic situations. Furthermore, additional costs

[1] Anaerobic Digestion has been implemented as centralised systems as well as decentralised systems (Araya, 2018; Clarke, 2018). In the scope of this research, we focus on decentralised anaerobic digestion.

are involved when smaller waste flows when the truck capacity is under-utilised (Amsterdam Zuidoost, 2016).

To address this, a few of the companies in the region have decided to work collectively in a pilot project. In the first phase of their pilot, the objective is to process the organic waste generated by the companies locally, using a waste processing infrastructure, which will be a bio-digester. The plan then is to introduce more forms of waste recycling, if this pilot project goes well. Although there are more than a thousand companies in the region, the first phase of the initiative will start with only a few of them.

The bio-digester will process the organic waste generated by the companies, producing by-products in the form of heat, electricity, digestate (the residual matter obtained from the processing) and nutrient-rich water. Currently, it has been planned that these by-products will be sold at market price to obtain a return on the capital expenditure of the waste processing infrastructure (Personal Communication). In some cases, the market-price of the digestate is negative. This occurs when farmers are paid money to apply digestate (Gebrezgabher, Meuwissen, Prins, & Lansink, 2010). It is assumed that this possibility can occur for the initiative as well, in which case the ”negative revenue” will be divided among all the participants.

4.2. Case Study from the Perspective of the Theoretical Concepts

This section discusses the case in greater detail, from the perspective of the theoretical concepts discussed in Chapter 3.The first sub-section will discuss the relevance of property rights in the case study, followed by the Institutional Analysis and Development framework and the Theory of Planned Behaviour. The insights obtained from this discussion will be used as an inventory for the System Identification and Decomposition stage (in Chapter 5), after which the relevant concepts will be structured to provide a complete view of the system.

4.2.1. Understanding the case study using the IAD framework

The IAD framework, as applied to the context of this research is described below. The external variables and action situation, along with the interactions, outcomes and evaluative criteria for their assessment are discussed. Figure 4.1 illustrates this with the help of a diagram. Please refer to appendix C for a detailed description of the application of the framework to the case study and an enlarged version of the figure (figure C.1)

1. Bio-physical conditions: The bio-physical conditions of the initiative are the region in which the initiative is situated and the infrastructure for which the investment needs to be made.

   The initiative will be carried out in the commercial region of Amsterdam Zuidoost, which hosts a range of companies and organisations. A few of these will be participating in the pilot phase of the initiative by investing in infrastructure for the processing of their organic waste.

   The attributes of the infrastructure considered are its cost and capacity.

2. Attributes of community: Each company in the region shares its willingness to set up an initiative to improve the local conditions of the neighbourhood. As stated by one of the companies involved, they are ”aware of our position in society and we play a role as a fore runner in the area and in city of Amsterdam” (Case Study Participant, Personal Communication, August 26, 2020). The organisation states that it wants to cooperate with its neighbours, large companies and citizens, and be a sustainable and innovative actor in its right.

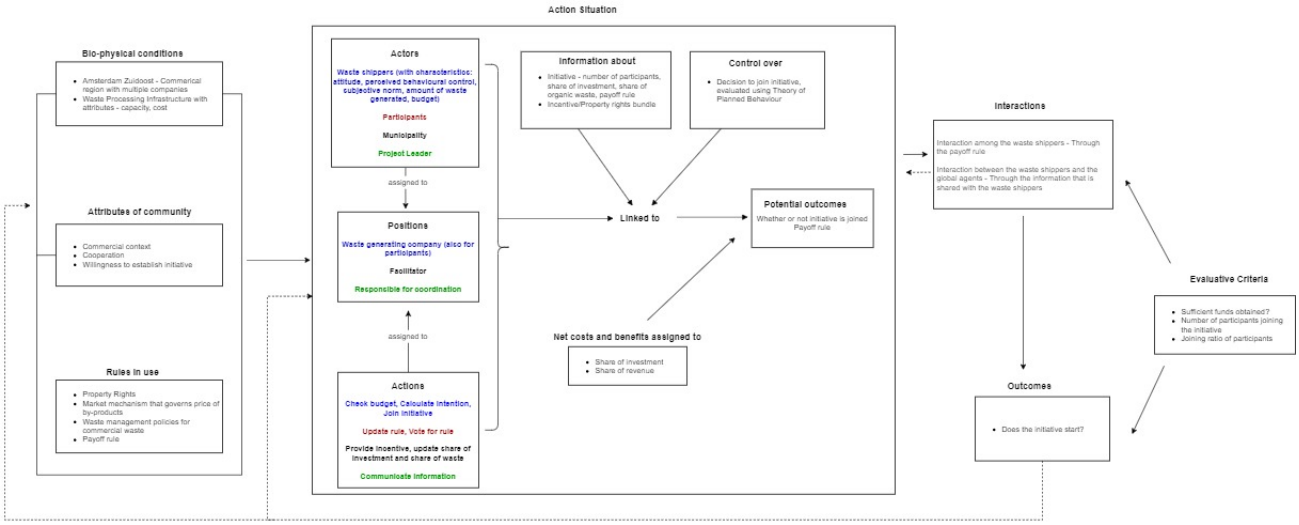


Figure 4.1: IAD framework applied to the case study (see appendix C for an enlarged version)

3. Rules-in-use: Currently, household waste and commercial waste is handled separately in Amsterdam. For commercial waste, the requirements for waste separation are not specified. A free-market scenario exists, and companies enter into independent contracts with large waste collecting and processing companies (City of Amsterdam, 2020). The prices of waste collection and waste processing are determined using the market conditions prevalent at the time, reflected in the institutional context.

   In the situation wherein the waste processing will take place in a decentralised form using the waste-processing infrastructure, the rules-in-use being considered are the property rights related to the initiative and the payoff rules that are defined for the initiative (discussed in chapter 5). Additionally, the price at which the by-products obtained from the waste processing will be sold in the market, will be determined from the market conditions, a reflection of the institutional context of the situation.

4. Action situation: The action situation of interest is the collective ownership of waste processing infrastructure when institutional incentives in the form of property rights bundles are provided.

   The actors involved are the 'waste shippers', i.e. the companies in the region that generate organic waste, the Municipality of Amsterdam, which acts as a facilitator in the initiative and the Project Leader, which coordinates the actions among the waste shippers [2]. The waste shippers can decide to join or not join the initiative based on the information they possess on the share of investment required, the budget held by them, the number of participants already present in the initiative, their attitude, perceived behavioural control and subjective norm and the property rights bundle provided to them. If a waste shipper joins the initiative, it becomes a 'participant' by paying its share of investment. It can receive monetary benefits (in case revenues are received), pay its share of revenue (in case of negative revenues) and send its organic waste for processing. It can also formulate rules for the initiative, if it holds the property rights bundle of a claimant or a proprietor, which is provided as an incentive. The incentives are provided by the Municipality of Amsterdam and the project leader, who also assess if the initiative can be started, based on the

[2] It must be noted here that other actors, such as the waste collecting and processing companies, the company that owns the technology for the waste processing infrastructure, etc. are also part of the initiative; however, they have not been included in the research as their actions in the initiative are beyond the scope of the research question that is to be addressed.

total funds obtained from the participants of the initiative.

4.2.2. Applying the Theory of Planned Behaviour to the Research

The decision-making of the waste-shippers, i.e. the companies interested in setting up and participating in the initiative is captured using the Theory of Planned Behaviour (TPB). The variables of the TPB, i.e., subjective norm, perceived behavioural control and attitude are the internal characteristics of the companies which determine whether they participate in the initiative. These variables in the context of the research have been explained below. Figure 4.2 depicts the theory as applied to this research. As financial resources directly determine the decision to join the initiative, this factor of PBC has been depicted separately (refer to discussion under 'Perceived Behavioural Control (PBC)' for detailed explanation)

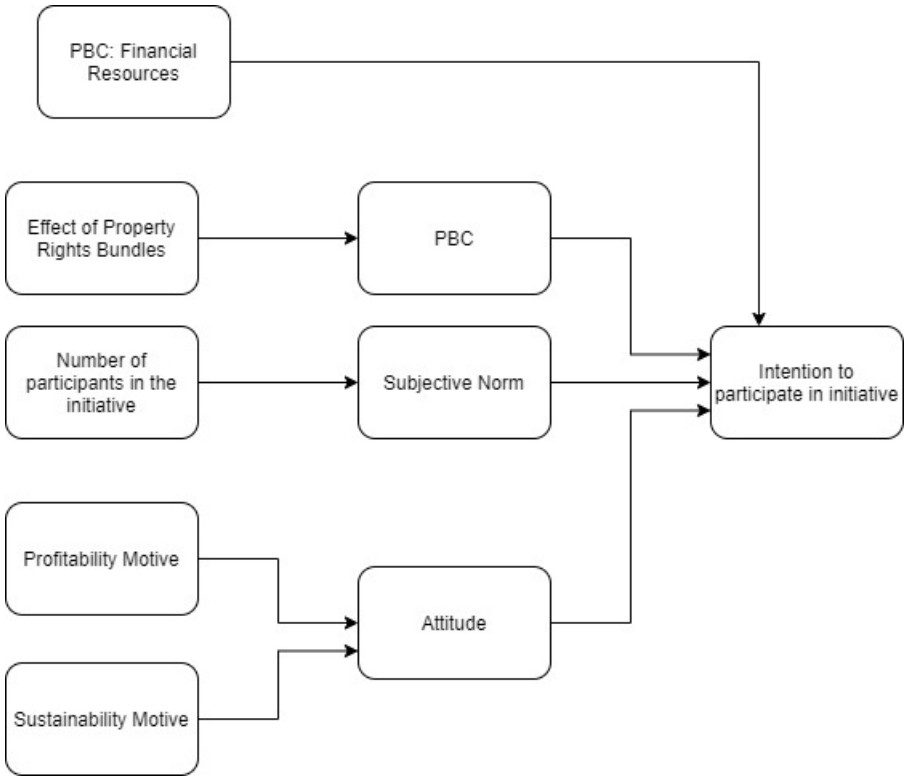


Figure 4.2: The Theory of Planned Behaviour depicted from the perspective of the research

Subjective Norm

As specified in section 3.3.2, in the case of a commercial decision, external stakeholders (such as the industry or consumers) or internal stakeholders (such as employees) can influence the intention of the company to perform a behaviour. In the case of this research, the influence of the external stakeholders, i.e. other companies present in the region is considered. This choice has been made as it is a case of collective action wherein other participants would have the maximum influence. Additionally, this choice helps to simplify the model and focus on the research question of the influence of property rights bundles.

Attitude

As discussed in section 3.3.3, strategic, moral/sustainability motives and institutional motives lead companies to participate in social initiatives. From the perspective of this research, strategic motives and

moral/sustainability motives are considered. Institutional motives have been excluded as this initiative is voluntary, with no institutional requirements to participate in it. From the research by Brønn and Vidaver-Cohen (2009), the factor of 'Concern for society's future', as explained in Section 3.3.3, is directly related to why companies have decided to participate in the initiative, as the initiative is their attempt to address the noise pollution, air pollution and traffic issues that occur due to the current waste management practices. For each company, the ratio of amount of organic waste that can be processed in a decentralised way, through the waste processing infrastructure, to the amount of organic waste generated is considered to be a proxy for the 'Concern for society's future' and in turn, the sustainability motive.

The factor of 'Create financial opportunity' from Brønn and Vidaver-Cohen (2009) is used in this research as a proxy for the profitability motive of why companies participate. As explained previously, the initiative does not have an economic objective, however, the revenue earned would be used to recover the investment in the infrastructure. For each company, the financial opportunity is measured by computing its Return on Investment (RoI). If the value of RoI is negative, there is no financial/economic opportunity created and hence the value of financial opportunity is zero (0). If the value of RoI is positive, the financial opportunity is the ratio between the calculated RoI and the maximum possible RoI for any other participant in the initiative.

Together, these motives make up the attitude of the companies in the initiative. However, the amount of influence each of them has is dependent upon the weight factor of each. As the factors for sustainability and profitability motive have been taken from the research by Brønn and Vidaver-Cohen (2009), the coefficient values have also been taken from the same research.

Perceived Behavioural Control (PBC)

As described in section 3.3.4, the financial readiness/financial capability and knowledge readiness are the factors considered in this research. The financial readiness/capability is measured by the availability of budget, which directly determines whether or not a company can participate in the initiative. It is measured by the amount of funds available with the companies to invest in the initiative. If the funds are insufficient, the company cannot participate. The knowledge readiness measures information or knowledge on the type of property rights bundle the company is provided (discussed in section 3.3.5).

Thus, the financial readiness/capability directly determines whether or not a company can participate, whereas the knowledge readiness is one of the determining factors of the intention to participate, as also depicted in figure 4.2.

4.2.3. Property Rights in the context of the Amsterdam Zuidoost initiative

Property rights determine how decisions are taken with respect to a resource. Well-defined property rights in the context of Amsterdam Zuidoost are the formal and informal rules that determine how companies can access, use, participate in the management, improvement and regulation of the waste processing infrastructure.

From the various property rights definitions and approaches considered by the scholars, a choice has been made to use the definition of property rights as applied to common-pool resources by Schlager and Ostrom (1992). This is because, as specified before, the distinction into the various categories provides the granularity using which the influence of property rights can be studied. Based on the definition of each type discussed in section 3.1.3, the property rights, from the perspective of the initiative, will thus be:

1. Access rights - Participants with access rights would be allowed to send their organic waste for

processing, however, no returns will be obtained on the investment done.

2. Withdrawal rights - Participants with withdrawal rights would be allowed to send their organic waste for processing, and obtain returns in case any revenues are made by the sale of by-products. They would also be required to pay their share of the revenue when negatives revenues are made.

3. Management rights - Participants with management rights would be allowed to participate in decision-making related to the regulation or making improvements in the waste-processing infrastructure, such as, how the by-products will be handled, how often it will be operated, etc.

4. Exclusion rights - Participants with exclusion rights would be allowed to determine who has rights of access, withdrawal or management, i.e. who can/cannot participate in the initiative, who can withdraw from the initiative (i.e. the waste processing infrastructure) and who can regulate or make improvements in the infrastructure.

5. Alienation rights - Participants with alienation rights would be allowed to transfer, sell or lease any of the previous components of rights.

4.2.4. Property Rights Bundles in the context of the Amsterdam Zuidoost initiative

Following this, as mentioned in section 3.1.5, the bundles that can be formed from these property rights are: Authorised Entrant, Authorised User, Claimant, Proprietor and Owner. In the current research, these property rights bundles will be assigned to the participants as the roles that they can take when in the initiative. Additionally, the property rights bundle of an owner will not be taken into account. This is because of time and simplicity constraints, and the focus of the research, which is on setting up of the initiative.

In the context of the initiative, the authorisations as possessed by the participants with the respective bundles are provided in table 4.2:

Property Rights Bundle	**Authorisation Granted**
Authorised Entrant	Can participate in the initiative by providing its organic waste for processing in the waste processing infrastructure (as authorised entrants only have access rights, they would be unable to withdraw/receive benefits from the resource)
Authorised User	Authorisation held by Authorised Entrants, and can obtain benefits through the sale of by-products of the waste processing, and would have to pay their share of the revenue in case of negative revenues
Claimant	Authorisation held by Authorised Users, and can participate in the formulation of management rights, i.e. the operational level rights of withdrawal determining who can obtain the products or benefits from a resource
Proprietor	Authorisation held by Claimants, and can participate in the formulation of exclusion rights, i.e. the operational level rights of access determining who can access the resource and how can it be accessed

Table 4.2: Property rights bundles in the case of the initiative

4.2.5. Security of Tenure in the context of the Amsterdam Zuidoost initiative

Property rights have been studied from the perspective of security of tenure, and the characteristics of robustness, excludability, duration and strength, as defined by Meinzen-Dick (2000). This perspective was chosen as it has been researched for the case of irrigation infrastructure. The characteristics that it shares with waste processing infrastructure are that it requires maintenance and is localised to one region, where it is used by multiple actors.

The concept of security of tenure is applied to the context of the initiative in this discussion using the aspects defined in section 3.1.8. From the discussion in the aforementioned section, it is known that these aspects determine the security of tenure of the property rights bundles that are provided to participants, which then affects their Perceived Behavioural Control. Thus, the aim of the current section is to determine the security of tenure for participants in Amsterdam Zuidoost. The resulting values of PBC will be discussed in section 5.3.1:

- Strength: As explained by Meinzen-Dick (2000); Meinzen-Dick and Mwangi (2009), in the case of water resources, stronger rights apply even during periods of scarcity whereas weaker rights could be denied during such times. Applying this to the case of the initiative, such a situation could be when there is limited capacity left for processing the waste in the infrastructure, and it has to be determined who would be allowed to send their waste for processing.

  However, such a situation is unlikely to occur because the institutions operational in the initiative are applicable to all the participants equally. Thus, if the institution is that participants can send a fixed amount of waste for processing, this would be applicable to all participants. Or, if the institution is that participants can send all their waste for processing, then this institution is also applicable for all. Although in this case it is possible that the maximum capacity is reached before one of the participants can send all of its waste for processing. In such a case, an institution would need to be developed to handle this situation when the number of participants in the initiative increases. Currently, this is not in the scope of the model as the setting up of the initiative is being explored from the perspective of a few companies, whose participation in the initiative will not cause the capacity of the waste processing infrastructure to exceed beyond its limit.

  Hence, as the institution will be same for all participants in the initiative, irrespective of the property rights bundle held by the participant, the strength will be the same for all bundles.

- Robustness: In the case of the initiative, this aspect is exhibited by the property rights bundles of Claimants and Proprietors (as they possess management and exclusion rights). In contrast, the bundles of Authorised Entrants and Authorised Users will not exhibit robustness.

- Excludability: In the case of the initiative, this aspect is exhibited by the property rights bundles of proprietors, as they possess the exclusion rights, which can determine who can be excluded from participating in the initiative and obtaining benefits from it.

- Duration: For the initiative, it has been determined that the pilot would last for seven years. Hence, it is assumed that all participants would be a part of the initiative for this duration (except in exceptional cases). As the duration of the initiative is known, it is considered that all property rights bundles exhibit this aspect of the 'security of tenure' attribute.

Table 4.3 summarises the discussion above, and denotes the aspects present for each property rights bundle with an asterisk ('*').

	Excludability	Robustness	Strength	Duration
Authorised Entrant			*	*
Authorised User			*	*
Claimant		*	*	*
Proprietor	*	*	*	*

Table 4.3: Property rights bundles and the aspects of property rights associated with each for the Amsterdam Zuidoost initiative

It must be kept in mind that in this discussion, all the aspects of the attribute are considered from the perspective of the initiative. However, these could vary based on the circumstances of the case and hence would need to be assessed separately for each case.

4.2.6. Authorisations in the context of the Amsterdam Zuidoost initiative

Property rights bundles of claimants or proprietors can participate in formulating operational level rights for a resource. In the context of the case study, participants that are claimants or proprietors can participate in formulating operational level rights for the initiative.

The rules that can be formulated by these participants are taken from the seven types of rules affecting the action situation (Ostrom, 2010). In the scope of this research, only the payoff rule will be considered. This rule is selected because it relates to the distribution of costs and benefits to the actors, which in the case of the initiative will be the distribution of the economic costs and benefits, which are important from the property rights perspective. Thus, both claimants and proprietors will formulate payoff rules.

4.3. Summary

This chapter helped identify the most important aspects from the case study that would be focused on in the research. The actors identified are the companies that generate organic waste and want the waste to be processed locally, and the Municipality of Amsterdam, which is the facilitator of the initiative and the Project Leader, that coordinates the interaction among the companies, and the companies and the Municipality of Amsterdam. Among the various characteristics possessed by the companies, this research will take into account their attitude, subjective norm, perceived behavioural control, amount of organic waste generated by them and the budget held for participation in social initiatives. The action situation was identified as the collective ownership of the infrastructure (participants who are claimants or proprietors also have a say in the management of the infrastructure/initiative). For the characteristics of the companies it was identified that the attitude is composed of the factors sustainability motive (determined by the amount of organic waste that is processed sustainably) and strategic motive (determined by the financial opportunity created through participation in the initiative), subjective norm is determined by the number of companies that join the initiative and perceived behavioural control is determined by the incentives (property rights bundles) and the amount of financial resources available to the company.

5

Concept Formalisation

This chapter describes the system to be modelled in section 5.1 and the assumptions in section 5.2. The insights obtained through these are formalised and described in section 5.3. This allows us to build the model narrative, which is provided in section 5.4. The model narrative helps to provide a complete picture of the relation and interaction among the theoretical concepts used in the model, which helps answer sub-question 2: How can we gain insights into the interaction and decision-making among actors to engage in initiatives for decentralised organic waste processing by companies?

5.1. System Description

This section describes the research problem, including the actors involved, the 'system' that is to be modelled, its boundaries and internal components. This corresponds to the first two steps of the modelling process, each of which is described in the sub-sections below.

5.1.1. Problem Formulation and Actor Identification

The first step of the modelling process provides helps to identify the main problem and the actors to be involved in the model. The question *'What is the problem?'* can be answered by answering the following sub-questions:

- What is the exact lack of insight that we are addressing?
  The main lack of insight that the research focuses on is the influence of property rights bundles on the decision of companies to jointly invest in waste processing infrastructure. In order to transition to a more efficient way of organic waste management, an initiative has been established by companies in Amsterdam Zuidoost to process the organic waste locally. However, the costs of the waste processing infrastructure are high, and joint ownership of the infrastructure has been suggested to distribute the costs among the companies. To incentivise more companies to participate in the initiative, this research explores the role of institutional incentives in the form of property rights bundles.
- What is the observed emergent pattern of interest to us?
  Currently, the high amount of investment required for the waste processing infrastructure is creating a barrier for the initiative to take-off.

- Is there is a desired emergent pattern, and if so, how is it different from the observed emergent pattern?
  The desired pattern is for the initiative to start with sufficient funds, for which the role of incentives in the form of property rights bundles is being explored. It is known that property rights are closely related to economic outcomes, and their role in the case of collective ownership or management in infrastructure is known through prior research (Meinzen-dick & Bakker, 2001). It has also been observed that providing a more complete set of rights leads to greater involvement in the management of resources while providing an incentive to invest in the resources Schlager and Ostrom (1992). However, this has mostly been done in an empirical setup and for cases wherein economic benefits are of primary importance. The aim of this research will be to understand whether bundles of property rights can also influence the decision of the companies to participate and invest in the initiative, which is being set up with a social inclination.

- What is the initial hypothesis on how the emergent patterns emerge, or, why do the observed and desired emergent patterns differ?
  The initial hypothesis is that providing incentives in the form of property rights bundles will incentivise the companies to participate and invest in the initiative. As a result, the number of companies that participate in the initiative when incentives are provided will be more than the number of companies that participate in the initiative when no incentives are provided.

5.1.2. System Identification and Decomposition

After identifying the problem, it is essential to demarcate the system that will form the focus of the model. The components of the system involved in the model are discussed here.

The system considered here is the waste processing initiative, along with the actors which are a part of it, their characteristics and the roles that they can take/be assigned which will together determine the resulting behaviour, the rules that govern their interactions, etc. In an agent-based model, these components will be adopted into agents, objects, the environment, rules, etc. Some aspects of these have been identified by applying the Institutional Analysis and Development (IAD) framework and have been discussed in Section 4.2.1. An overview of these has been provided.

1. Actors involved - The actors involved in the initiative are the companies, the Municipality and the knowledge institutes. Out of these, some of them are capable of taking their own decisions, and hence will be the agents whereas the rest will be objects. These are given below:
   Agents - As identified by applying the Institutional Analysis and Development (IAD) framework in Section 4.2.1, the agents in the agent-based model will be:

   (a) Waste shippers – The companies that generate waste and are taking steps to reduce the current inefficiencies in waste management. These generate organic waste and hold a fixed budget for participation in the initiative. Their participation is based on their intention to join the initiative which is affected by the subjective norm, their perceived behavioural control and attitude towards participation. The influence of each of these factors is different for each company.

   (b) Participants - The waste shippers that join the initiative are the participants in the initiative.

   The following actors will be included in the model as globals, i.e. the procedures executed globally in the model are considered to be performed by them:

(a) Municipality of Amsterdam - The facilitator of the initiative. It provides legal permission for the initiative and the land required to place the waste processing infrastructure.

(b) Project Leader - This agent is responsible for the co-ordination among the agents and the agents and the Municipality of Amsterdam, required for setting up the initiative.

The incentives will be provided by the project leader along with the Municipality of Amsterdam.

2. Environment – Entities that are not affected by the agents, but that affects the agents can be considered as part of the environment. These entities in the case of this research are given below. These represent the external variables in the IAD framework:

   (a) Waste Processing Infrastructure – This is part of the bio-physical conditions in the IAD framework, as explained in Section 4.2.1.
   The infrastructure affects the agents as its capacity constraints determine how many maximum agents (specifically, waste shippers) can participate in the initiative. The waste processed by the infrastructure produces by-products in the form of heat, electricity, digestate and nutrient-rich water, which are sold in the market or then given to nearby companies in the region that can utilise one or more of these by-products.

   (b) Market price for the by-products - This is part of the rules-in-use in the IAD framework, as explained in Section 4.2.1. The by-products that are obtained from the waste processing infrastructure affect the amount of investment returned to the companies that have invested in the infrastructure. The digestate produced can sometimes have a negative market-price, denoting that the buyers have to be paid for it to be disposed of.

   (c) Institutions in the initiative - The institutions in the initiative can be divided into the property rights and operational-level rules:

      - Property rights are provided in the form of bundles. These are the incentives provided to the waste shippers by the Municipality of Amsterdam and the project leader. This is part of the rules-in-use in the IAD framework, as explained in Section 4.2.1.
      - The operational-level rules being considered in the model are the payoff rules, which determine how the costs and benefits will be divided among the companies. This rule can be updated by those participants in the initiative who hold the property rights bundles of Claimants or Proprietors.

5.2. Assumptions

The application of the IAD framework helped to identify the most significant components and relations which should be considered in the research. As a result, some assumptions have been made so as to simplify the system to focus on the most important aspects. These assumptions with respect to the system have been listed below:

1. Within the action situation of collective ownership of the infrastructure by the companies, it is assumed that these companies have complete information on the states and values of the other companies. For example, they calculate their attitude towards joining the initiative based on the maximum Return on Interest (This is for the strategic motive included in the attitude aspect, see Section 5.3.1 for details). For this they require information on the lowest share paid by the participants who are already part of the initiative (The difference in share of investment occurs when participants pay as per the amount of waste they generate). Under the assumption of

complete information, these companies are able to know the value of lowest share paid by the participants.

2. The budget, considered as a characteristic of the actors in the action situation, remains constant throughout the duration when the initiative setup processing is taking place, i.e. the duration of the model run. In reality, however it is possible that the budget allocated for initiatives could vary based on the financial results of the company.

3. The weight factor assigned to the companies for the constructs in the Theory of Planned Behaviour is assumed to remain constant through the time the initiative is being set up. In reality, the preference given to the constructs could vary over time. This is also applicable for the weight factors assigned to the factors that make up the attitude.

4. The amount of organic waste generated by the waste shippers, also considered a characteristic of the actors in the action situation, is assumed to be constant for the time the initiative is being set up. While in reality, the amount of organic waste generated could vary daily or monthly, this assumption helps to focus on the influence of property rights on the companies.

5. From the costs and benefits applicable to the situation, the only operational costs that have been considered are the costs of operating the waste processor. In addition to these, there could also be other operational expenses such as labour cost, administrative costs, transaction costs, etc. It should be mentioned here that through the assignment of property rights bundles, the ex post transaction costs spent on deciding the distribution of resources, operational costs and benefits are minimised, although ex ante costs are involved in assigning the property rights bundles.

6. The subjective norm construct of the TPB for an individual or a company is the perceived social pressure that can affect the intention to perform an action. In the context of companies, this perceived pressure can be from internal stakeholders such as employees and shareholders, as well as external stakeholders such as the industry or the government. For the scope of this research however, only the influence of the neighbouring companies in the region has been considered for all companies. However, as this is 'subjective' in nature, the value of this characteristic could vary among the actors.

7. To restrict the focus of the action situation to the influence of property rights bundles on the establishment of the initiative, it is assumed that participants joining the initiative remain in the initiative for the entire duration it is operational.

8. It is assumed that the companies participating in the initiative and in the region are (Small and Medium-sized Enterprises) SMEs, as per the definition by European Commission (n.d.). According to this definition, companies with less than 250 employees are considered to be medium-sized. This assumption has been made due to data availability on the amount of waste generated by SMEs.

9. Furthermore, it is assumed that the companies participating are offices or businesses. This assumption is based on the knowledge that majority of the type of companies participating in the initiative are offices or businesses. This assumption affects the values used for the amount of waste generated by the companies, discussed under the model assumptions.

Some assumptions have also been with respect to the model, in order to simplify it. These are listed below:

1. The waste shippers will allocate a certain amount of funds, i.e. a budget, against which the financial capability to participate in the initiative will be assessed. In the model, this is achieved by assigning a random number between a 'minimum budget' value and a 'maximum budget' value for each agent. Based on a response received from one of the waste shippers in Amsterdam Zuidoost, this assumption is true as they do have a budget for investment. However, as this information has been confirmed by only one potential participant, this assumption stands as one.

2. The complete bundle of property rights contains five bundles: authorised entrant, authorised user, claimant, proprietor and owner (Schlager & Ostrom, 1992). In the scope of this research, only the first four bundles have been considered. This is because according to the owner property bundle, users with this role can sell, lease or transfer their property rights to another user. However, as the scope of the research is to consider the influence of property rights bundles for setting up the initiative, i.e. for participants joining the initiative, the owner role has been left out of scope.

3. Users with the property rights bundles of proprietors and claimants have the authority to formulate operational level rules of management and withdrawal for the resources (Schlager & Ostrom, 1992). As per this definition, both claimants and proprietors can formulate payoff rules, position rules, choice rules, etc., from the list of rules that are present in an action situation of the IAD framework (Ostrom, 2010; Schlager & Ostrom, 1992). In addition to these, proprietors can also formulate boundary rules, i.e. exclusion rules which determine who can/cannot access the resource.
   In the context of this research, for the scope of the model, only the payoff rule has been modelled. This was a scope choice to simplify the model.

4. The model is limited in that it does not depict the additional rights of the proprietors to formulate exclusion rights, i.e. boundary rules. This was also a scope choice to simplify the model.

5. From literature, it is known that offices generate 730 kg of organic waste/year and businesses generate 410 kg of organic waste/year. In this research, it is assumed that the companies generate an amount of waste between these values, as exact data for the companies in the initiative is unknown.

6. The operational cost per ton of waste processing is assumed to be fixed for the duration of the model run, i.e. 2 years.

7. For anaerobic digestion, the retention time is the time taken to complete the degradation of the waste. This is taken as 30 days, based on the upper value defined in Mao, Feng, Wang, and Ren (2015).

5.3. Concept Formalisation

The concepts discussed above are formalised so that they can be made more comprehensible. Software data structures are used for this purpose (van Dam et al., 2013). Some of the variables are provided below, for the detailed list, please refer to Appendix E. It should be noted here that due to confidentiality reasons, the value of cost of infrastructure has not been displayed. Furthermore, the values used for maximum budget are only representative. The actual values used in the model are not reported for the same reasons.

Global Variables:

- $minWaste$, in kg, integer > 0, slider variable, >= 15, <= 55 ((Gemeente Amsterdam, 2017), refer appendix D, section D.5 for calculation details)
- $maxWaste$, in kg, integer > 0, slider variable, >= 60, <= 100. ((Gemeente Amsterdam, 2017), refer appendix D, section D.5 for calculation details)
- $maxBudget$, in euros, integer > 0, slider-variable, >= 200, <= 400
- $incentiveExperiment$, integer >= -1, slider-variable. Takes values -1, 0, 1, 2, 3; values 0 to 3 correspond to the incentive provided, -1 corresponds to all incentives provided in an increasing order
- $costInfra$, in euros, integer > 0, fixed value (Due to confidentiality reasons, the value of this is not displayed)
- $totalCapacity$, in kg, integer > 0, slider-variable, >= 100, <= 3600 (obtained from website of the waste processing technology manufacturer). Default value is chosen as 500 kg so that appropriate results and and patterns can be captured, which could be missed if the entire capacity (3600 kg) is considered.
- $maxParticipants$, integer, = 75. Calculated as totalCapacity / 48, where 48 kg is the average of the waste generated by offices and businesses, the types of companies considered in this research ((Gemeente Amsterdam, 2017), refer appendix D for calculation details).
- $shareInvestmentSame$. Share of investment obtained as cost of infrastructure divided by number of participants. Floating point > 0

Waste Shippers:

- $organicWasteQty$, amount of organic waste generated by agents. Floating point > 0, random value between minWaste and maxWaste, values are random normally distributed among agents
- $budget$, budget present with agents. Floating point > 0, random value between minBudget (0) and maxBudget
- $shareInvestmentProportionate$, share of investment to be paid when total cost of infrastructure divided based on the amount of waste generated. Floating point > 0, value of share of investment if it is to be paid in proportion to the amount of organic waste generated, calculated as (organicWasteQty / totalWasteGenerated) * costInfra
- $shareInvestment$, share of investment to be paid to participate, can either be equal to shareInvestmentSame or shareInvestmentProportionate. Floating point > 0.
- $initialStrMotive$, initial strategic motive of attitude. Integer, = 0
- $attitudeStrMotive$, strategic motive of attitude. Floating point > 0
- $initialSustMotive$, Initial sustainability motive of attitude. Floating point > 0, calculated as explained in Section 5.3.1 below
- $attitude\_SustMotive$, sustainability motive of attitude. Floating point > 0, calculated as explained in section 5.3.1 below

- $weightFin$, coefficient of profitability motive of attitude. Floating point, random-normal value with mean 0.57 and standard deviation 0.2 ((Brønn & Vidaver-Cohen, 2009), refer appendix D, section D.5 for calculation details)
- $weightSust$, coefficient of sustainability motive of attitude. Floating point, random-normal value with mean 0.72 and standard deviation 0.2 ((Brønn & Vidaver-Cohen, 2009), refer appendix D, section D.5 for calculation details)
- $attitude$, floating point > 0, calculated as $(weightFin * attitudeStrMotive) + (weightSust * attitude\_SustMotive)$
- $weightAttitude$, coefficient of attitude. Floating point, random-normal value with mean 0.214 (Ham, Pap, & Stimac, 2018) and standard deviation 0.2
- $pbc\_strength$, Strength aspect of security of tenure. Integer, 0 / 1
- $pbc\_excludability$, Excludability aspect of security of tenure. Integer, 0 / 1
- $pbc\_duration$, Duration aspect of security of tenure. Integer, 0 / 1
- $pbc\_robustness$, Robustness aspect of security of tenure. Integer, 0 / 1
- pbc, floating point > 0, calculated as $(pbc\_strength + pbc\_excludability + pbc\_duration + pbc\_robustness)/4$
- $weightPBC$, coefficient of PBC. Floating point, random-normal value with mean 0.362 (Ham et al., 2018) and standard deviation 0.2
- sn, floating point > 0, calculated as $numParticipants/maxParticipants$ or $initialNoOfParticipants / maxParticipants$
- $weightSN$, coefficient of subjective norm. Floating point, random-normal value with mean 0.307 (Ham et al., 2018) and standard deviation 0.2
- intention, intention of agents to participate in the initiative. Floating point > 0, calculated as $(weight_{PBC} * PBC) + (weight_{Attitude} * attitude) + (weight_{SN} * SN)$ (Chu & Chiu, 2003)

5.3.1. Calculation of intention values

The agent variables corresponding to the TPB concepts and their factors are initialised. These variables are updated through the course of the model run. Intention value is calculated as shown previously (Chu & Chiu, 2003):

$$(weight_{PBC} * PBC) + (weight_{Attitude} * attitude) + (weight_{SN} * SN)$$

The calculation for each component is described below.

Calculating the value of subjective norm

Subjective norm is based on the number of companies in the region that join the initiative. The value of subjective norm which will be considered by the companies will be calculated in the following way:

1. Maximum number of companies in the region that can be allowed to participate in the initiative, based on the average waste generated and the capacity of the infrastructure, is 75, i.e. value of $maxParticipants$

2. Initial number of waste shippers joining the initiative: $initialNoOfParticipants$ and the final updated value: $numParticipants$

3. This ratio of $initialNoOfParticipants/maxParticipants$ or $numParticipants/maxParticipants$ is the value of subjective norm, and will be between 0 and 1

4. Higher is the value of this ratio, higher is the value of subjective norm (as more companies join the initiative, the social pressure on the companies that have not joined the initiative increases)

Calculating the value of attitude

The value is based on the strategic motives and sustainability motives of the companies:

1. Attitude sustainability motive is based on the belief that participating in the initiative will lead to sustainable outcomes (measured through the amount of organic waste processed through the initiative, in a decentralised way).
   Sustainability motive is the ratio between the amount of waste that participants can send for processing and the amount of waste generated by them.

2. Initially, all waste shippers are only allowed to send a fixed limit of waste: $initialLimitWaste$. This is calculated as:
$$\frac{totalCapacity}{initialNoOfParticipants}$$
   The value of $sustainabilitymotive$ will be:
$$\frac{initialLimitWaste}{organicWasteQty}$$
   Later in the model, the value of sustainability motive depends on whether or not there is a limit on the amount of waste that can be processed, as seen from the $limitOnWasteInput$ variable.
   - If value is 1, there is a limit and value of sustainability motive is:
$$\frac{maxOrganicWaste}{organicWasteQty}$$
   - If value is 0, there is no limit and as all waste that is generated can be processed, the value of sustainability motive is 1.

3. The strategic motive is based on the $ReturnonInvestment(ROI)$ earned by participating in the project. This is calculated as:
$$\frac{revenue - cost}{shareInvestment}$$

4. Both the strategic and sustainability components have a weight component attached to them: w_{fin} and w_{sust}, respectively.

5. The overall value of attitude is given by:
$$(w_{fin} * strategicMotive) + (w_{sust} * sustainabilityMotive)$$

Calculating the value of Perceived Behavioural Control

Perceived Behavioural Control (PBC) in this research is considered from the perspective of the 'knowledge readiness' and 'financial readiness' of the companies. Out of these, the knowledge readiness is determined by the budget present with the companies, which will be a random number between a minimum value (0) and a maximum budget. The value of knowledge readiness is dependent upon the type of property rights held by the agent. The overall value is determined by the aspects: strength, robustness, duration and excludability of the property rights bundles. Table 5.1 denotes the aspects present for each property rights bundle with a 1. Each of these aspects hold equal weight in determining the value, which will be an average of the aspects present in that property rights bundle:

$$\frac{pbc_{strength} + pbc_{excludability} + pbc_{duration} + pbc_{robustness}}{4}$$

	Excludability	Robustness	Strength	Duration
Authorised Entrant			1	1
Authorised User			1	1
Claimant		1	1	1
Proprietor	1	1	1	1

Table 5.1: Components and their impact on PBC

5.4. Model Narrative

The model narrative was built using information from the case study and from literature. The important aspects of its development are mentioned below:

- The basic setup of the model was grounded in the case study. This included the following: agents (including the default number of agents, their waste-generating behaviour and characteristics such as the willingness to cooperate and collaborate with other agents), waste processing infrastructure (including the cost and capacity), time-frame provided for establishing the initiative and interaction between the companies and with the Municipality (modelled as globals).
- The decision-making of the agents was studied using the Theory of Planned Behaviour. The factors included and the values used for these were based on literature.
- The amount of digestate, electricity and heat produced is based on the amount of organic waste fed into the bio-digester for processing. In addition to that, the amount is also based on the calorific value of the biogas, amount of digestate produced per tonne of input, etc., and these values are obtained from literature. Please refer appendix E for the calculations.
- The market-prices of digestate, electricity and heat were based on literature.
- The incentives, i.e. the property rights bundles provided to the agents are based on literature by Schlager and Ostrom (1992). The choice to model them such that they are provided in an incremental order was also based on literature. The five types of property rights defined with respect to common-pool resources differ in the authorisation they provide to those who hold this right. Access rights provide the least authorisation and alienation rights provide the highest authorisation (discussed in section 3.1). More authorisations are added while going up the hierarchy, hence

providing the rights in an incremental order allows us to examine the influence each type has on the decision of the agents.

The model narrative will clarify the order in which the activities take place, and how the aspects defined in this chapter are related to each other in the model. The complete flow is depicted in Figure 5.1.

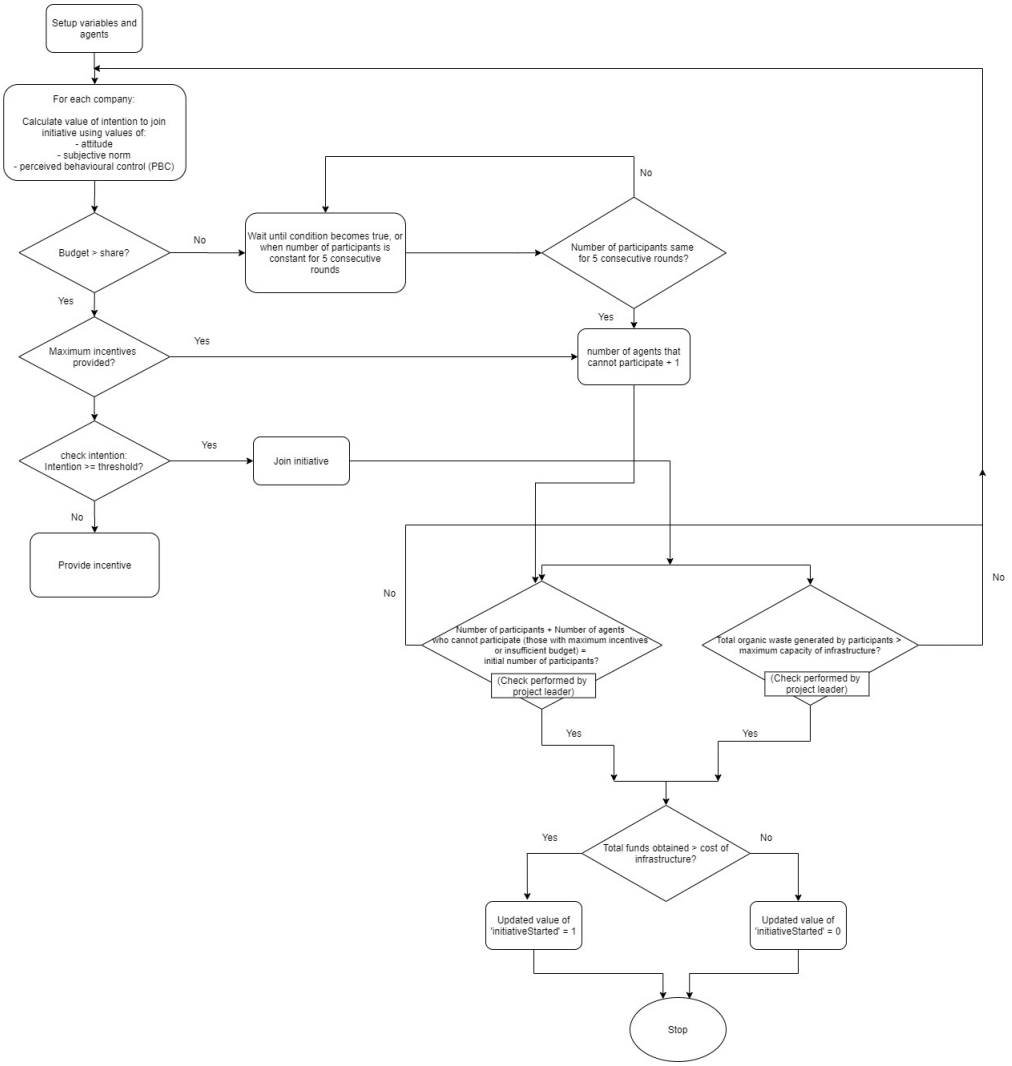


Figure 5.1: Model Narrative Flowchart

Setup variables and agents: The model begins with the setup of an initial number of agents (waste shippers), who have expressed their interest to participate in the initiative. Based on this number and the default payoff rule (all agents pay an equal share of investment and send an equal amount of waste for processing), the share of investment for each participant and the limit of amount of waste they can send for processing is decided. This is depicted in Figure 5.2.

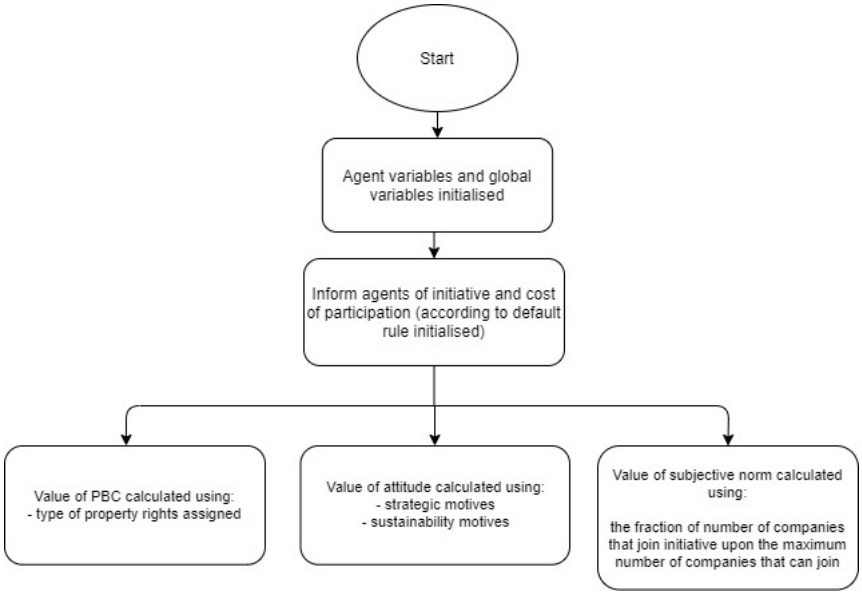


Figure 5.2: Setup of variables and agents

Each agent generates a fixed amount of waste and holds a fixed amount of budget for participation in the initiative, both of which are randomly assigned. The total amount of waste generated by all waste shippers determines the amount of by-products produced which can be sold in the market. Based on the market price of digestate, heat and electricity, the total amount of revenue that can be obtained is calculated. The agents are also assigned a default role ('Authorised Entrant') which will be assumed by them when they join the initiative. All of the values defined/calculated above determine the values of the characteristics of attitude, perceived behavioural control and subjective norm for each agent.

Join initiative: In each tick, the agent calculates its intention, checks its intention and joins the initiative if the condition is satisfied. If the budget possessed by the agent is greater than its share of investment, the agents calculate their intention to join the initiative based on the values of attitude, perceived behavioural control and subjective norm. If the intention is greater than the threshold value, the agent joins the initiative as a 'participant', pays the share of investment and assumes the role, i.e. the property rights bundle it was offered as incentive (if it was offered an incentive to join the initiative). After all agents have decided whether or not to join the initiative, if the rule is that all agents must pay an equal share of investment, the share of investment is updated as $(= totalCostOfInfrastructure/newNumberOfParticipants)$ and the amount of organic waste that can be sent for processing is updated as $(= totalCapacity/newNumberOfParticipants)$. This is depicted in Figure 5.3.

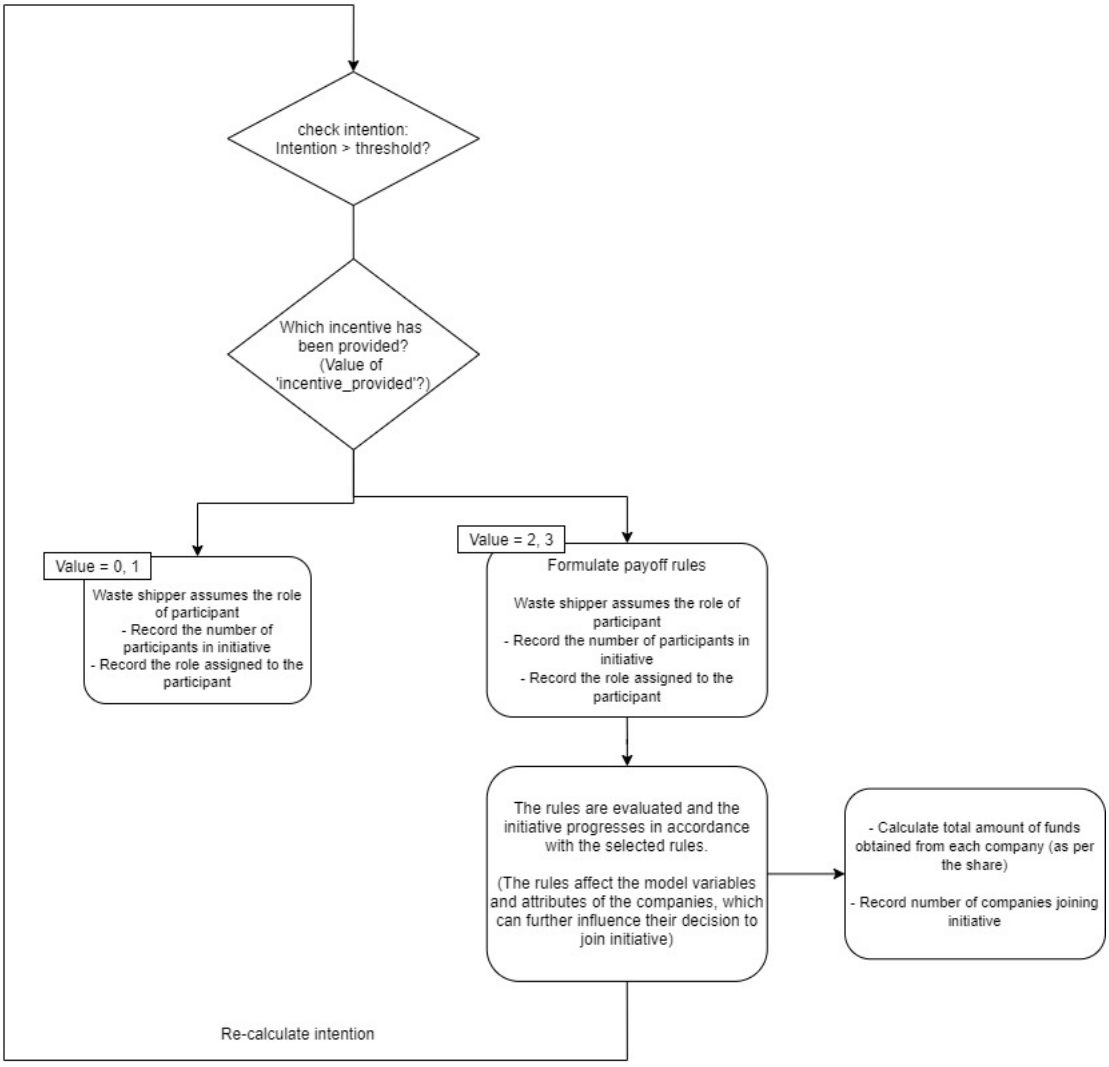


Figure 5.3: Joining the initiative

For an agent, if the intention is lesser than the threshold value, it does not join the initiative and the decision-making continues for this agent

Additionally, before each agent checks its intention, a global check is performed to ensure that the maximum capacity of the infrastructure has not been reached.

Provide incentive: In the next tick, the agents that have not yet joined the initiative but possess sufficient budget to join the initiative, are provided the next higher property right bundle as an incentive. These agents re-calculate their intention based on the updated values of attitude, perceived behavioural control and subjective norm (which have updated values due to the change in limit on amount of waste that can be sent for processing, the change in share of investment, the change in the number of participants, the change in PBC due to higher property rights bundle). The agent then checks its intention again: if it is greater than the threshold value, it joins the initiative, otherwise it does not. This sequence of steps repeat until the agents have been provided all incentives. This is depicted in figure 5.4.

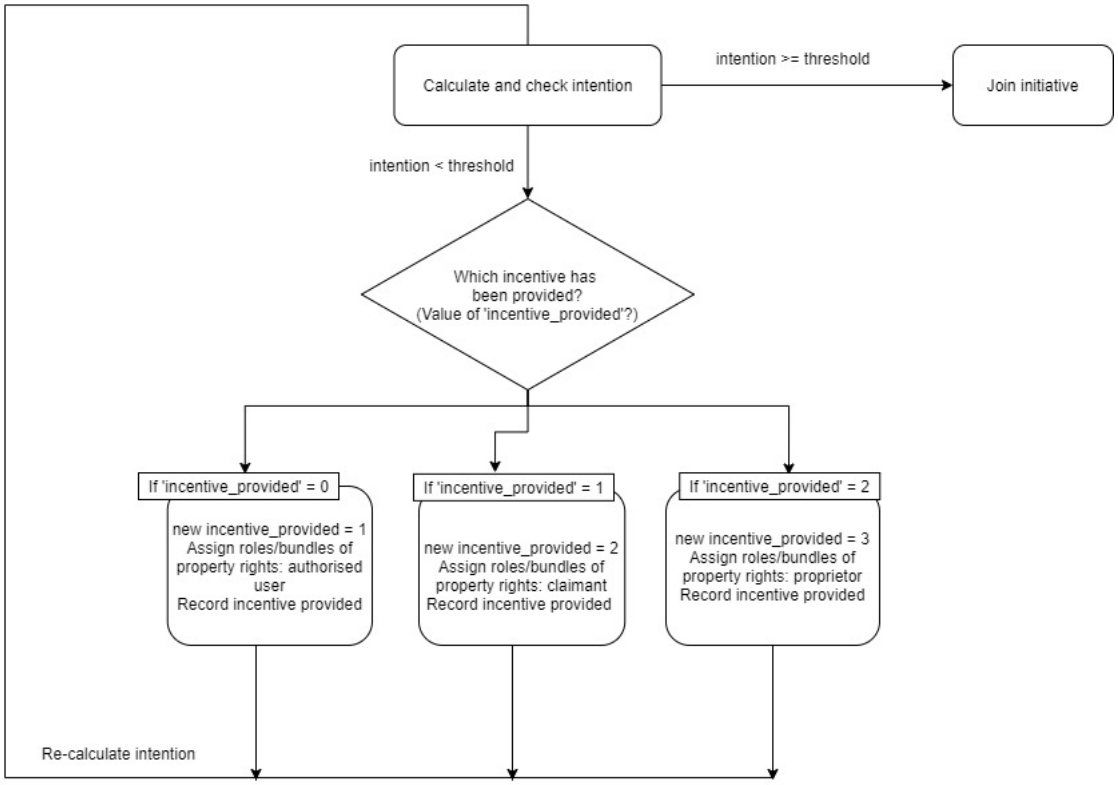


Figure 5.4: Providing incentive

In the same tick, the agents who have joined as claimants or proprietors have the authorisation to update the payoff rule (an alternative of the existing rule, which is that agents pay their share of investment in proportion with the amount of waste they generate, and as a result, can send all their waste for processing). This is done through voting for one of the two rules, based on the sustainability and profitability criteria, which are calculated in a way similar to the sustainability motive and profitability motive of attitude (see section 5.3.1).

In each tick, the number of participants and the number of agents who have not joined (because they have been provided all incentives, or because the maximum capacity of the waste processing infrastructure has been reached) are recorded. If at the end of five consecutive rounds, the number of participants remains the same, then the difference between them and the number of agents that did not joined the initiative is recorded as the number of agents with insufficient budget.
If the sum of the number of participants in the initiative and number of waste shippers with insufficient budget is equal to the initial number of participants, it is then checked if the total funds obtained are more than or equal to the total cost of infrastructure. If sufficient funds have been obtained, the initiative can start. If not, the initiative fails to start. The model terminates after recording if the initiative can start or if number of ticks equals 23 (maximum time-frame for the initiative setup process has been reached).

5.5. Model Implementation

The agent-based model was implemented in Netlogo 6.1.1. The code can be found at: `https://bit.ly/366kuRi`

5.6. Summary

This chapter described the problem and the system that are modelled. The initiative in Amsterdam Zuidoost is to be modelled for the case of joint ownership of the waste processing infrastructure when incentives in the form of property rights bundles are provided to the companies. The agents, objects, institutions that are to be included were also specified. The chapter also provided information on how these aspects are formalised. The model narrative was provided and assumptions made at the model and system level were discussed. Overall, the chapter provided the answer to sub-question 2: How can we gain insights into the interaction and decision-making among actors to engage in initiatives for decentralised organic waste processing by companies?

6

Model Verification and Sensitivity Analysis

The developed agent-based model is verified to ensure that there are no errors in implementation and that it does what is expected, this is discussed in section 6.1. A sensitivity analysis is performed for those model inputs which have not originated from literature and have been assumed in order to understand how the change in their values affects the model outcomes. This is discussed in section 6.2.

6.1. Model Verification

The model verification step is performed to make sure that the model narrative has been translated correctly into the model code. This step is crucial to make sure that any mistakes that might have been made are not carried over to the data analysis and results. The steps followed for the verification of the model will be described here. As suggested by van Dam et al. (2013), the model was verified by: Recording and Tracking Agent Behaviour, Single Agent Testing, Interaction testing in a minimal model and multi-agent testing.

6.1.1. Recording and Tracking Agent Behaviour

For this step, the agent variables and global variables were recorded to check if the values were initialised and being updated as required for the model to operate correctly. The actions performed are listed below, and any unexpected or incorrect behaviour has been reported.

- Initial values were checked for the correct data type. A few variables which were to be of the boolean type, were being compared with numeric values in the conditional statements: identified and corrected
- A variable with a non-zero default value was initialised to the correct value: verified for all and corrected for one variable
- Model variable was assigned before use: mistake identified and corrected

- Variables were being updated correctly in the functions and updated values were passed to calling function: verified
- Maximum number of ticks set to correct value: verified

For each of the procedures, the initial and final values of the variables were recorded and checked to detect any deviations from expected behaviour. Some of the checks are mentioned below:

- Global Variables:
  - Intention threshold values being set correctly for each incentive type, verified
  - No incentive value is set and slider value is correctly set when no incentives are provided: verified
  - Initial values of global variables are correctly set: verified
  - Slider variables were initialised with correct upper and lower limits: verified
- To $inform - waste\_shippers$: Condition for calling calculate-intention procedure was present: verified
- To $calculate - intention$:
  - Values for TPB variables were being set correctly, as per definition: corrected for the 'pbc' variable and re-verified
  - '$intention$' calculated as per '$incentiveProvided$' value: verified
  - Update values for variables handled for the case when '$numParticipants$' is zero: verified
  - Update values for variables handled for negative values: verified
- To go:
  - Condition for calling $inform - waste\_shippers$ procedure was present: verified
  - Condition for calling $check - intention$ procedure was present: verified
  - Check for amount of time/condition until which model needs to be run: corrected and re-verified
  - Model terminates as per stopping condition: corrected and verified
- To check-intention:
  - '$incentiveProvided$' value updated based on the incentive being provided: verified
  - If maximum incentives are provided to an agent, no new incentives can be provided to it: verified
  - Counter values are updated correctly, with no agent calculated twice: corrected and re-verified
- To join-initiative:
  - Role assigned to agent based on the incentive it was provided: verified
  - Appropriate checks are present for share of investment to be paid and amount of waste that can be sent for processing: verified

- To formulate-rules:
  - Only agents with appropriate roles can formulate rules: verified
  - Agents (with appropriate roles) can formulate rules only once: verified
- To check-votes:
  - '$investmentSame$' and '$limitOnWasteInput$' values updated correctly based on the operational rule selected: updated based on theoretical check and re-verified
  - Updated operational rule reflected back into model flow: verified
- To-report generateOrganicWaste:
  - Values generated are within the limits defined: verified
  - Value generated in procedure passed correctly to calling variable: verified

6.1.2. Single Agent Testing

At the beginning of the model, there is only one agent type. This step was checked against one agent of the type. No abnormalities were observed. After the second agent type is introduced in the model as part of the model flow, an agent of this type was checked for its states and values, and no abnormalities were found.

6.1.3. Interaction Testing in a Minimal Model

Two agents were initialised, using which the model flow was tested. All updates and values were correctly reported.

6.1.4. Multi-agent Testing

Three tests were performed here, with an increasing number of agents in each case. While checking for the logic and performing the theoretical prediction, it was found that two of the variables which were to be updated, remained constant at the allocated value. The corrections were then verified. Boundary conditions were tested for possible errors Model flow was checked to verify that procedures were being called in order as set in the conceptual model.

6.2. Sensitivity Analysis

A sensitivity analysis is performed to measure the impact on the model outcomes due to a change in the input values. Sensitivity analysis is required for those variables in the model whose values have been assumed. Thus, this is done for: i) Standard deviation of the weight coefficients of TPB variables and weight coefficients of factors of attitude, ii) Standard deviation of the amount of waste that can be generated and iii) Maximum value of the budget.

Results of the sensitivity analysis are captured using the Key Performance Indicator of 'Number of participants', which is the final number of participants joining the initiative (Two additional KPIs have been defined for the experiments, and are discussed in the following chapter.)

6.2.1. Standard deviation of the weight coefficients

In this research, it has been considered that the weight coefficients of TPB variables and weight coefficients of factors of attitude are distributed random-normally, for which the mean and standard deviation

of the distribution is to be known. From their work on the application of the Theory of Planned Behaviour to predict the intention of business students to implement Corporate Social Responsibility (CSR) initiatives, Ham et al. (2018) find that the coefficients of PBC, attitude and subjective norm are 0.362, 0.214 and 0.307 respectively, which have been considered as the mean values of the coefficients. This study also took into account the factor 'CSR in education', which has been left out in this research as it is not a part of the scope.

As no information was available on the value of standard deviation for these coefficients, three arbitary values were chosen and a sensitivity analysis was performed, with the experiments repeated 300 times, to check if these values had any influence on the model KPI 'Number of Participants'. A box-plot was plotted to view the extent of changes in the outcome, which has been shown in the Figure 6.1 and Figure 6.2. The highest value of number of participants is 6, denoting that for all cases, these are the maximum number of participants (out of a possible 7) that join the initiative. One observation is that the variation between each standard deviation value for both the cases (base case and in the increasing incentives case) is low.

Additionally, for both cases with standard deviation as 0.2, the majority of the values lie in the range of 1 to 2 participants, barring a few outliers that take higher values. For the other two values of standard deviation, the range of number of participants is slightly higher. Although the difference is low, we can state that the model is slightly sensitive to the values of coefficients of the TPB variables.

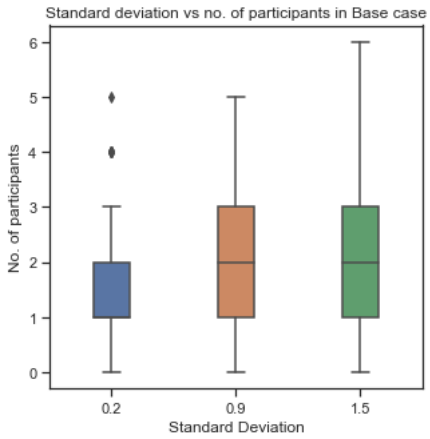


Figure 6.1: Variation in range of number of participants against the SD of weight coefficients in the base case

6.2.2. Standard deviation of the amount of waste generated

According to the definition of SMEs (Small and Medium-sized Enterprises) by the EU (European Commission, n.d.), SMEs are businesses whose number of employees are less than 250. In the case of the initiative, not all the companies involved fit into the category of SMEs as per this definition. However, since our focus is on one of the branches of the companies, the business or office can be compared to an SME, due to the number of employees present in that branch. As a result of this assumption, we can obtain the amount of waste generated by the companies.

From Gemeente Amsterdam (2017), we know that the amount of waste generated per year for offices and businesses is 730 kg/year and 410 kg/year, respectively. In our case, we assume that the waste processing infrastructure is run every 30 days, based on the upper limit of retention time given in the work by Mao et al. (2015). Thus, the amount of waste generated by participants is measured per month, and this comes out to be in the range of 34 kg - 61 kg, for the case of the Amsterdam Zuidoost

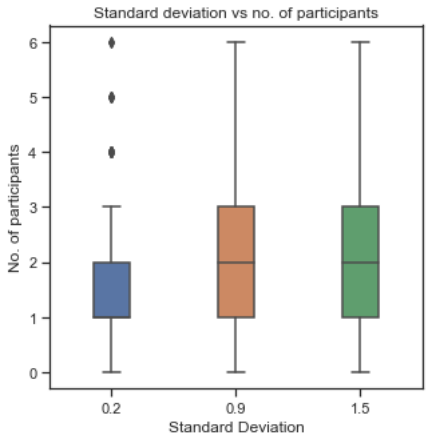


Figure 6.2: Variation in range of number of participants against the SD of weight coefficients in the increasing incentives case

initiative. Furthermore, it is considered to be normally distributed. From the range, the mean of the waste generated is calculated as the mean between the min-Waste and max-Waste (as set by the user using the sliders). However, there is no information on the standard deviation of the values. Hence the value of standard deviation is assumed to be 20 kg (lower than the default value of the minimum waste generated) and two additional values (50 kg and 80 kg) were taken to perform the sensitivity analysis, and the experiment was repeated 300 times for each case.

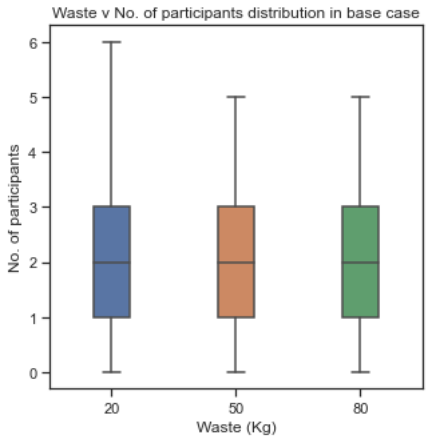


Figure 6.3: Variation in number of participants when the standard deviation of waste is varied in the base case

From the Figure 6.4 it is seen that the variation in range is similar to the standard deviation value considered in the model (20 kg), and the values obtained for all the cases are comparable. In the base case (Figure 6.3) when no incentives are provided, more variation is seen in the KPI when the standard deviation is 20 kg, as compared to when it is 50 kg or 80 kg. However, the difference between the variations is small, and not conclusive to state that the standard deviation values have an effect on the final results.

Hence it can be concluded that the choice of value of standard deviation does not have a significant influence on the results.

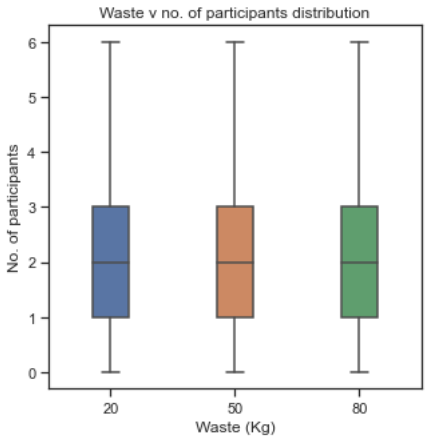


Figure 6.4: Variation in number of participants when the standard deviation of waste is varied

6.2.3. Maximum value of budget

In this model, it is considered that the companies have a fixed budget, using which they decide if they have the financial resources to participate in the initiative. However, due to lack of data, the value to be used in the research was not known. Hence, a sensitivity analysis was done to find that value of maximum budget at which the initiative starts. This was required so that we could obtain results that can help answer the main research question. The experiment was repeated 100 times, and it was found that the initiative only starts in increasing incentives when the value is €200 (Figure 6.5). This value was then considered as the default value for the model runs. In base case the initiative did not

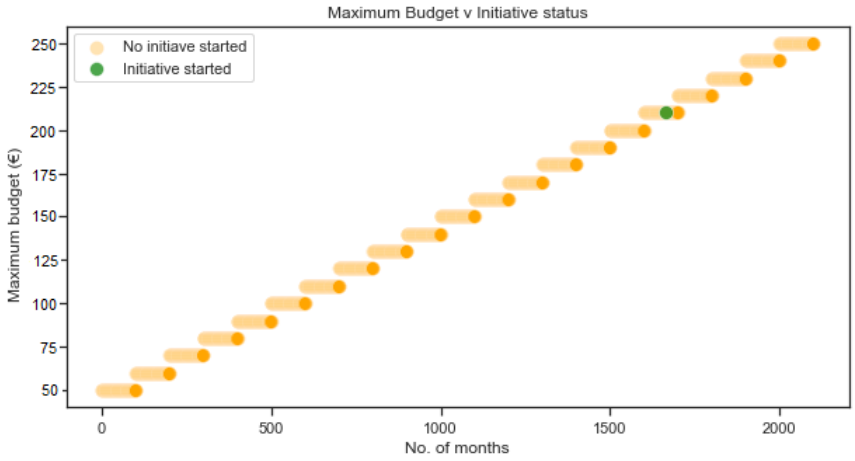


Figure 6.5: Number of months (ticks) v/s Maximum Budget for the increasing incentives case.

start (Figure 6.6).

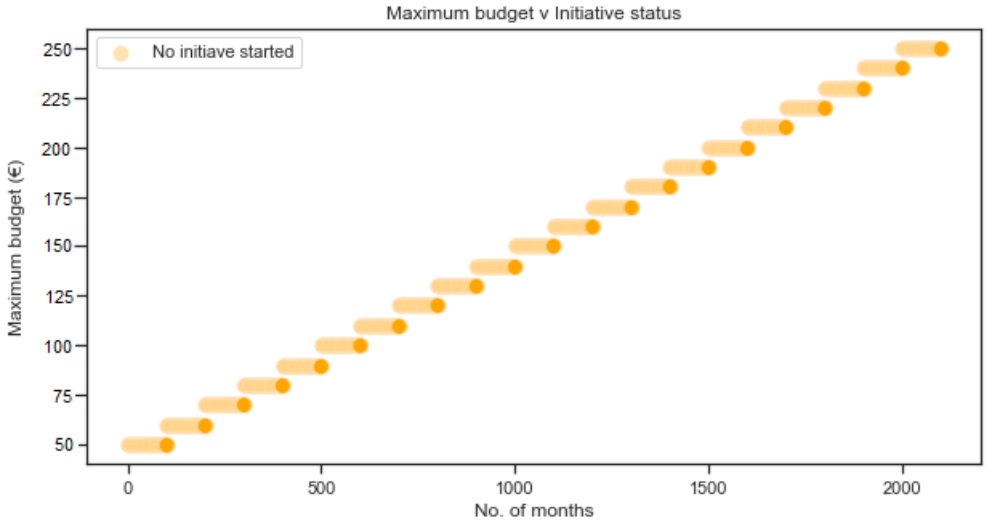


Figure 6.6: Number of months (ticks) v/s Maximum Budget for base case

6.3. Summary

This chapter described the steps taken to verify the model. It also described the sensitivity analysis conducted for a few values in the model. It was found that the model is slightly sensitive to the standard deviation of the weight coefficients of the Theory of Planned Behaviour variables, but is not sensitive to the standard deviation of the amount of waste. Due to a lack of data on the maximum budget held by the companies, sensitivity analysis was conducted to obtain this value.

7

Experimentation

In order to understand the influence of property rights bundles in varying conditions, experiments that can help provide further insights were designed and conducted. The design aspects are discussed in section 7.1 and the experiments in section 7.2. The Key Performance Indicators (KPIs) used to measure the model outcomes are also provided. This chapter answers the sub-question 3: How can we measure the effects of property rights in initiatives for decentralised organic waste processing by companies?

7.1. Experiment Design Aspects

The variables chosen for these experiments are those model inputs and agent properties, which could influence the outcomes. These are mentioned in table 7.1, along with the default values. The variables change based on the hypotheses tested and the significance of each variable is discussed under the respective hypotheses.

7.1.1. Key Performance Indicators (KPIs)

The influence on the outcomes has been measured using the Key Performance Indicators (KPIs):

1. Number of participants The final number of participants joining the initiative. The higher is the value of this KPI, higher is the influence of the property rights bundle in question.

Parameter	**Default Value**	**Value based on**
maxBudget	200	Sensitivity analysis, discussed in section 6.2.3
min-waste	34	Literature: Gemeente Amsterdam (2017) and calculations
max-waste	61	Literature: Gemeente Amsterdam (2017) and calculations
initialNoOfParticipants	7	From case study
incentiveExperiment	-1	Model design

Table 7.1: Variables selected in experiments along with default values

2. Joining ratio - It is defined as the ratio of final number of participants that join the initiative to the initial number of participants in the initiative. Higher is the value of this KPI, higher is the influence of the property rights bundle in question.

3. Number of times the initiative is started - It records the number of times the initiative is started. Similar to the previous two KPIs, higher is the value of this KPI, higher is the influence of the property rights bundle in question.

7.1.2. Scenario Space

Each experiment is explored for the five scenarios, which represent the different possibilities of the incentives that can be provided. These scenarios are as following:

1. Base case, i.e. when no incentives are provided. Only the default property rights bundle of 'Authorised Entrants' is provided to the companies.

2. Increasing incentives, when all property rights bundles are provided in an increasing order

3. Only incentive 1, i.e. property rights bundle of 'Authorised User' is provided

4. Only incentive 2, i.e. property rights bundle of 'Claimant' is provided

5. Only incentive 3, i.e. property rights bundle of 'Proprietor' is provided

7.2. Experiments

Two types of experiments are conducted: i) To test the hypotheses, and ii) To obtain results specifically for the case study and for general results.

The experiments for the hypotheses are described below.

7.2.1. Experiment 1: Property rights and sustainability motive (minimum organic waste)

This experiment will test the influence of the different property rights bundles with respect to varying values of minimum waste. The minimum organic waste variable is selected as it is related to the sustainability motive of the agents. The values that will be varied for this experiment are provided in table 7.2. The default value of minimum waste is 34 kg, and a total of 10 values in intervals of 5 were selected. The experiment was repeated 200 times to account for the randomness and to ensure that the results obtained can be relied upon.

The hypothesis tested is (Hypothesis 1): Property rights can incentivise agents irrespective of the minimum amount of organic waste they can generate, a proxy for the sustainability motive.

Parameter	Default Value	Possible Values
maxBudget	200	-
min-waste	34	15, 20, 25, 30, 35, 40, 45, 50, 55
max-waste	61	-
initialNoOfParticipants	7	7
incentiveExperiment	-1	-1, 0, 1, 2, 3

Table 7.2: Parameters and their possible values for the influence on minimum organic waste

7.2.2. Experiment 2: Property rights and sustainability motive (maximum organic waste)

The experiment will test the influence of the different property rights bundles with respect to varying values of maximum waste. The maximum organic waste variable is selected as it is related to the sustainability motive of the agents. The values that will be varied for this experiment are provided in table 7.3. The default value of maximum waste is 61 kg, and a total of 10 values, in intervals of 5 were selected. 200 repetitions were done for this experiment.
The hypothesis tested is (Hypothesis 2): Property rights can incentivise agents irrespective of the maximum amount of organic waste they can generate, a proxy for the sustainability motive.

Parameter	Default Value	Possible Values
maxBudget	200	-
min-waste	34	-
max-waste	61	60, 65, 70, 75, 80, 85, 90, 95, 100
initialNoOfParticipants	7	7
incentiveExperiment	-1	-1, 0, 1, 2, 3

Table 7.3: Parameters and their possible values for the influence on maximum organic waste

7.2.3. Experiment 3: Property rights and maximum budget

This experiment will test the influence of the different property rights bundles with respect to varying values of maximum budget. This variable is selected in order to determine if the increase in value of maximum budget leads to an increase in the number of participants joining the initiative. This experiment can help explore if the amount of financial resources possessed by the agents has any influence on their decision to join (or not join) the initiative. The values that will be varied for this experiment are provided in table 7.4. The default value of maximum budget is 200, and a total of 9 values, in intervals of 25 were selected. In total 200 repetitions were done for the experiment.
The hypothesis tested is (Hypothesis 3): Property rights can incentivise agents irrespective of the maximum amount of budget possessed by them.

Parameter	Default Value	Possible Values
maxBudget	200	200, 225, 250, 275, 300, 325, 350, 375, 400
min-waste	34	-
max-waste	61	-
initialNoOfParticipants	7	7
incentiveExperiment	-1	-1, 0, 1, 2, 3

Table 7.4: Parameters and their possible values for the influence on maximum budget

7.2.4. Experiment 4: Property rights bundles and initial number of participants

This experiment will test the influence of the different property rights bundles with respect to varying values of initial number of participants. This variable is selected in order to determine if an increase in the initial number of participants has any influence on the number of participants joining the initiative, and thereby the Joining Ratio. In this experiment, the initial number of participants is a proxy for the initial subjective norm of the agents. In the model, the initial subjective norm is given by the ratio

between initial number of participants and the maximum number of participants in the initiative (which is a fixed value).

Parameter	Default Value	Possible Values
maxBudget	200	-
min-waste	34	-
max-waste	61	-
initialNoOfParticipants	7	7, 12, 17, 22, 27, 32, 37, 42, 47, 52, 57, 62, 67
incentiveExperiment	-1	-1, 0, 1, 2, 3

Table 7.5: Parameters and their possible values for the influence on initial number of participants

This experiment is designed to explore if a higher value of initial subjective norm combined with the incentives of property rights bundles can lead to more participants in the initiative. The values that will be varied for this experiment are provided in table 7.5. The default value is 7, and a total of 13 values, in intervals of 5 were selected and a total of 200 repetitions were done for this experiment.
The hypothesis tested is (Hypothesis 4): Property rights can incentivise agents irrespective of the initial number of participants.
The experiments for the results specific to the case study and for the general results are described below.

7.2.5. Experiment 5: To obtain results for Amsterdam Zuidoost

The model was run using the default values for the variables maximum budget, minimum waste, maximum waste and initial number of participants, based on the values of the case study. The value of 'incentiveExperiment' was varied over the runs to understand the influence of the different incentives for the case study. The experiment was repeated 500 times to account for randomness. The variables and their values are depicted in table 7.6.

Parameter	Default Value	Possible Values
maxBudget	200	200
min-waste	34	34
max-waste	61	61
initialNoOfParticipants	7	7
incentiveExperiment	-1	-1, 0, 1, 2, 3

Table 7.6: Parameters and their possible values for the influence on minimum organic waste

7.2.6. Experiment 6: To obtain general results

A full parameter sweep was conducted for the variables with a range of values, both of which are depicted in table 7.7. This experiment was conducted to obtain the results for all the different combinations of inputs.

7.3. Summary

This chapter discussed the experiments designed to obtain the data from which the results can be analysed were discussed. The four hypotheses to be tested as part of the experiments were specified. The chapter answered sub-question 3: How can we measure the effects of property rights in initiatives for decentralised organic waste processing by companies?, by defining the Key Performance Indicators

Parameter	Default Value	Possible Values
maxBudget	200	200, 225, 250, 275, 300, 325, 350, 375, 400
min-waste	34	15, 20, 25, 30, 35, 40, 45, 50, 55
max-waste	61	60, 65, 70, 75, 80, 85, 90, 95, 100
initialNoOfParticipants	7	7, 12, 17, 22, 27, 32, 37, 42, 47, 52, 57, 62, 67
incentiveExperiment	-1	-1, 0, 1, 2, 3

Table 7.7: Parameters and their possible values for the influence on minimum organic waste

(KPIs) that will be used to analyse the results. These KPIs are: Number of participants, Joining Ratio, and Number of times the initiative is started.

8

Data Analysis and Results

This chapter discusses the results obtained from the data analysis. Section 8.1 provides insights into the results for the case of the Amsterdam Zuidoost initiative, and section 8.2 explains them from a generic perspective. Section 8.3 provides a detailed discussion on the results of the experiments. Section 8.4 describes the model validation and results. The chapter answers research sub-question 4: Which factors determine the effect of property rights on the initiative by companies for organic waste processing in the case of Amsterdam Zuidoost?

8.1. Results for Amsterdam Zuidoost

This section discusses the results for the case of Amsterdam Zuidoost, using the indicators Joining Ratio and Number of times the initiative is started.

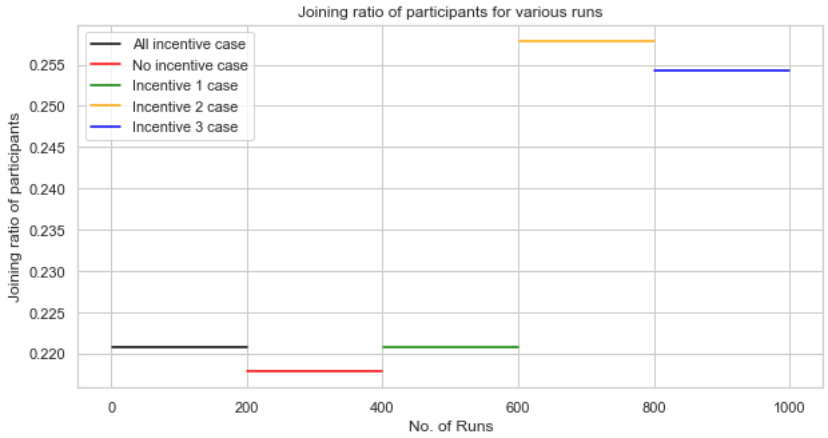


Figure 8.1: Joining Ratio of participants for Amsterdam Zuidoost

Figure 8.1 depicts that maximum participants join the initiative as claimants, followed by proprietors and then the rest. The lowest ratio is observed when no incentives are provided. However, as some of the values are very close to each other, their statistical significance was calculated to obtain clear results. The Kruskal-Wallis test was used for this purpose, as the data is not normally distributed (this was verified using a QQ-plot, please refer to appendix F for the plots)

The confidence interval was chosen to be 95%, and the statistical significance between distributions was compared with the base case. Table 8.1 depicts that statistical significance is observed between the distributions of the base case and the case when incentive 2 and incentive 3, i.e. the property rights bundle of claimants and proprietors is provided, respectively. The complete table is provided in appendix F.

	All incentives	**Base case**	**Incentive 1 case**	**Incentive 2 case**	**Incentive 3 case**
Base case	0.74	1	0.86	0	0.03

Table 8.1: Statistical Significance for Joining Ratio in the Amsterdam Zuidoost case

In all the cases of incentives for the case of Amsterdam Zuidoost, depicted in figure 8.2, it is seen that the initiative starts only in the case when all incentives are provided. Furthermore, this is for a very small percentage (1%) of the runs. The initiative fails to take off for all other cases.

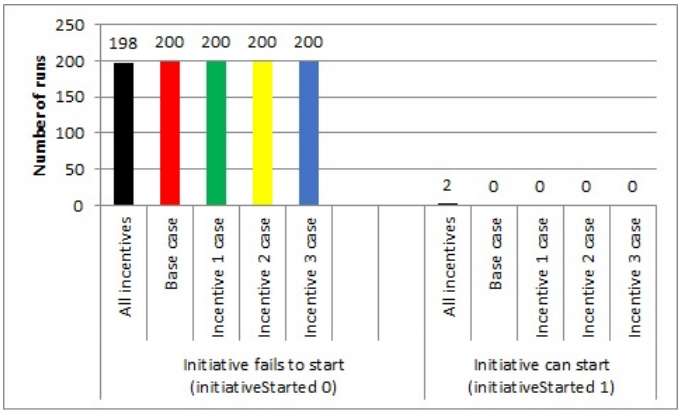


Figure 8.2: Number of times the initiative starts for Amsterdam Zuidoost

From the above two graphs, we see that although the Joining Ratio is higher for the case when only the property rights bundle of claimants or proprietors is provided, the initiative does not start in those cases. This can be attributed to the fact that participants with these bundles also possess the authorisation to formulate the payoff rule. As discussed in section 4.2.6, this rule decides the division of costs among the participants. It is possible that the participants updated the rule such that the share of investment is low for the participants, which leads to more participants joining the initiative, but this does not lead to sufficient funds. This hypothesis can be tested by checking the value of share of investment for the participants for the different cases of incentives: in the case when payoff rule cannot be updated (base case and incentive 1), the value of share of investment would be higher than in the case when payoff rule can be updated (incentive 2, incentive 3 and all incentives). Currently however, these values are not recorded as KPIs, and hence there is a lack of information to test the hypothesis stated previously.

8.2. General Results

This section highlights the general results obtained from the data analysis.

1. Correlation among Variables This section discusses the most significant correlations among the input and output variables.

In figure 8.3 we see the correlation amongst the input and output variables when all incentives are provided in an increasing order. The following observations can be made:

(a) The strongest correlation is seen between the final number of participants ($numParticipants$) and initial number of participants ($initialNoOfParticipants$), a proxy for the initial subjective norm of the participants (discussed in Section 8.3.3).

(b) There is also a high correlation between the initial number of participants ($initialNoOfParticipants$) and the number of Authorised Entrants ($AEParticipants$). This indicates that as the initial number of participants increases, more number of participants join as Authorised Entrants, denoting that incentives in the form of property rights bundles may not be required to increase participation.

(c) It is also seen that there exists a high correlation between the number of Authorised Entrants ($AEParticipants$) and final number of participants ($numParticipants$). Based on the discussion above, this is an expected result.

(d) There is a significant correlation between the total funds obtained from participants ($totalSumObtained$) and the number of times the initiative is started ($initiativeStarted$). This is an expected result, since the initiative can only start when sufficient funds are available.

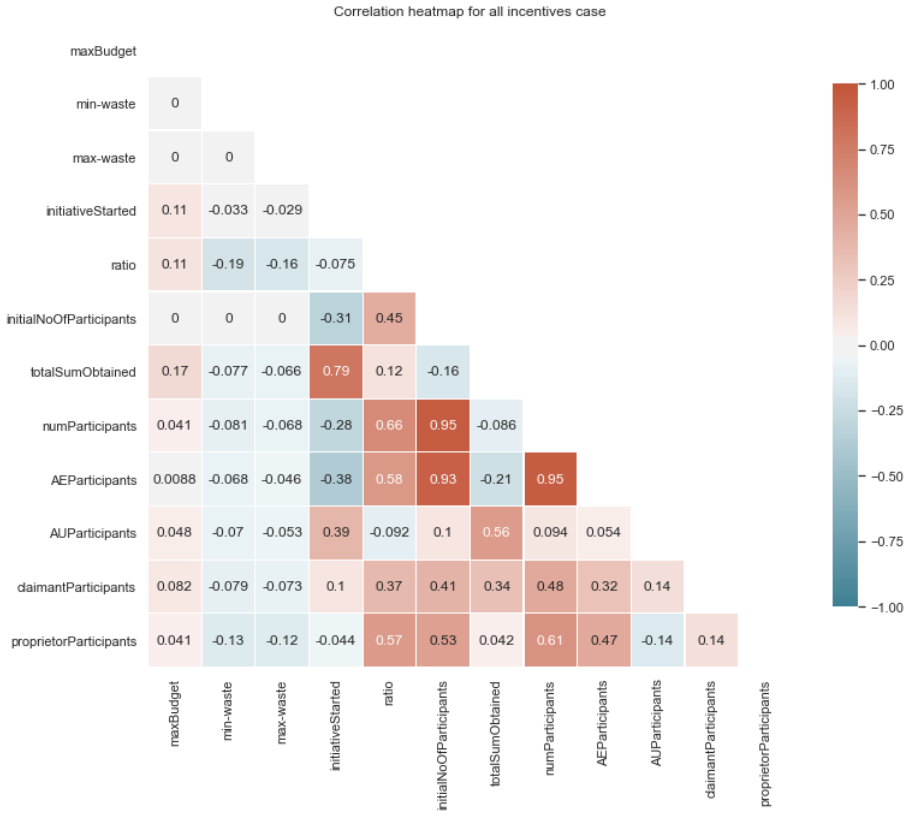


Figure 8.3: Correlation heat map for the increasing incentives case

2. Figure 8.4 depicts that in the case when no incentives are provided, the final number of participants ($numParticipants$) is highly positively correlated with the initial number of participants ($initialNoOfParticipants$), indicating that increasing the initial number of participants leads to

an increase in the final number of participants that join the initiative. This is an insight from the model, discussed in section 8.3.3.

A high positive correlation is also observed between the total sum obtained ($totalSumObtained$) and the final number of participants ($numParticipants$). This is an expected result, since the investment for the infrastructure is obtained from the participants. Furthermore, the payoff rule in the base case is that all participants pay an equal share of investment. Hence, as more participants join the initiative, more will be the investment obtained.

Based on above discussion, the observation that total sum obtained ($totalSumObtained$) is positively correlated with the initial number of participants ($initialNoOfParticipants$) is an expected outcome.

An expected result observed is the direct correlation between the final number of participants ($numParticipants$) and Authorised Entrants ($AEParticipants$), as these are the only type of participants for this case. The joining ratio is also strongly positively correlated with the final number of participants ($numParticipants$), which is an expected result as the ratio is directly determined by this parameter.

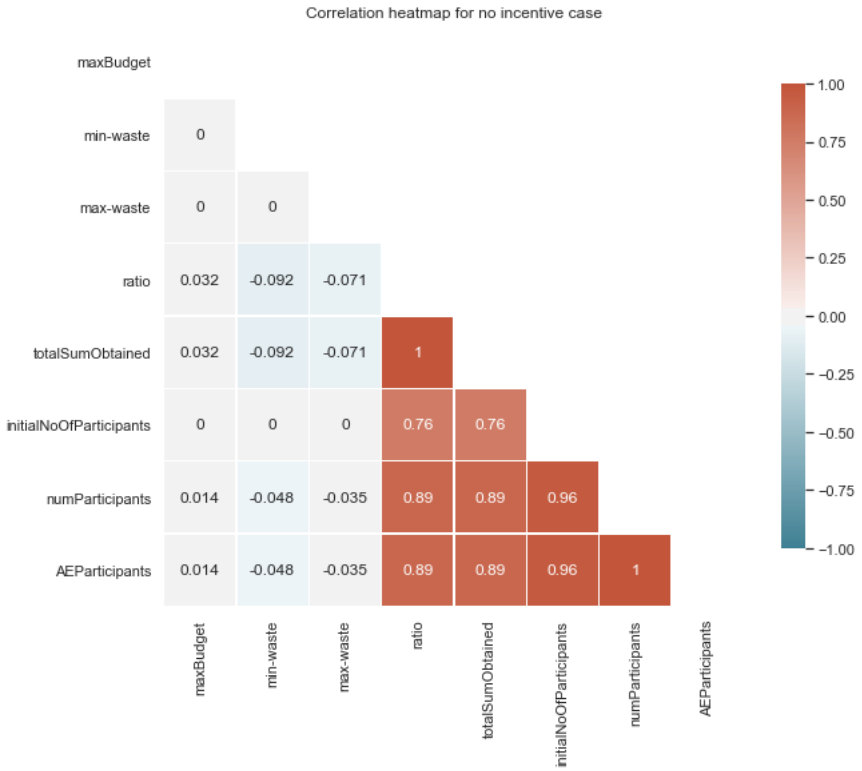


Figure 8.4: Correlation heat map for the case when no incentives are provided

3. Ratio of participants joining the initiative

Figure 8.5 illustrates the mean of the ratio of participants ($ratio$) joining the initiative for the various cases of incentives that are provided. The mean value is chosen to provide an overall estimate of the value in each case.

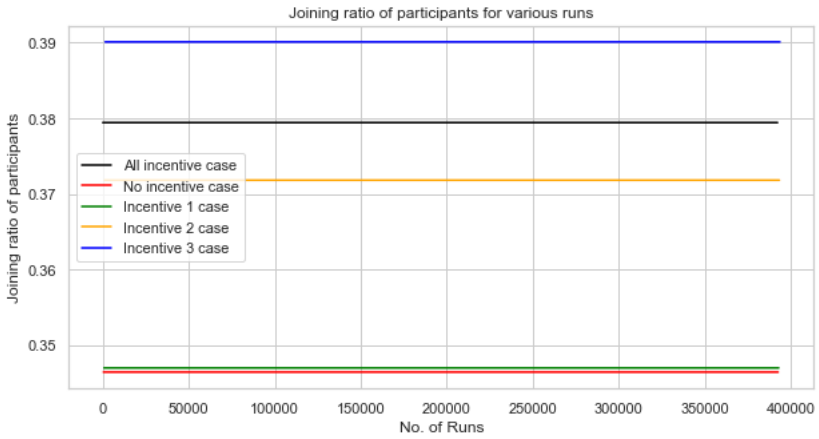


Figure 8.5: Number of runs v/s Ratio of participants joining (mean value)

The ratio of participants joining the initiative decreases in the following order of incentives:

- Property rights bundle of 'Proprietor'
- All property rights bundles, provided in an increasing order
- Property rights bundle of 'Claimants'
- Property rights bundle of 'Authorised Users'
- No incentive, i.e. the default property rights bundle of 'Authorised Entrant'

This order denotes that maximum participants join as Proprietors, followed by Claimants, Authorised Users and finally Authorised Entrants; confirming that the property rights bundle 'Proprietor' is most effective at increasing the participation of the companies.

However, as some of the values are very close to each other, statistical significance was calculated using the Kruskal-Wallis test (please refer to Appendix F for details). The values obtained are shown in table 8.2. There is no statistical significance between the base case and the case when incentive 1 is provided, hence, we cannot draw any conclusion on the influence of incentive 1. However, for the rest of the incentives, providing the incentive does lead to more participation than when no incentive is provided.

	All incentives	**Base case**	**Incentive 1 case**	**Incentive 2 case**	**Incentive 3 case**
Base case	0	1	0.51	0	0

Table 8.2: Statistical Significance for Joining Ratio for the different cases of incentive provision

4. Number of times the initiative is started

   From figure 8.6, it is seen that the initiative starts only for the case when incentives are provided in an increasing order. Even then, the percentage of times the initiative starts is 30%. Please refer to appendix F for more discussion related to this.

8.3. Results of Experiments

This section discusses the results of the experiments that were designed in the previous chapter. Based on these results, the hypotheses specified in relation to the experiments will be accepted or rejected.

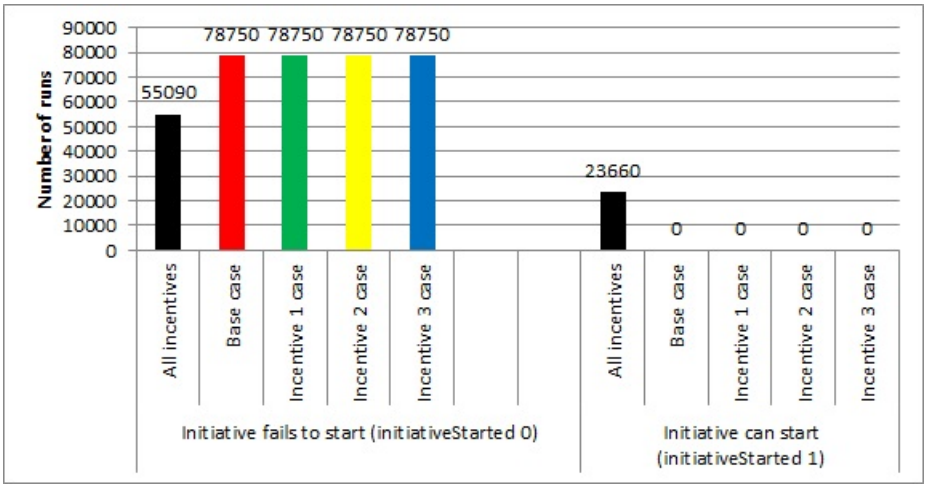


Figure 8.6: Number of times the initiative is started for the different cases of incentives being provided

8.3.1. Property rights bundles and minimum/maximum waste

This section provides the results for the experiments conducted for the minimum waste/maximum waste variables.

The amount of waste generated by the agents is a random value between minimum waste and maximum waste, which are input variables in the model. A change in these values leads to an increase or decrease in the range for the waste that is generated by the agents. Furthermore, the amount of waste generated by the agents is one of the determining factors used to measure their sustainability motive (However, it must be noted that the sustainability motive is also affected by other factors such as the prevalent payoff rule, and if there exists a limit on the amount of waste that can be sent for processing. Hence, although amount of waste generated is related to the sustainability motive, it is not a direct proxy). We are interested in determining if property rights bundles incentivise the agents irrespective of these value of minimum waste and maximum waste, and compare the value of Joining Ratio for each value of minimum waste and maximum waste across the five cases, i.e., the plots are compared vertically.

1. Property rights bundles and minimum waste

   Figures 8.7 to 8.11 which depict the box-plots for the Joining Ratio for the base case and the four cases in which incentives are provided are used to test hypothesis 1.

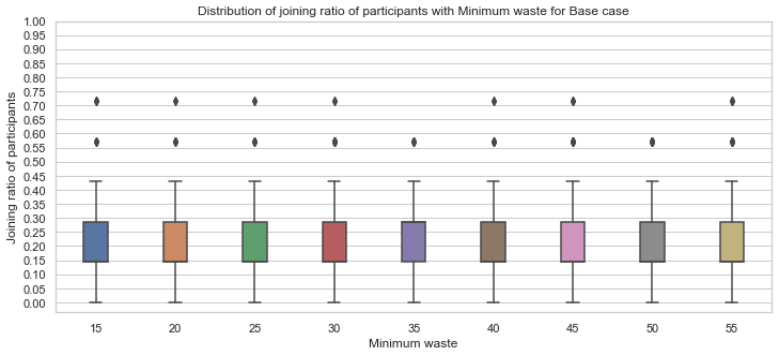


Figure 8.7: Joining Ratio for Base case (Minimum Waste)

As an overlap is observed in the Joining Ratio values for the same value of minimum waste across

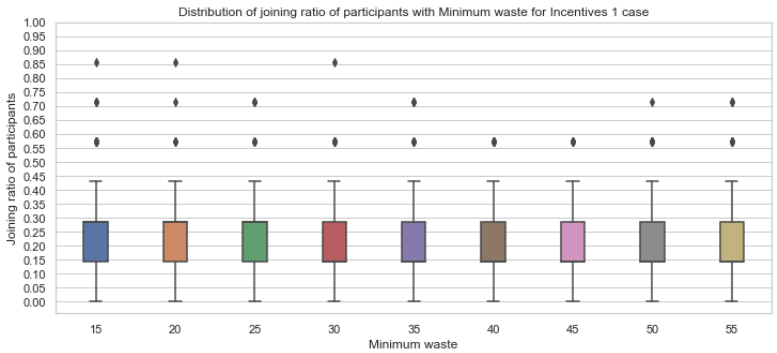


Figure 8.8: Joining Ratio for Incentive 1 case (Minimum Waste)

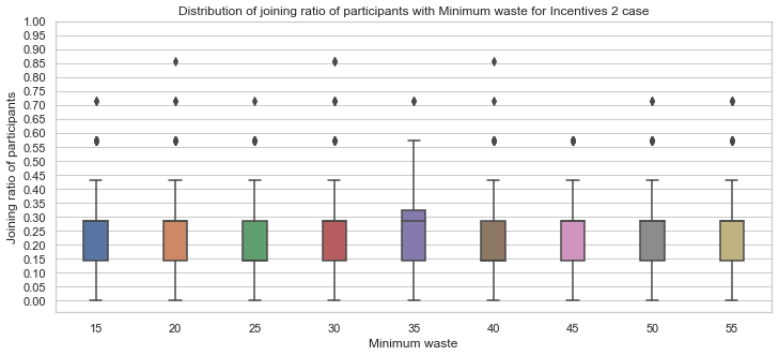


Figure 8.9: Joining Ratio for Incentive 2 case (Minimum Waste)

the five cases, it is necessary to conduct a statistical significance test to ensure that the results analysed are not of the same distribution. The Kruskal-Wallis test was used to determine the statistical significance as the dependent variables are not normally distributed, which is verified using QQ-plots, depicted in appendix F. This test is used since the data obtained is not normally distributed, including that of the output data not being normally distributed. p-values obtained from the test were considered to be statistically significant below the significance level of 5% . The table with the p-values is also present in appendix F.

The output data is analysed by comparing the distributions of each of the four incentive cases with the base case, for all values of minimum waste.

(a) Base case and all incentives case - From the table it is seen that only three values from the distributions exhibit statistical significance. Additionally, from figures 8.7 and 8.11 the Joining Ratio values do not increase for these values of minimum waste, which can indicate that providing all incentives has no influence on the participation of the agents. However, this result is obtained for only three data points, which is insufficient to determine if the hypothesis can be accepted or rejected, and hence no conclusive evidence can be drawn.

(b) Base case and incentive 1 case - Statistical significance is observed for only two values of minimum waste, and as seen in the plots 8.7 and 8.8, the value of Joining Ratio does not increase, which can indicate that providing all incentives has no influence on the participation of the agents. However, as discussed above, as this result is obtained for only two data points, no conclusive evidence can be drawn.

(c) Base case and incentive 2 case - Statistical significance is seen for four out of the nine values

of minimum waste taken into account. From figures 8.7 and 8.9, the value of Joining Ratio for incentive 2 is higher than the value of Joining Ratio for the base case for only one value of minimum waste. Similar to above, although this can indicate that incentive 2 does not lead to more participation as compared to base case, the lack of sufficient data (less than 50% of data-points are statistically significant) results in a lack of conclusion for this case.

(d) Base case and incentive 3 case - Except for one value of minimum waste, statistical significance is present for all other values. From figures 8.7 and 8.10, we see that the value of Joining Ratio increases for some values of minimum waste. For example, for minimum waste values 25kg, 30kg and 35kg. However, this is not true for values 15kg, 40kg and 55kg. Hence, we cannot state that providing the property rights bundle of Proprietors leads to an increase in the Joining Ratio of participants for all values of minimum waste. Thus, the hypothesis is rejected.

Overall, the hypothesis that property rights bundles can incentivise agents irrespective of the minimum amount of waste generated by them is rejected when property rights bundle of Proprietors is provided. This may indicate that when incentive 3 (property rights bundle of Proprietors) is provided, the participation of companies could be dependent on the amount of minimum waste that can be generated, and thereby on the the sustainability motive of the companies. For the rest of the incentive cases, no conclusive evidence can be drawn.

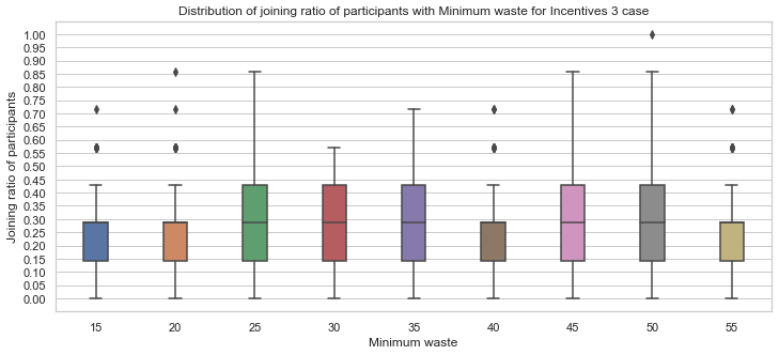


Figure 8.10: Joining Ratio for Incentive 3 case (Minimum Waste)

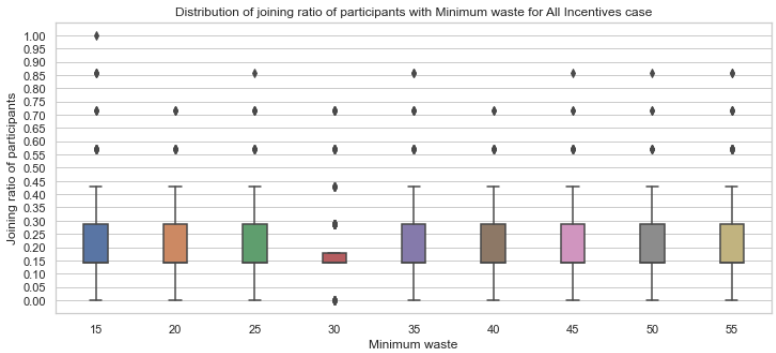


Figure 8.11: Joining Ratio for all incentives case (Minimum Waste)

2. Property rights bundles and maximum waste

The value of maximum waste determines the maximum possible value of waste that the agents can generate, which is one of the factors that determines the sustainability motive for the compa-

nies. However, similar to the case of minimum waste, the sustainability motive is also affected by other factors such as the prevalent payoff rule, and if there exists a limit on the amount of waste that can be sent for processing. Hence, maximum waste is related to the sustainability motive, but is not a direct proxy.

Figures 8.12 to 8.16 which depict the box-plots for the Joining Ratio for the base case and the four cases in which incentives are provided are used to test hypothesis 2.

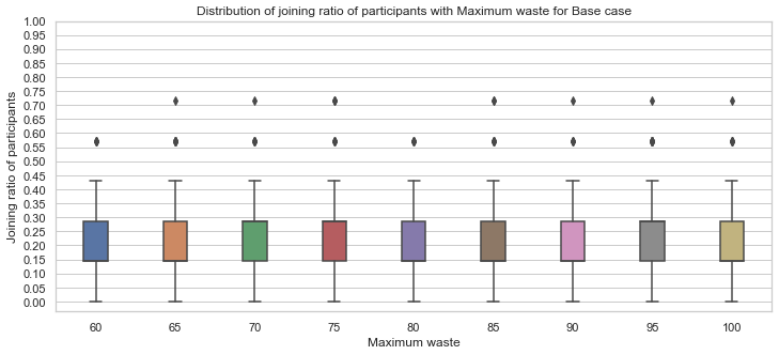


Figure 8.12: Joining Ratio for Base case (Maximum waste)

As an overlap is observed in the Joining Ratio values for the same value of maximum waste across the five cases, it is necessary to conduct a statistical significance test to ensure that the results analysed are not of the same distribution. The Kruskal-Wallis test was used to determine the statistical significance between the distributions. The QQ-plots and p-values are provided in appendix F.

The output data is analysed by comparing the distributions of each of the four incentive cases with the base case, for all values of maximum waste.

(a) Base case and all incentives case - From the table it is seen that only one value from the distributions exhibit statistical significance. Additionally, from figures 8.7 and 8.11 the Joining Ratio values does not increase for this value of maximum waste, which can indicate that providing all incentives has no influence on the participation of the agents. However, this result is obtained for only one data points, which is insufficient to determine if the hypothesis can be accepted or rejected, and hence no conclusive evidence can be drawn.

(b) Base case and incentive 1 case - Statistical significance is not observed for any of the values of maximum waste, and hence, no conclusive evidence can be drawn.

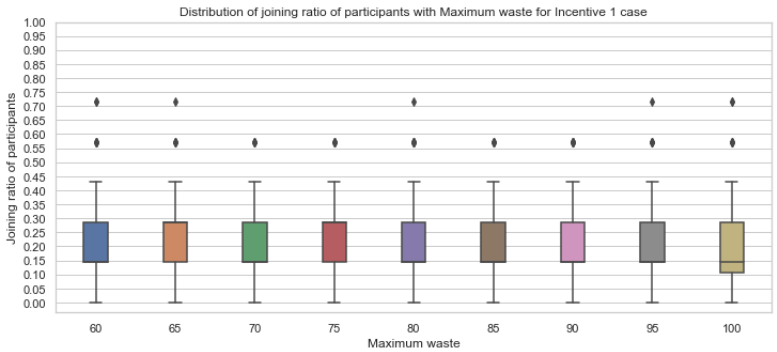


Figure 8.13: Joining Ratio for Incentive 1 case (Maximum waste)

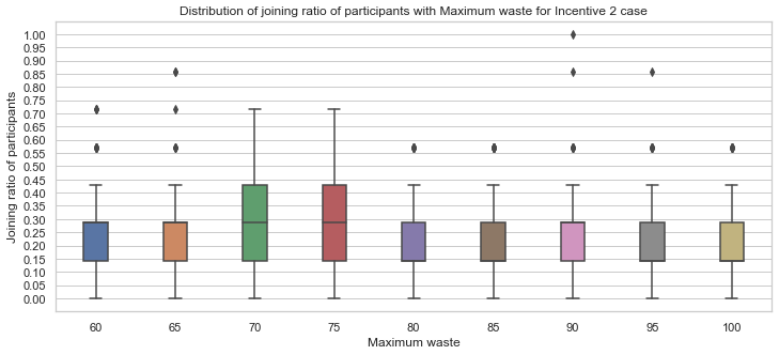


Figure 8.14: Joining Ratio for Incentive 2 case (Maximum waste)

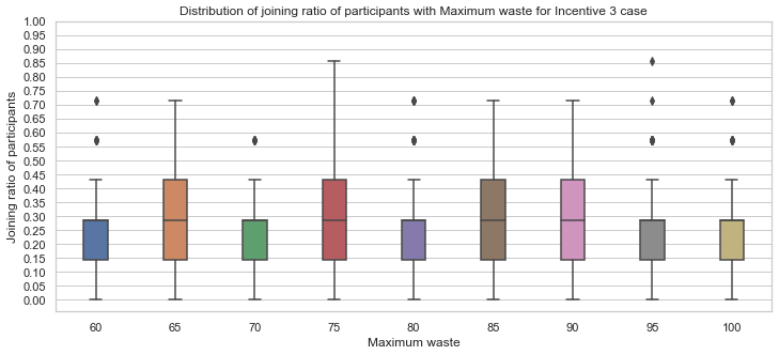


Figure 8.15: Joining Ratio for Incentive 3 case (Maximum waste)

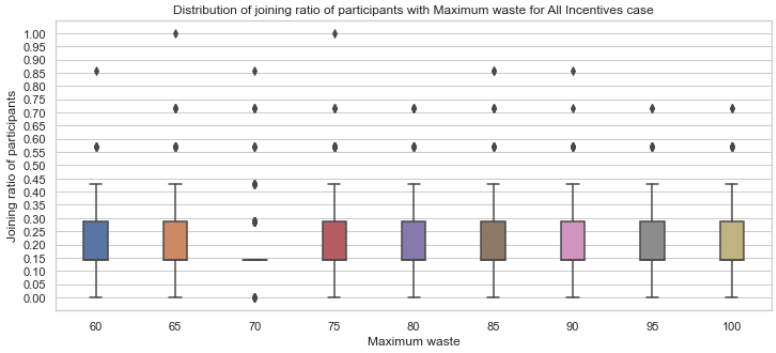


Figure 8.16: Joining Ratio for all incentive case (Maximum waste)

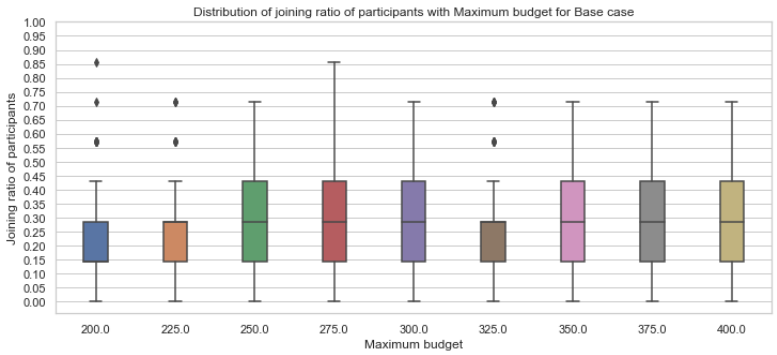


Figure 8.17: Joining Ratio for Base case (Maximum budget)

(c) Base case and incentive 2 case - Statistical significance is present for only one value of maximum waste from the two distributions Additionally, from figures 8.7 and 8.11 the Joining Ratio values does not increase for this value of maximum waste, which can indicate that providing all incentives has no influence on the participation of the agents. However, this result is obtained for only one data points, which is insufficient to determine if the hypothesis can be accepted or rejected, and hence no conclusive evidence can be drawn.

(d) Base case and incentive 3 case - Statistical significance is observed for five values of maximum waste. From the figures 8.7 and 8.10, we see that the value of Joining Ratio increases for some values of minimum waste. For example, for maximum waste values 65kg and 90kg. However, this is not true for the value 60kg. Due to lack of consistent results, we cannot state that providing the property rights bundle of Proprietors leads to an increase in the Joining Ratio of participants for all values of maximum waste. Thus, the hypothesis is rejected.

Overall, the hypothesis that property rights bundles can incentivise agents irrespective of the maximum amount of waste generated by them is rejected when property rights bundle of Proprietors is provided. This may indicate that when incentive 3 (property rights bundle of Proprietors) is provided, the participation of companies could be dependent on the amount of maximum waste that can be generated, and thereby the sustainability motive of the companies. For the rest of the incentive cases, no conclusive evidence can be drawn.

8.3.2. Property rights bundles and maximum budget

Figures 8.17 to 8.21 depict the box-plots for the joining ratio for the base case and the four cases in which incentives are provided, which are used to test hypothesis 3.

The budget possessed by the participants is used to determine if they can join the initiative. This value is a random number between zero and maximum budget. As the value of maximum budget increases, the range within which the budget values can be defined increases. We are interested in determining if property rights bundles incentivise the agents irrespective of the value of maximum budget. We compare the value of Joining Ratio for each value of maximum budget across the five cases, i.e., the plots are compared vertically.

As an overlap is observed in the Joining Ratio values for the same value of maximum budget across the five cases, it is necessary to conduct a statistical significance test to ensure that the results analysed are not of the same distribution. In this case as well, the Kruskal-Wallis test was used to determine the statistical significance at a 95% confidence interval. The QQ-plots and p-values are provided in

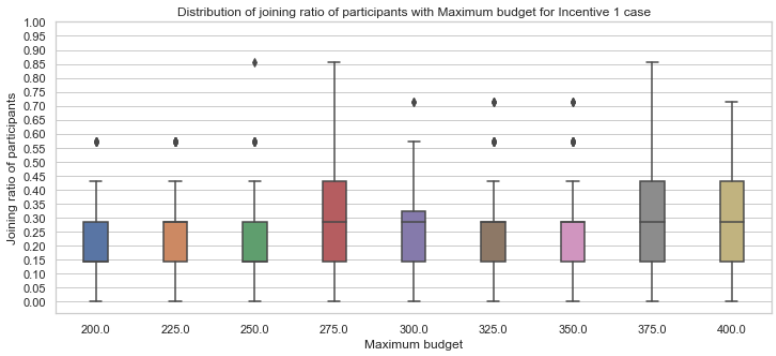


Figure 8.18: Joining Ratio for Incentive 1 case (Maximum budget)

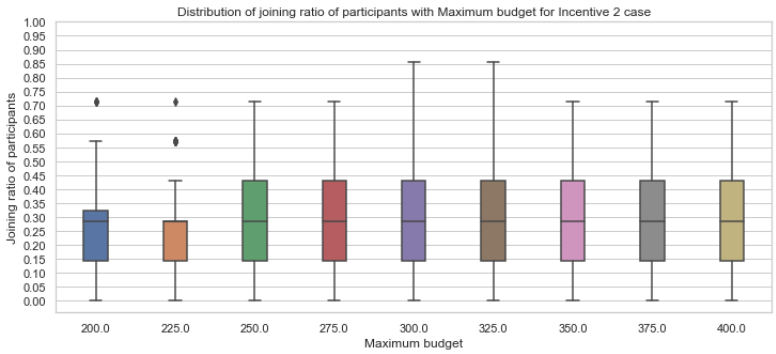


Figure 8.19: Joining Ratio for Incentive 2 case (Maximum budget)

appendix F.

The output data is analysed by comparing the distributions of each of the four incentive cases with the base case, for all values of maximum budget.

1. Base case and all incentives case - Statistical significance is observed between the two distributions from all values of maximum budget greater than or equal to €300. On vertically comparing the plots in the figures 8.17 and 8.21, it is observed that the value of Joining Ratio increases for these five values of maximum budget, out of the possible five values of maximum budget (remaining four are statistically insignificant). Hence, the hypothesis is accepted in this case.

2. Base case and incentive 1 case - No statistical significance is seen for any of the values of maximum budget, and hence we cannot derive any conclusions.

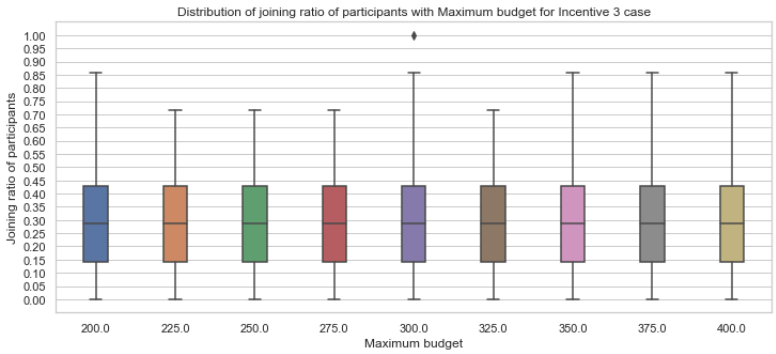


Figure 8.20: Joining Ratio for Incentive 3 case (Maximum budget)

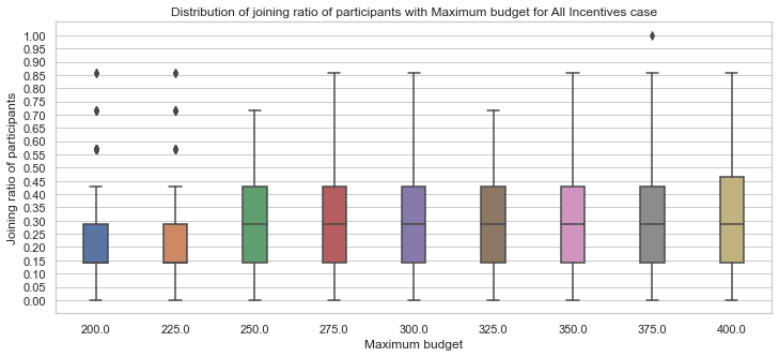


Figure 8.21: Joining Ratio for All Incentives case (Maximum budget)

3. Base case and incentive 2 case - Statistical significance is seen for only one value of maximum budget (at €325). From figures 8.17 and 8.19, although the value of Joining Ratio is higher for incentive 2 as compared to the base case for this value, one data point is insufficient evidence to make any conclusive derivations for all values of maximum budget.

4. Base case and incentive 3 case - Except for one value of maximum budget, statistical significance is present for all other values. From figures 8.17 and 8.20, we see that the value of Joining Ratio increases for some values of maximum budget. For example, for maximum budget values €300 and €325. However, this is not true for values €250 and €275. Hence, we cannot state that providing the property rights bundle of Proprietors leads to an increase in the Joining Ratio of participants.

Overall, the hypothesis that property rights bundles can incentivise agents irrespective of the maximum amount of budget possessed by them is accepted only for the case when all property rights bundle are provided in an increasing order (that is All incentives case). The hypothesis is rejected for the property rights bundle of Proprietors, and we do not have sufficient data to draw any conclusion for the property rights bundles of Authorised Users and Claimants.

8.3.3. Property rights bundles and initial number of participants (initial subjective norm)

Figures 8.22 to 8.26 depict box-plots for the Joining Ratio for the base case and the four cases in which incentive is provided, for increasing values of initial number of participants. These will be used to test hypothesis 4. Here, the initial number of participants is taken as a proxy for the initial subjective norm of the agents. In the model, the initial subjective norm is given by the ratio between initial number of participants and the maximum number of participants in the initiative (which is a fixed value).

As we are interested in determining if the property rights bundles can incentivise the agents irrespective of the initial number of participants (initial subjective norm). We compare the value of Joining Ratio for each value of initial number of participants across the five cases, i.e., the plots are compared vertically.

As an overlap is observed for some of the Joining Ratio values for the same value of initial number of participants (initial subjective norm) across the five cases, it is necessary to conduct a statistical significance test to ensure that the results analysed are not of the same distribution. As explained before, the Kruskal-Wallis test is used to test the statistical significance at a 95% confidence level. The QQ-plots and p-values are provided in appendix F.

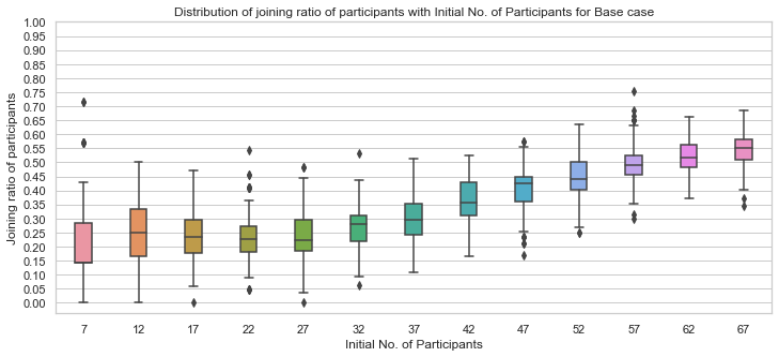


Figure 8.22: Joining Ratio for Base case (initial number of participants)

The output data is analysed by comparing the distributions of each of the four incentive cases with the base case, for all values of initial number of participants.

1. Base case and all incentives case - Statistical significance is observed between the two distributions for all values except for two (when initial number of participants is 7 and 52). On vertically comparing the plots in the figures 8.22 and 8.26, it is observed that when the initial number of participants is relatively low (less than or equal to 32), the value of Joining Ratio is higher for the all incentives case as compared to the base case. After this, the values for the two cases are either equal to each other, or the value of Joining Ratio is higher for the base case as compared to the all incentives case, denoting that providing an incentive to the agents does not lead to more participation. As the results are not consistent for all values of initial number of participants, the hypothesis is rejected.

2. Base case and incentive 1 case - Statistical significance is seen for only one value of initial number of participants (27). Furthermore, the value of Joining Ratio remains the same for both cases, indicating that there is no influence of property rights bundle of Authorised Users. However, one data point is insufficient evidence to draw any conclusions, and hence no conclusions are derived in this case.

3. Base case and incentive 2 case - Statistical significance is seen for seven of the thirteen data points. From figures 8.22 and 8.24, it is observed that the value of Joining Ratio is higher for incentive 2 case as compared to the base case for majority of the values, except when initial number of participants is 7 in which case the Joining Ratio remains same for both cases. Hence, as the Joining Ratio does not increase for all the statistically significant values in the two cases, this hypothesis is rejected.

4. Base case and incentive 3 case - Except for two values of initial number of participants, statistical significance is present for all other values. From figures 8.22 and 8.25, we see that the value of Joining Ratio increases for all values of initial number of participants, except one: when initial number of participants is 57 for incentive 3, the inter-quartile range in the box-plot increases, but the median value decreases, as compared to the same observations for the base case. This indicates that the value of Joining Ratio has reduced when incentive 3 is provided for initial number of participants equal to 57. Thus, as the value of Joining Ratio does not increase for all values of initial number of participants across the two cases, the hypothesis is rejected.

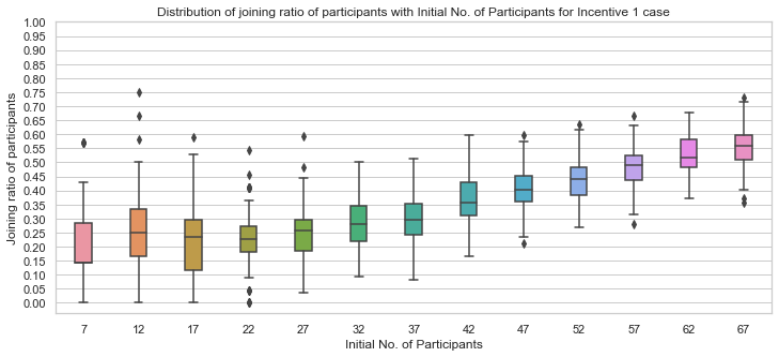


Figure 8.23: Joining Ratio for incentive 1 case (initial number of participants)

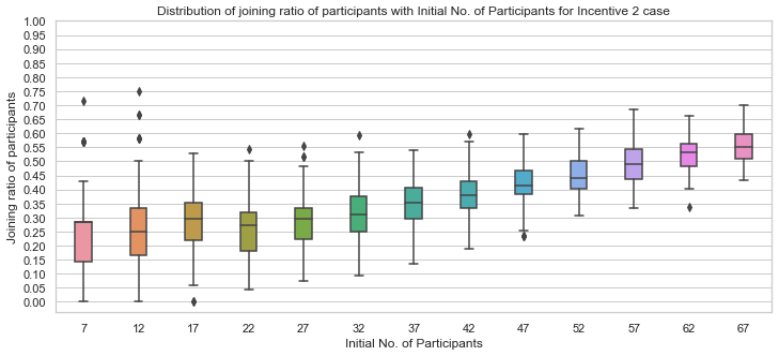


Figure 8.24: Joining Ratio for incentive 2 case (initial number of participants)

Overall, the hypothesis that property rights bundles can incentivise agents irrespective of the initial number of participants/initial subjective norm is rejected for all cases in which an incentive is provided, except for incentive 1 case for which the results are inconclusive.

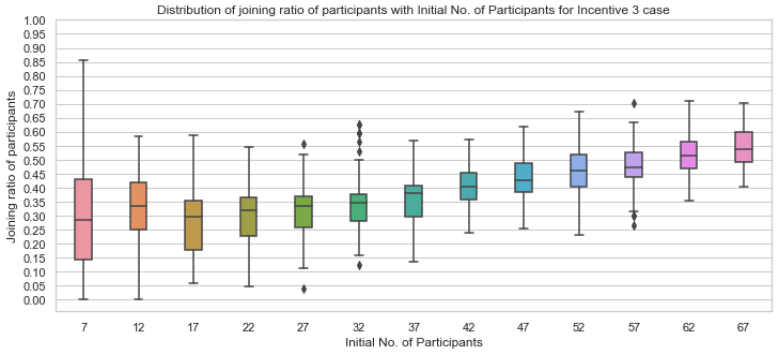


Figure 8.25: Joining Ratio for incentive 3 case (initial number of participants)

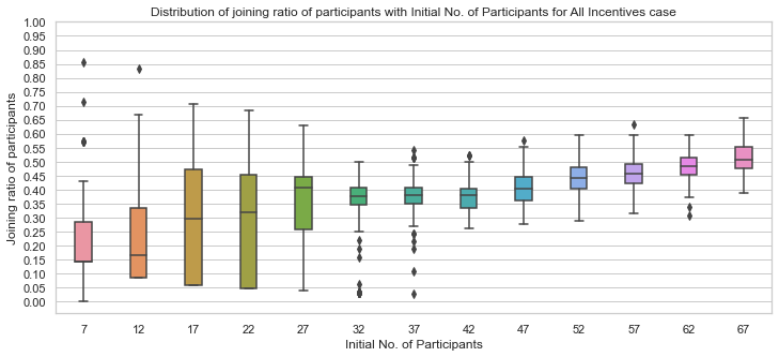


Figure 8.26: Joining Ratio for all incentives case (initial number of participants)

8.3.4. Overall Results for Experiments

	All incentives	Incentive case 1	Incentive case 2	Incentive case 3
H1 (minwaste)	Failed to be rejected	Failed to be rejected	Failed to be rejected	Failed to be rejected
H2 (maxwaste)	Failed to be rejected	Failed to be rejected	Failed to be rejected	Failed to be rejected
H3 (maxbudget)	Accepted	Failed to be rejected	Failed to be rejected	Rejected
H4 (initial subjective norm)	Rejected	Failed to be rejected	Rejected	Rejected

Table 8.3: Summary of Results of Hypotheses

The results of all experiments are summarised in table 8.3. The four hypotheses defined in this research are formulated to test whether property rights bundles can incentivise agents independent of the values of minimum waste, maximum waste (sustainability motive), initial number of participants (initial subjective norm) and maximum budget. All the four hypotheses fail to be rejected due to a lack of consistent results across the different property rights bundles. The results are thus inconclusive for the experiments.

8.4. Validation

This step of the modelling process determines if the model that was built is indeed useful to answer the research question (van Dam et al., 2013). In this research, as quantification of property rights has not been done previously, the results cannot be validated with the help of similar model outputs.

Here, the model structure has been tested using a sensitivity analysis for the standard deviation of waste and weight coefficient. It was found that the model is slightly sensitive to these variables. Complete results are reported in chapter 6.

From the perspective of the results, the response obtained from a participant of the case study confirmed that the preferred property right bundle for the company to join the initiative would be proprietor or owner (Case Study Participant, Personal Communication, August 26, 2020). In the model results for Amsterdam Zuidoost, the property rights bundle of proprietors or claimants lead to more participation as compared to when no incentives are provided. The results are partially validated for the case. However, general results have not been validated.

8.5. Summary

This chapter discussed the data analysis results from a generic perspective, perspective of the case study and for the experiments. For the case study, it was found that the property rights bundle of claimants or proprietors leads to more participants joining the initiative as compared to when no incentives are provided. However, due to statistical insignificance, it could not be determined which of the two bundles have a higher influence (claimants or proprietors). In general, property rights bundles (Proprietors, All incentives provided incrementally and Claimants, in that order) leads to more participants joining the initiative than when no incentives are provided. However, for both the case study and in general, the initiative fails to start due to a lack of funds. The formulated hypotheses fail to be rejected, which could indicate that the influence of property rights bundles is dependent on the input variables considered in the hypotheses.

9

Discussion

This chapter reviews the insights and observations made during the course of the research (section 9.1. It also reviews the assumptions (section 9.3) and limitations of the research (section 9.4).

9.1. Implementation of Theoretical Concepts

In the current academic literature, property rights are generally discussed from a qualitative perspective, and this research attempts to analyse them in a quantitative way for the given context. Quantification of property rights has not been done before, and therefore a choice was made to quantify them in terms of security of tenure. Security of tenure encompasses the fundamental attributes of robustness, strength, duration and excludability. This perspective was chosen as the concept has been applied to irrigation infrastructure. The characteristics that it shares with waste processing infrastructure are that it requires maintenance and is localised to one region, where it is used by multiple actors. Property rights can also possess other characteristics such as multiplicity, quality of title, etc. using which they can be quantified, based on the context.

Property rights have been studied from the perspective of security of tenure, and the characteristics of robustness, excludability, duration and strength, as defined by Meinzen-Dick (2000). This perspective was chosen as it has been researched for the case of irrigation infrastructure.

This research also takes into account that possessing some of the rights allows the users to create rules related to the use of the resources. This is achieved by implementing a possible version of the payoff rule, one of the seven working rules of the action situation. Other alternative approaches are also possible, such as the implementation of the boundary rule, position rule, etc. or a combination of one or more rules. It would be interesting to note if the choice of approach affects the outcomes obtained regarding the incentivising influence of property rights and their bundles.

The implementation of property rights bundle as incentive also determines the implementation of the decision-making theory. This research uses the Theory of Planned Behaviour (TPB) and literature on property rights to understand the influence of property rights bundles in the context of waste processing infrastructure. It uses the Perceived Behavioural Control (PBC) variable of the TPB, which denotes the perceived control an individual has with respect to performing a behaviour (Ajzen, 1991), to examine the influence of property rights bundles. The PBC variable represents those factors that are beyond the scope of those performing the behaviour. In the current research, this is translated to the perceived

control that a company has when participating in the initiative. Furthermore, the approach followed is that the companies do not have a say in which type of incentive they are provided. However, if the companies could indicate their preference, the implementation could change as the property rights bundle would not have been an external factor. In that case, more research would be required to determine how property rights could be implemented in terms of the Theory of Planned Behaviour or any other behavioural theory.

9.2. From the perspective of the model

The current implementation is discussed here, with the possible implications.

1. The agents are offered an incentive only once (for each type). Additionally, the agents in the model join at different times, based on the incentive provided. Hence, the payoff rule is updated by proprietors/claimants as they join. In case when the payoff rule becomes favourable to an agent after it has been provided all incentives, it cannot join the initiative because it has already reached its limit of incentives. This situation could be updated in a future version of the model, such that if there is a change in the payoff rule after an agent has been provided all incentives, it could be offered incentives again (starting from the most basic incentive) and its intention to join the initiative must be re-assessed.

2. For the payoff rule for the case when the distribution of share is according to the amount of waste generated: currently the model takes into account all the agents for determining the distribution of share of investment for potential participants. However, the distribution of share of investment should take into account only the participants in the initiative.

9.3. From the Perspective of Assumptions

This research made some assumptions in order to simplify the system and the model. This helped to focus on the main research problem. The implications of these assumptions are discussed in this section.

1. The companies, i.e. the waste shippers and participants in the initiative are fully aware of the states and behaviours of the other companies. This implies that the system is assumed to operate under a case of complete information. This does not correspond to what is observed in reality, because informational delays are likely to occur and there is the possibility that all companies do not have the same amount of information. This information mismatch can lead to time delays, communication gaps and additional management costs for the initiative. When developing the solution/policies for the initiative based on the results of this research, the additional aspects must be taken into consideration. This could be in the form of assigning additional time for establishing the initiative, anticipating the overhead costs, etc.

2. For the case of the initiative, the model is calibrated for values corresponding to the initiative. Currently, as the number of potential participants in the initiative is low, the capacity of the waste processing infrastructure used is at its minimum (500 kg). This is done so that the appropriate results and patterns can be captured, which could be missed in case the entire capacity is considered. This is because the capacity is used to determine the limit of waste that the participants can send for processing. Based on the number of initial participants in the initiative, the value of capacity must be updated.

3. For the subjective norm, only the neighbouring companies in the region have been considered to influence the norm. However, a more accurate representation could have been obtained by considering also those stakeholders who can influence the companies' decisions. Additionally, due to the way it is measured, the value of subjective norm is the same for all companies. However, these values should vary among the companies because they are subjective, and hence, specific to the company. Thus, it is recommended that in order to get more accurate results, the values for the TPB constructs should be obtained through a survey or questionnaire.

4. The values considered for the weight coefficients of the variables of the Theory of Planned Behaviour, i.e. attitude (and its two factors), perceived behavioural control and subjective norm have been obtained from literature. In order to obtain more accurate results, it is suggested to conduct a survey for the companies in Amsterdam Zuidoost.

5. In this research, the factors that influence the participation of companies in initiatives (strategic motive, sustainability motive, financial readiness, knowledge readiness, subjective norm) have been taken from literature. It is possible that these factors are not representative for the companies in Amsterdam Zuidoost. This is a limitation of the current study, and in order for the results to be more accurate, it is suggested that a survey is conducted of the factors that are relevant to the case study.

6. Similarly, for values such as the retention time of the bio-digester, amount of organic waste generated by the companies, budget available with the companies, etc., data from the case study would have provided more accurate results.

9.4. Limitations

The limitations of this research are due to a lack of time and resources. Despite this, they present an opportunity for further research.

1. The property rights bundle of owner is left out of scope, due to simplicity constraints. As a result, the incentivising influence of this bundle is unexplored in this research. This is discussed further under Recommendations.

2. As discussed before, only the payoff rule has been implemented in the model. Including more rules (individually or in combination) could lead to additional insights of interest. This is discussed further under Recommendations.

3. A thorough validation has not been done of the model and the results due to time constraints. Although the model is based on literature and a real world case study, validation of the model with the help of experts would have helped to make the model more realistic, or could have helped to add practical insights from those who have worked in the domain.

9.5. Summary

This chapter provided insights into alternative views possible for the theoretical concepts of property rights and the Theory of Planned Behaviour. A few assumptions were discussed, one of which was that all agents have complete information of the initiative. Limitations of the research, such as lack of validation through expert interviews and modelling choices are discussed.

10

Conclusion and Recommendations

This chapter provides the answers to the research questions in section 10.1. Based on the results obtained, recommendations have been made for policy-makers, future research and the case study participants in section 10.2. The relevance of this research from a CoSEM perspective is discussed (section 10.3) and a societal perspective (section 10.4) . The academic contribution is provided in section 10.5.

10.1. Answers to the research question

The main research question to be addressed for this research was: What is the influence of different bundles of property rights on the participation of companies in initiatives for organic waste processing?

This question has been broken down into sub-questions, each of which was answered and is reviewed below.

1. *What are property rights and how can they be formalised in the context of waste processing initiatives by companies?*

   This question was answered in chapters 3 and 4. A literature review was conducted on property rights, the findings of which were applied to the Amsterdam Zuidoost case, as discussed in section 4.1.3.

   Property rights are a set of formal or informal rules, that determine how the allocation of resources is done among individuals. For the case of the Amsterdam Zuidoost initiative, property rights are the formal and informal rules that determine how companies can access, use, participate in the management, improvement and regulation of the waste processing infrastructure.

   The types of rights considered were based on the classification by Schlager and Ostrom (1992) into access rights, withdrawal rights, management rights, exclusion rights and alienation rights. The five types of property rights bundles that can be formed from these rights were also obtained from the classification by Schlager and Ostrom (1992). Table 10.1 summarises the bundles from the perspective of the initiative.

Property Rights Bundle	Authorisation Granted
Authorised Entrant	Can participate in the initiative by providing its organic waste for processing in the waste processing infrastructure (as authorised entrants only have access rights, they would be unable to withdraw/receive benefits from the resource)
Authorised User	Authorisation held by Authorised Entrants, and can obtain benefits through the sale of by-products of the waste processing, and would have to pay their share of the revenue in case of negative revenues
Claimant	Authorisation held by Authorised Users, and can participate in the formulation of management rights, i.e. the operational level rights of withdrawal determining who can obtain the products or benefits from a resource
Proprietor	Authorisation held by Claimants, and can participate in the formulation of exclusion rights, i.e. the operational level rights of access determining who can access the resource and how can it be accessed

Table 10.1: Property rights bundles in the case of the initiative

Although the waste processing infrastructure has not been considered as a common pool resource, this classification based on common-pool resource was used as it provides the granularity using which the influence of property rights can be studied.

An alternative approach could be to consider the infrastructure as a common-pool resource, in which case the companies in the initiative could self-organise to manage the infrastructure. The property rights would be formed, managed and allocated by the companies present in the initiative. In the current approach, the companies which are a part of the initiative can only update the operational payoff rule, whereas in the alternative approach they could also form the operational rule/s.

Furthermore, in this research, property rights were studied from a theoretical perspective with the help of a literature review. The insights obtained from this exercise were translated into the case for Amsterdam Zuidoost, based on which the model was built and outcomes obtained. Another possible perspective would have been to take into account practical insights related to the rights for the Amsterdam Zuidoost initiative, by taking inputs from the companies in the region. Adopting this into the existing research and integrating with the theoretical concepts could have led to further insights into the implementation of property rights in the initiative.

2. How can we gain insights into the interaction and decision-making among actors to engage in initiatives for decentralised organic waste processing by companies?

   This question was answered in chapter 3 and in chapter 4. Insights into the interaction among agents were obtained through the application of the Institutional Analysis and Development (IAD) framework, which helped identify the most important components and relations between the components.

   Waste shippers, the Municipality of Amsterdam and the project leader, were the actors identified. The waste shippers assume the role of participants when they join the initiative, and the role of Authorised Entrant/Authorised User/Claimant or Proprietor, based on the bundle they are offered. The characteristics taken into account for each waste shipper was its attitude, perceived behavioural control, subjective norm and the weight coefficient for each (the importance given

to each factor). The waste shippers also generate organic waste and have a fixed budget. Two main types of rules-in-use were identified: the property rights, the bundles of which were considered as incentives in the action situation, and the operational payoff rule, which is updated by the participants who are claimants or proprietors in the initiative. The payoff rule for the initiative is that either all participants pay an equal share of investment, or they pay a share proportional to the amount of waste generated. The revenue distribution would also be done accordingly.

The decision-making of agents was studied using the Theory of Planned Behaviour (TPB). It was determined that the perceived behavioural control component of the TPB be used to study the influence of property rights. The attitude component of the theory was studied through the sustainability and profitability/strategic motives of the companies. The subjective norm was determined by the number of participants in the initiative. These factors, along with their weight coefficients, determined the intention of the waste shippers to participate in the initiative, using the equation:

$$intention = (weight_{PBC} * PBC) + (weight_{Attitude} * attitude) + (weight_{SN} * SN)$$

The current research approach has provided insights into the influence of property rights based on the context and the decision-making theory that was chosen. This choice was based on literature review of the factors that influence the decision-making of companies in social initiatives and the context of the case study considered. Thus, if the case study provided a different context (for example, the initiative being undertaken for purely commercial reasons) and the factors considered for the decision-making would have been different (for example, if values, beliefs and norms of the companies would have been considered) then another decision-making theory could have been used for the analysis. Thus, the outcome could have differed based on the this choice.

3. How can we measure the effects of property rights in initiatives for decentralised organic waste processing by companies?
This question was answered in chapter 7 and in chapter 8. The indicators that were used are:

   - Number of participants in the initiative
   - Joining Ratio, which determines the ratio of number of participants in the initiative to the number of initial participants in the initiative
   - Number of times the initiative can start, measured using the 'initiative started' variable. This indicator denotes the number of times the initiative had sufficient funds for it to start, for a given number of runs.

   These KPIs were chosen as they capture the values of interest to determine the influence of property rights bundles on the participation of companies. Alternative KPIs can be defined based on the context and objective of the research. For example, if the objective is to determine the amount of time taken to establish the initiative, one of the KPIs that could be used is the number of ticks. The value could also be recorded for each agent according to the requirement.

   Through the research conducted, we were also able to know that the number of times the initiative can start, which is based on the amount of funds collected, is quite low (1% for the case of Amsterdam Zuidoost and 30% for the general result). This indicates that external financial support (for example, in the form of participation subsidies or tax benefits) could increase the percentage of times the initiative can start. By expanding the scope of the research and including such

financial incentives and combining them with the incentives currently considered (property rights bundles), we can verify if financial incentives can indeed lead to a higher number of times when the initiative is started. The scope of the research could also be expanded to include another form of incentive, such as a policy mandate, that could influence the outcomes.

However, the reason for these values could be the way this aspect has been modelled. The investment for the infrastructure is obtained from the participants, based on the payoff rule. The current implementation is a simplified rule for the division of investment among participants, and does not take into account the amount of funds left to be obtained for the initiative when the rule is updated by the model agents. Hence, different results can be expected if the rule implementation is updated.

4. Which factors determine the effect of property rights on the initiative by companies for organic waste processing in the case of Amsterdam Zuidoost?

   The answer to this question was obtained in chapter 8. The agent-based model built for this research was calibrated for the case of Amsterdam Zuidoost by taking into account data: the minimum amount of organic waste that can be generated by the companies present in the region, the maximum amount of organic waste that can be generated by the companies present in the region, initial number of participants and the maximum budget held by the participants. Experiments were run by varying these values and through the results obtained from the experiments, it is known that the initial number of participants in the initiative is strongly correlated to the final number of participants that join the initiative. According to the results obtained, the joining ratio of participants is higher when property rights bundle of claimants or proprietors are provided as compared to when no incentives are provided. However, which of the two bundles has a higher influence for the participants in the case study could not be confirmed due to statistical insignificance between the two distributions. Furthermore, it also could not be determined with sufficient confidence if incentive 1 (property rights bundle of Authorised User) or if provision of all incentives leads to increased participation. Hence, more research is required to know if these cases can indeed incentivise participation, and which of the property rights bundle of claimants or proprietors have a higher influence on the participation of the companies.

Answer to the main research question

Based on the answers to the sub-questions, we can answer the main question: *What is the influence of different bundles of property rights on the participation of companies in initiatives for organic waste processing?*

From the perspective of the definition used in the research, four types of property rights bundles are considered to be applicable to the case of waste processing infrastructure. The participation of the companies has been considered from an investment perspective, i.e. whether the property rights are an incentive to invest in the initiative. Considering the base case to be the situation wherein no incentives are provided, it can be seen that property rights do have a role to play in the initiative being started with sufficient funds.

To understand the influence of property rights bundles on the participation of companies in the initiative, an agent-based model was developed. The model is based on concepts from literature and information from the case study to make it as realistic as possible. However, the focus was to understand the influence of property rights, and so other aspects were kept simplified, such as the operational aspects of the bio-digester or the possibility of companies leaving the region to move to another loca-

tion. A trade-off was made between the overall complexity and the research objective considering the limited time available for the research.

Furthermore, as the incentivising influence of each property rights bundle was to be observed, it is provided in increasing order. The model is built under the assumption that in the beginning when the initiative is being set up, an initial number of participants would be present who would calculate their intention based on the share of investment, subjective norm, etc. and then decide if they would join the initiative. However, an alternative approach to this could be that the initiative could proceed by fixing the share of investment required from each participant (irrespective of the number of participants), after which all companies in the region could calculate their intention as per this value. An important point to be considered is that the influence of property rights bundles on companies especially for social initiatives has not been documented. Even in the case of the Amsterdam Zuidoost, the initiative is still in its beginning phases and has not been established yet. Hence, based on the information available and assumptions that have been made, it can be said that the model could have been made more realistic had more information been known (about such an implementation) or validation would have been done with experts.

From the results obtained through the data analysis for the case of the general results, it is known that property rights bundles function as incentives, especially those of proprietors. The maximum ratio of participants joining the initiative is observed for proprietors, followed by claimants. The case when all property rights bundles are provided in an increasing order also leads to higher participation as compared to the case when no incentives are provided.

This could indicate that higher is the property rights bundle provided, stronger is the incentive offered by the bundles.

However, the results of the experiments which determine if property rights bundles influence the participants to join the initiative for all values of input variables is inconclusive. The influence of property rights bundles with respect to variables of minimum waste, maximum waste, initial number of participants and maximum budget cannot be determined. It could be that the influence that property rights bundles have on the participation of companies in the initiative is also based on these variables. More research is required to confirm this.

10.2. Recommendations

This section provides recommendations for future research, for policy makers and for the case study participants.

10.2.1. For future research

This section discusses the limitations of the current work, while providing recommendations on how the limitations can be addressed in future research on property rights.

1. From the model result, it is known that the property rights bundles of claimants and proprietors could influence the participants to join the initiatives. The influence on the decision of companies to join the initiative is also seen when property rights bundles are provided in an increasing order. However, their influence cannot be determined when considering it from the perspective of the variables: minimum waste (sustainability motive), maximum waste (sustainability motive), maximum budget and initial number of participants (initial subjective norm), because the results obtained are inconclusive. This implies that there could be other factors which lead to the influence of the property rights bundles seen for the case of proprietors and claimants. As mentioned

before, the hypotheses were tested with respect to the minimum and maximum waste (sustainability motive), maximum budget and initial number of participants (initial subjective norm). Further research could study the influence from the perspective of revenue and cost of processing, which determine the strategic motive of the participants. Another possibility is to study the influence from the perspective of the payoff rule, i.e. whether the type of payoff rule determines the influence of property rights bundles.

2. The agent-based model developed in this research is an attempt to capture the influence of these rights for the claimants and proprietors in the Amsterdam Zuidoost initiative. However, the model developed in this case allows these participants to only formulate payoff rules of costs and benefits. As a result, the effects of other rules is unknown. It is possible that if, for example, boundary rules could be formulated, proprietors in the initiative (who have rights to determine who can participate in the initiative) could define a selection criteria for the companies to participate, which could impact the number of participants that join the initiative, and thereby the subjective norm, or the value of costs and benefits for each agent. This could be considered in future versions of the model.

3. Although influence of property rights bundle of claimants/proprietors was established from the perspective of general results, their influence with respect to the variables minimum and maximum waste, maximum budget and initial number of participants could not be determined. It is recommended that if these variables are of interest to study how they influence property rights bundles, more research should be done on them.

4. An alternative approach to study the influence of property rights and their bundles could be through the common-pool resource perspective, in which case the companies in the initiative could self-organise to manage the infrastructure. The property rights would be formed, managed and allocated by the companies present in the initiative. In the current approach, the companies which are a part of the initiative can only update the operational payoff rule, whereas in the alternative approach they could also form the operational rule/s. This approach could help determine if property rights and its bundles encourage participation of companies when they self-organise to manage the resource, including investing in it.

5. It was assumed that after a participant joins the initiative, it remains in the initiative till the time the initiative is operational. This assumption could be relaxed such that the influence of property rights bundles when participants are allowed to withdraw from the initiative is also examined. This case could be especially relevant for the case of owners, who must have alienation rights that can allow them to transfer their rights to another agent in the initiative/outside of the initiative. By including this role in a future version of the model, the literature on property rights would benefit from the richer insights that may be obtained.

   The following two recommendations are specifically from the model implementation perspective:

6. The agents are offered an incentive only once (for each type). Additionally, the agents in the model join at different times, based on the incentive provided. Hence, the payoff rule is updated by proprietors/claimants as they join. In case when the payoff rule becomes favourable to an agent after it has been provided all incentives, it cannot join the initiative because it has already reached its limit of incentives. This situation could be updated in a future version of the model, such that if there is a change in the payoff rule after an agent has been provided all incentives, it

could be offered incentives again (starting from the most basic incentive) and its intention to join the initiative must be re-assessed.

7. It is recommended that in the next version of the model, the implementation of the payoff rule could be made more realistic. This is especially required when the payoff rule is based on the share of organic waste generated. Currently the model takes into account all the agents for determining the distribution of share of investment for potential participants. However, the distribution of share of investment should take into account only the participants in the initiative.

10.2.2. For policy-makers

1. The number of participants joining the initiative is strongly positively related to the initial number of participants in the initiative. Hence, in order to increase participation, the initiative setup process should start with a high number of initial participants. For this sufficient interest must be generated among the potential participants, or they might be provided other forms of incentives to encourage initial participation.

2. The number of authorised entrants in the initiative is strongly positively related to the initial number of participants. This indicates that when the initial number of participants is high, most participants join as Authorised Entrants, which is the default role for the initiative and no incentives need to be provided for this case.

3. As the percentage of the initiative starting is very low (6%) due to the lack of funds, external financial support could be required, which can be provided in the form of subsidies, tax benefits, etc.

10.2.3. For participants in Amsterdam Zuidoost

1. Specifically for the case of Amsterdam Zuidoost, the strongest influence is of the property rights bundle of claimants or proprietors. Hence, with the current research, these bundles should be considered to be provided as incentives. More research should be conducted to clarify which bundle has a higher influence, and whether the other bundles could also influence the participation.

2. Despite provision of incentives, the initiative starts only in two out of the two hundred runs considered for the case when incentives are provided in an increasing order. This indicates that if the initiative is setup according to the model conceptualised in this research, external financial support could required to start the initiative.

10.3. Relevance to CoSEM

The Complex Systems Engineering and Management (CoSEM) program studies socio-technical systems such as large scale infrastructures which consist of both social elements, such as the actors, institutions (including the laws, cultural practices, norms etc), and technical elements, such as the technical characteristics of the infrastructure. In the scope of this research, the influence of property rights on the participation of companies for decentralised waste processing initiatives was studied. This arrangement involves the interaction of property rights, which are a form of institutions and hence the social element, with the waste processing infrastructure and its technical characteristics, such as its capacity and cost. By combining the social and technical aspects, we can explore the interaction between them

in order to better understand how these affect each other and the outcomes. This is especially relevant to policy-makers who can devise better policies by looking at the system in a holistic perspective, so that the impact can be understood before the policies are framed.

10.4. Societal Relevance

With the growing awareness for better management of waste, a solution such as a decentralised waste processing infrastructure can prove to be an effective one due to the advantages it provides: reduced transportation emissions, reduced kilometres travelled, and the provision of by-products which can be used to reduce the dependence on fossil fuels. If these advantages are recognised by a growing number of people, it is likely that the solution could be adopted by many communities. However, the high cost of investment could be a deterrent to their adoption. By studying the role of institutional incentives in the form of property rights, we are able to explore whether these incentives can lead to a higher rate of adoption for the infrastructure. The results of the study could be interesting for policy-makers and government bodies to see if this form of an incentive can be provided to increase the number of initiatives adopting this solution.

This could lead to the need for an efficient way of managing these infrastructures, so that institutional barriers do not prevent their uptake or cause allocation challenges.

10.5. Scientific Contribution

The current research contributes to science in two ways:

1. The influence of property rights has been studied in the case of economic activities and for efficient economic allocation of resources. However, its influence in the case of socially-inclined activities, especially for waste management initiatives, has not been studied before. By combining the definition of property rights from an institutional economics perspective and a behavioural theory such as the Theory of Planned Behaviour, this research attempts to provide a broader perspective on how property rights can be applied to such initiative set-ups.

2. Secondly, this research is carried out using an agent-based model which attempts to quantify property rights. There is a lack of literature on agent-based models applied to explore property rights, and it is hoped that this research provides a starting point for the same.

A

Property Rights Attributes - Additional Information

The attributes of property rights, discussed in literature, but not applicable to the research are mentioned in this section.

1. The exclusivity of property rights, describes how an asset or resource can be used, as well as how its use can be restricted for others. It could include the right to access and enjoy the resources (‘ius utile’), right of withdrawal (‘ius fruendi’ or ‘usufructus’) and the right to prevent interference (‘ius excludendi’). These categories or types of property rights are similar to the property rights components, described in section 3.1.3, and applied in the context of the research.

The ‘strength’ of property rights: the strength with which the rights are owned is defined as the extent to which an owner’s decision about the use of the rights is aligned with how the resource is actually used. If the user can determine the use and this dominates the decision of how to use the resource, the owner is said to have absolute ownership. ‘Freehold’ and ‘leasehold’ are concepts related to ownership of property rights for land as a resource. Finally, the value of property rights is determined by the mechanism according to which rights are defined and enforced. This could be either the legal system (Feder & Feeny, 1991) or the norms and customs (Brandao & Feder, 1995; as cited in Musole, 2009). As resource values rise, more actors are expected to participate in sharing the value. As a result, more benefits can be obtained when property rights are made more specific (Libecap, 1986). The value of property rights is dependent upon the structure or system of property rights.

B

Behavioural Theories

Darnton (2008) provides an overview of the various types of models of behaviour that can be applied to study human behaviour and the factors that influence behaviour.

Some of these models of behaviour are at the individual level, while some others explain behaviour due to the influence of higher levels of scale (Darnton, 2008). The models of individual behaviour take into account factors beyond economic factors such as cost/benefit calculations. We focus on models of individual behaviour change, as our objective is to understand the influence of property rights in a fairly static scenario, focusing on a small time scale. In the case of models of behaviour at higher levels of scale, the factors of economy, demography and culture are included, however, these are considered to remain constant in our research as they change over wider time scales.

Within the models of individual behaviour, the main factors that are taken into account are attitude, norms, agency, habit, emotion and contextual factors. For the case of the initiative, the influence of habit is not relevant, since the behaviour being studied is not a recurring behaviour. Along with that, the decision to participate in the initiative is based on rational factors, such as the amount of funds present to participate, outcomes achieved as a result of participation in the initiative, etc. The decision is unlikely to be based on emotional reasons. Factors beyond the control of the companies are taken into account, as these represent the external drivers that can influence participation, which in this case are the incentives offered to the companies. Norms are also taken into account, as the initiative is a collective effort, wherein multiple companies participate. It would hence be worthwhile to understand if the presence of other companies influences the decision of the companies. The final factor taken into account is attitude, which is based on the beliefs attached to the behaviour in question, i.e. participation in the initiative. This factor is important from the perspective of the initiative because setting up the initiative can improve the current waste management practices, and hence, the companies hold a strong belief for participation in the initiative, which is hence a primary motive for the companies to set it up/participate in it.

The Theory of Interpersonal Behaviour is not considered since it includes one of its factors as habit which is not relevant to this case (see appendix B. The Theory of Reasoned Action is a predecessor of

the Theory of Planned Behaviour, and does not include the influence of perceived behavioural control, which is significant in the scope of this research. The Value Belief Norm theory is also used in the case of environmental research, however, it would be insufficient in this case as it fails to consider the influence of factors such as presence of financial resources, which are critical for participation in the initiative.

Another theory that was considered for this research was the Collective Action theory (Ostrom, 2009). This theory takes into account that when individuals come together, they may behave in a manner in which they maximise the benefits for themselves, however, the joint outcomes achieved are lower than possible. Hence, its focus is on those situations in which individuals are motivated to cooperate together to achieve optimal outcomes, rather than focusing on personal gains. This research however, considers a situation wherein the participants have voluntarily come together to take collective action. As a result, the issue of lack of cooperation among them is not taken into account. This factor, however, may come into play when new participants, i.e. those who are not present during the setting up of the initiative, are invited to join the initiative. This theory was not chosen for further analysis.

C

IAD Framework - Additional Information

Each component of the IAD framework with respect to the case study is discussed here. Figure C.1 depicts this visually. As there are multiple actors, they have been represented in different colours. The corresponding entries in 'Positions' and 'Actions' have also been represented accordingly.

1. Bio-physical conditions: The bio-physical conditions of the initiative are the region in which the initiative is situated and the infrastructure for which the investment needs to be made.
   The initiative will be carried out in the commercial region of Amsterdam Zuidoost with many companies.
   The attributes of the infrastructure considered are its cost and capacity.

2. Attributes of community: Each company in the region shares its willingness to set up an initiative to improve the local conditions of the neighbourhood. As stated by one of the companies involved, they are "aware of our position in society and we play a role as a fore runner in the area and in city of Amsterdam" (Case Study Participant, Personal Communication, August 26, 2020). The organisation states that it wants to cooperate with its neighbours, large companies and citizens, and be a sustainable and innovative actor in its right. Hence, within the commercial context, there is cooperation and willingness to establish the initiative.

3. Rules-in-use: The rules-in-use considered are the policies related to commercial waste management for Amsterdam, property rights related to the initiative, market mechanisms that determine the market price of the by-products and the payoff rules that are defined for the initiative.

4. Action Situation: The components of the action situation with respect to the initiative are described below.

   (a) Actors and their characteristics: In the case of the initiative, there are multiple types of actors present:

   - Waste shippers, which are commercial and non-commercial organisations, all of which produce organic waste and possess the finances available to participate
   - The Municipality of Amsterdam, which acts as a facilitator in the initiative
   - The project leader, which coordinates actions among the companies, and,

- Other companies, which are not included in the scope of the research

(b) Positions: The positions of the actors involved are the roles mentioned above (waste generating companies, waste collecting and processing companies, facilitating, etc.). In addition to this, another position will be that of a 'participant', which is the position assumed by a waste shipper when it joins the initiative.

(c) Actions that can be taken by actors: Waste shippers can take the following actions:

- Check for budget availability
- Calculate their intention to join
- Join initiative
- Formulate rules
- Vote for a rule

Other actors (The municipality and the project leader) can take the following actions:

- Provide incentive
- Calculate updated share of investment

(d) Amount of information available: The following information is available to the waste shippers in the initiative:

- Number of participants in the initiative (initial and updated)
- Maximum number of waste shippers that can participate in the initiative
- Share of investment for participation in the initiative
- Share of organic waste that can be sent for decentralised waste processing
- The operational rule applicable at that point in time
- The incentive available to the waste shipper

(e) Outcomes that actors affect: The participants with appropriate rights can affect the operational level rule that is applicable to the initiative and its setup, i.e. amount of funds paid by the participants, amount of waste sent for waste processing

(f) Benefits and costs: The distribution of costs and benefits is according to the rules set in the initiative. By default, the participants pay an equal share of investment and send in a fixed quantity of waste for processing

5. Interactions: The interaction among the agents can be divided as:

- Interaction among the waste shippers - Through the payoff rule set by them for payment of share for the infrastructure and the amount of waste that can be sent for processing
- Interaction between the waste shippers and the global agents - This is done through the information that is shared with the waste shippers, such as information on the number of waste shippers in the initiative, current share of investment.

6. Outcomes: The outcomes affected by the actors are whether or not the initiative starts, based on the funds available and number of actors that join the initiative.

7. Evaluative Criteria: These are the Key Performance Indicators, using which it is known whether the initiative is set up. These are: Number of participants in the initiative, Joining Ratio and Number of times the incentive is started.

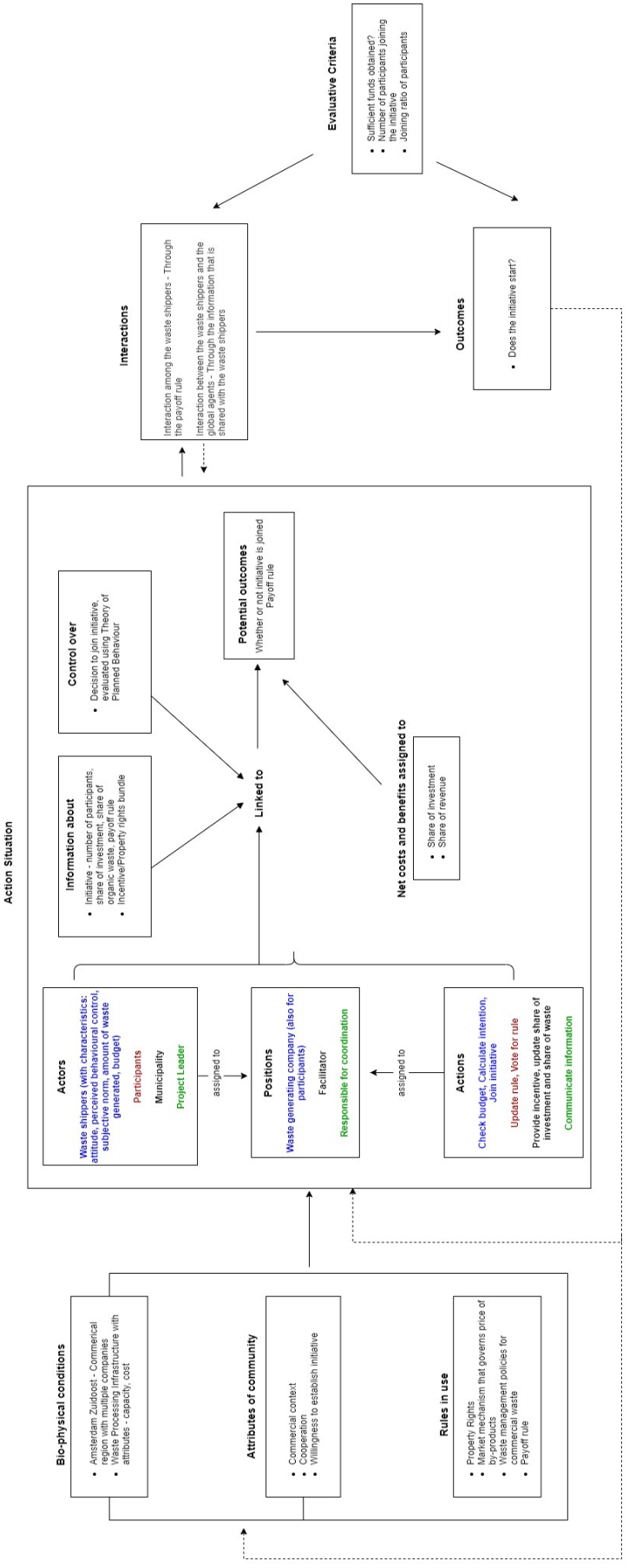


Figure C.1: IAD Framework applied to Amsterdam Zuidoost

D

Model Description using the ODD Protocol

The agent-based model built to address the research objective has been described using the Overview, Design Concepts and Details (ODD) protocol. This protocol helps to describe the model in sufficient detail, such that it can be easily understood and replicated, if required (Grimm et al., 2020).
The structure of the model description has been adopted from Grimm et al. (2020), and the most relevant aspects are included in the description. As some aspects could be discussed elsewhere, links to relevant sections and figures are provided.

D.1. Overview - Purpose

The purpose of the agent-based model created in this research is to study the influence of property rights on the decision of companies to join an initiative related to decentralised organic waste processing.
Property rights are provided in the form of bundles (Schlager & Ostrom, 1992), which are the roles that the companies can take when participating in the initiative. Incentives are provided in increasing order of property rights. Their influence on the decision-making behaviour of the agents (i.e. the companies in the model) has been analysed using the Theory of Planned Behaviour (TPB) (Ajzen, 1991). As per Meinzen-Dick (2014); Meinzen-Dick and Mwangi (2009), an important aspect of property rights is their security of tenure, the components of which are strength, robustness, exclusivity and duration. In this model, these aspects are considered as part of the perceived behavioural control, one of the concepts in the TPB (described in detail in section 3.4)

D.2. Entities, State Variables and Scales

- Agents: Two agents are included in the model, Waste shippers, and Participants:

    1. Waste shippers are the companies which will be informed of the initiative and decide whether or not to join it, based on their intention. These are potential participants.
    2. Participants are the waste shippers that have joined the initiative.

The incentives are provided by the project coordinator along with the Municipality, however these are not explicitly modelled; the model itself represents these agents.

- Overall environment: The model is set in a business/commercial context, wherein a group of waste shippers are trying to establish decentralised waste processing for the region. Each waste shipper decides whether or not to join the initiative based on its intention, calculated using TPB values and the budget. Thus, waste shippers hold a maximum budget for participation, some knowledge related to the initiative (perceived behavioural control), is influenced by the other companies that are present in its surroundings (subjective norm). Additionally, the companies hold some strategic and social motives to participate in the initiative (attitude).
- Temporal resolution: Each tick in the model represents one month, as the waste shippers meet every month to discuss the progress wherein new information becomes available to them. This could be, for example, the incentive provided, new number of participants that have joined, changes in operational rule and share of investment. and decide on whether or not they will join the initiative. With the newly available information, the waste shippers recalculate their intention.
- Time: Companies in the Amsterdam Zuidoost region that are interested in participating in the initiative have been provided a time limit of two years to set it up. Thus, this is the duration considered for the model as well. It has been considered that each tick of the model will represent one month, because it is assumed that each step (communicating with the companies, calculating the cost of joining the initiative, etc.) will take one month. Hence, the model will run for a maximum of 23 ticks, i.e. 2 years.
- State Variables: The agents, i.e. the waste shippers in the model possess some properties, such as their budget, values of TPB concepts (perceived behavioural control, attitude and subjective norm) and the factors that affect these (such as strategic and social motives), role (corresponding to the incentive, i.e. property rights provided).
- Global variables: These include number of companies in the region, number of participants that join the initiative, capacity of the waste processing infrastructure, amount of by-products produced, price at which the products will be sold, etc.

D.3. Process Overview and Scheduling

The processes that take place in the model, and the order of execution is described.

1. As part of the model setup, initial global variables and agent (Waste shipper) variables are initialised. The complete list of variables is provided in Appendix B.
   (a) Initial global variables
      i. Total cost of infrastructure
      ii. Total capacity of the infrastructure
      iii. Price of by-products (heat)
      iv. Lower limit of price of by-product (digestate)
      v. Upper limit of price of by-product (digestate)
      vi. Mean of price of by-product (digestate)
      vii. Control variables

(b) Within the model setup, the initial number of agents, i.e. waste shippers is created and their properties are initialised. This value is taken as input from the slider variable and represents the situation wherein an initial number of waste shippers express their interest in participating in the initiative). The properties initialised are:

i. The share of investment for each of the waste shippers, calculated as total cost of infrastructure / initial number of participants
ii. Amount of organic waste generated
iii. Budget available with the agent
iv. Initial value of Perceived Behavioural Control (PBC)
v. Initial value of attitude
vi. Initial value of subjective norm
vii. Value of weight coefficient of PBC
viii. Value of weight coefficient of attitude
ix. Value of weight coefficient of subjective norm
x. Value of weight coefficient of strategic motive of attitude
xi. Value of weight coefficient of sustainability motive of attitude
xii. Share of cost of operation of the waste processing infrastructure
xiii. Default role provided for participation in the initiative

(c) The following global variables are calculated after agent variables have been initialised:

i. Total amount of waste generated
ii. Average amount of waste generated
iii. Based on the total amount of waste generated, the initial values of the amount of by-products produced is obtained
iv. The price of the by-products
v. The cost of operation of the waste processing infrastructure. This is equivalent to the cost of generating the by-products

2. In the go procedure, the following values are computed:

(a) The total revenue that can be obtained from selling the by-products

(b) The share of revenue for each agent, based on the payoff rule

(c) The price of digestate, updated every 12 ticks, as it is considered that the price changes every year based on the contract that is made

(d) The maximum possible revenue that can be obtained by participating in the initiative

3. Following the initialisation, the agents call the inform-waste_shippers procedure is called. Within this procedure, for each agent, a check is made for whether it possesses sufficient budget (budget > share of investment) for participating in the initiative. If it is satisfied, the calculate-intention procedure is called.

4. Within the calculate-intention procedure, an initial check is made for the incentive provided.

(a) Based upon the incentive provided, the value of PBC is updated (explained in section 3.4).

(b) The other variables of the TPB, i.e. attitude and subjective norm are also updated, based upon the the number of participants that have joined the initiative, the amount of organic waste generated by the agent, (if any) limit on amount of organic waste that can be sent for processing, and the financial opportunity that is available.

(c) Using the updated values of the constructs and the equation below, the intention value is calculated/re-calculated (Chu & Chiu, 2003):
$(weight_{PBC} * PBC) + (weight_{Attitude} * attitude) + (weight_{SN} * SN)$

5. Once the intention value has been calculated/re-calculated, the check-intention procedure is called (under the condition that the budget for participation is greater than the share of investment). The following steps occur in this procedure for each agent:

   (a) It is checked that the agent has not already joined the initiative and has not been provided all incentives.

   (b) If the above conditions are true, the intention of the agent is checked against the intention threshold (discussed in section B.5). If the value of intention is greater than the threshold value, the agent can participate. However, the agent can only participate if the maximum capacity of the infrastructure has not been reached. Hence, this condition is checked next.

   (c) If the maximum capacity has not been exceeded and the agent is allowed to participate in the initiative, the agent joins the initiative, and assumes the agent type 'participant'. The number of participants is updated.

      i. Following this, the join-initiative procedure is called, wherein the participant is assigned the role of Authorised Entrant/Authorised User/Claimant/Proprietor, based on the incentive it was provided. The share of investment that it needs to pay and the amount of waste it can send for processing is recorded.

   (d) In the condition that the intention value is less than the intention threshold value, the waste shipper is provided a higher value of incentive.
   If all incentives have been provided, this is recorded in an agent variable, and the agent cannot participate any more, as all possible incentives have been provided to it.

6. After the intention has been checked for all waste shippers, the agents of type participants, who are authorised to make rules, i.e. participants who have been assigned the role of a claimant or a proprietor, then call the 'formulate-rules' procedure. Each claimant or proprietor can vote for a rule only once in a given run.

7. In this procedure, these participants can decide on the payoff rule, i.e., how the cost and benefit distribution will take place when participating in the initiative.

   (a) Two types of operational rules are possible here: in the first case, all participants pay an equal share for the infrastructure and send an equal amount of waste for processing. This is also the default rule for the initiative. In the second case, the participants pay a share proportional to the amount of organic waste generated, and can send all their waste for processing.

   (b) Each participant can vote for one of the two rules, based on its values for the voting criteria. In this model, the agents use their attitude values (strategic motive and sustainability motive) to vote.

i. Agents calculate their sustainability motive and strategic motive for the case when share of investment is equal
ii. Agents also calculate their sustainability motive and strategic motive for the case when share of investment is proportional to the amount of waste they generate
iii. The value given to each rule is calculated as: sustainabilityMotive * weightSust + strategicMotive * weightFin, wherein weightFin denotes the weight given to the strategic motive, and weightSust denotes the weight given to the sustainability motive
iv. The rule which is allotted the higher value is the one which gets the vote.

8. After all claimants or proprietors have voted for a rule, the check-votes procedure is called. In this procedure, one of the claimants or proprietors checks the votes for each rule, and the one with the higher number of votes is selected as operational.

9. The agents that are not yet a part of the initiative then compute their intention values based on the updated rule, and the conditions for budget and share of investment are also checked according to the updated rule.
It could be possible that due to the change in the share of investment caused by the change in payoff rule, waste shippers that could not participate earlier are now able to do so (if their budget > new value of share of investment). These agents then calculate their intention to join, against the default incentive, i.e. role as Authorised Entrant.

10. For the terminating condition, it is checked if there has been any change in the number of participants since the last 5 ticks - this waiting period is required to provide time for the agents to calculate their intention to join until the maximum incentive is provided.

11. For all the agents, it is checked if they have been provided all incentives or if they have joined the initiative or if they cannot join the initiative (budget insufficient). If the sum of these agents equals the initial number of participants, it is checked if the total sum obtained is more than the cost of infrastructure. If the sum is sufficient, the initiative can start.

12. The model terminates when maximum ticks have been reached or it is known if the initiative can start or not.

D.4. Initialization and Input data

1. Values related to the agents: based on TPB, discussed above.

2. Environment values: The by-products (compost, electricity and heat) are planned to be sold at market-prices. For the same, the values of amount of by-products obtained and their market prices are obtained from literature.

3. Others: Variable related to the waste processing infrastructure, such as the capacity, has been obtained from the manufacturing company (through the website).

4. Randomness – will be included from the values of:

   - Budget (random-float value between min-budget and maximum-budget)
   - Organic waste produced (using the random-normal function)
   - Weight coefficients of the factors of TPB
   - Weight coefficients of the factors of attitude

D.5. Submodels

The sub-models used in the main model are described here:

1. The distribution of some of the values used in the model is considered to follow a random-normal distribution. As per (Gordon, n.d.; SAGE Research Methods, 2010), many of the physical, biological and psychological measurements are said to approximate normal distributions. In the case of this research, the below are assumed to follow the random normal distribution:

    - Coefficients of the variables in the Theory of Planned Behaviour: in order to obtain the random-normal values of the coefficients, the function takes as input the mean and standard deviation of the values. The mean for the three coefficients is taken from the work by Ham et al. (2018) who use the Theory of Planned Behaviour to predict the intention to implement Corporate Social Responsibility among business students. These values were chosen due to lack of accurate data, and as they can represent a general case for an initiative. Along with the variables of the Theory of Planned Behaviour, the authors also consider the influence of education on the intention. As this variable is not applicable to the research, it has not been considered. The mean values for the other variables is: attitude coefficient - 0.214, PBC coefficient - 0.362, subjective norm coefficient - 0.307. The standard deviation is assumed to be 0.2 and a sensitivity analysis is performed, the results of which are discussed in chapter 6.
    - Coefficients of the factors of the attitude variable: The factors 'Concern for society's future', representing the sustainability motive and 'Create financial opportunity', representing the profitability motive, are based on the work by Brønn and Vidaver-Cohen (2009). The values of the factors are 0.720 and 0.572, respectively; and are considered to be the mean of the coefficient values. Along with the standard deviation of 0.2, the two values are input to the random-normal function to produce random normally distributed values of coefficients of the attitude factors.
    - Amount of organic waste generated by the waste shippers: According to Gemeente Amsterdam (2017), businesses generate 410 kg organic waste per year and offices generate 730 kg organic waste per year. Per month, this translates to approximately 34 kg and 61 kg, respectively. The average of this is 47.5kg, rounded off to 48kg. As it has been assumed that the companies in the initiative generate an amount of organic waste between these values, these are the lower and upper limits of the default values used in the model for min-waste and max-waste, respectively. The value of average waste is used to determine the maximum number of participants int he initiative

2. The calculation of the intention threshold values - To obtain the threshold value of intention, the mean value of all possible values of intention is calculated. This is done in the following manner:

    - The values of the constructs of TPB are considered. For PBC, these are: 0.5, 0.75 and 1 (based on property rights).
      For attitude and subjective norm, these values range from 0 to 1, and intervals of 0.1 are taken to give a total of 11 possible values for each.
    - As the random-normal function is used for the coefficients of the TPB constructs, their values are obtained directly from executing these functions. To account for the randomness, the combinations of all values of TPB constructs and their weight coefficients is repeated 40

times, giving a total of 14,520 runs. The intention is calculated using the formula: weight(SN) * SN + weight(PBC) * PBC+ weight(attitude) * attitude = intention (Chu & Chiu, 2003)

- The intention threshold value is calculated for each level of incentive value, by selecting the PBC values that correspond to it.

E

Variable Description and Values

	Variable	Type	Description	Default value/Formula
1	initialNoOf Participants	integer, global	Initial number of participants	7 (as the number of participants in the Amsterdam Zuidoost initiative is 7)
2	costInfra	integer	Total cost of infrastructure	0 (Due to confidentiality reasons, the value of this variable is not displayed)
3	totalCapacity	integer	Total capacity of infrastructure	500
4	min-waste	integer	Minimum waste produced by agents	34
5	max-waste	integer	Maximum waste produced by agents	61
6	organicWasteQty	floating point	Quantity of organic waste produced by each agent	Random-normal value between min-waste and max-waste
7	totalWaste Generated	floating point	Total amount of waste generated by all agents	sum [organicWasteQty]
8	amtOccupied	floating point	Amount of capacity of waste processing infrastructure utilised	totalWasteGenerated / totalCapacity
9	avgWaste Generated	floating point	Average amount of waste generated by all agents	mean [organicWasteQty]
10	maxOrganicWaste	floating point	Maximum amount of waste that can be sent for processing (in case of a limit)	initial value: avgWasteGenerated Updated value: totalCapacity / (numParticipants + 1)
11	initialLimitWaste	floating point	Initial limit on amount of waste that can be sent for processing	totalCapacity / initialNoOfParticipants
12	maxBudget	integer	Maximum budget held by agent	200
13	minBudget	integer	Minimum budget held by agent	0

14	budget	floating point	Maximum budget allocated for waste management	Random between minBudget and maxBudget
15	shareInvestment Same	floating point	Share of investment if all agents are to pay equally	costInfra / initialNoOfParticipants, then updated to costInfra / numParticipants
16	shareInvestment Proportionate	floating point	Share of investment if all agents are to pay in proportion to amount of organic waste generated	(organicWasteQty / totalWasteGenerated) * costInfra
17	shareInvestment	floating point	Share of investment to be paid by agent (based on payoff rule)	shareInvestmentSame or shareInvestmentProportionate
18	maxParticipants	integer	Maximum number of participants in the initiative	75; value chosen based on average waste generated by agents (refer Appendix <>)
19	provide-incentive?	boolean	Switch variable, to denote if incentive is to be provided	True/False
20	incentive- Experiment	integer	Value of incentive to be provided (if provide-incentive? Is true)	Possible values: -1 (when all incentives are to be provided in an increasing order), 0 (Default property rights bundle is provided, i.e. Authorised Entrant, equivalent to no incentive),1 (Property rights bundle - Authorised User) 2 (Property rights bundle - Claimant)3 (Property rights bundle - Proprietor)
21	prRole	string	Role assigned to companies as per property rights	“Authorised Entrant” ; other possible values: “Authorised User” / “Claimant” / “Proprietor”
22	elecGenerated	floating point	Amount of electricity generated as by-product(kWh)	totalCapacity * 1375 * amtOccupied / 1000
23	heatGenerated	floating point	Amount of heat generated as by-product (GJ)	totalCapacity * 5.375 * amtOccupied / 1000
24	digestate- Generated	floating point	Amount of digestate generated as by-product (tonne)	totalCapacity * 0.84 * amtOccupied / 1000
25	productionCost	integer	Processing cost (in eur/tonne) for each tonne of waste generated	85
26	cost	floating point	Total cost of waste processing	productionCost * 12 * totalCapacity * amtOccupied / 1000
27	elecPrice (euro/kWh)	list of floating point	Monthly price of electricity (based on values in NL)	NA

28	heatPrice (euro/GJ)	floating point	Price of heat	26.06
29	digestatePrice-Lower (euro/tonne)	integer	Lower limit of digestate price	-5000
30	digestatePrice- Upper (euro/tonne)	integer	Upper limit of digestate price	2000
31	digestatePrice-Mean (euro/tonne)	integer	Mean value of price of digestate	-1500
32	digestatePrice- SD (euro/tonne)	integer	Standard deviation of price of digestate	1167
33	digestatePrice (euro/tonne)	floating point	Random-normal value of digestate price	Random-normal value between digestate price lower and digestate price upper
34	maxRevenue	floating point	Maximum possible revenue that can be obtained through sale of by-products	((elecGenerated * 0.0773) + (heatGenerated * heatPrice) + (digestateGenerated * digestatePriceUpper)) * 12
35	revenue	floating point	Revenue obtained in that month from sale of by-products	((elecGenerated * item k elecPrice) + (heatGenerated * heatPrice) + (digestateGenerated * digestatePrice)) * 12
36	sn		Value of subjective norm (initial and as updated in the model)	initialNoOfParticipants / maxParticipants
37	pbc_robustness	integer	Robustness of property rights bundle	0
38	pbc_duration	integer	Duration of property rights	1
39	pbc_strength	integer	Strength of property rights	1
40	pbc_excludability	integer	Excludability of property rights	0
41	pbc	floating point	Overall perceived behavioural control of property rights	(pbc_robustness + pbc_duration + pbc_strength + pbc_excludability)/4
42	initialStrMotive	floating point	Initial value of strategic motive	0
43	attitudeStr- Motive_ROI	floating point	RoI for participation in initiative	(revenueShare - costShare) / shareInvestment
44	attitudeStrMotive	floating point	Financial opportunity created as a result of participation in the initiative	if attitudeStrMotive_ROI <= 0, attitudeStrMotive = 0 else attitudeStrMotive = attitudeStrMotive_ROI / maximumROI
45	initialSust- Motive	floating point	Initial value of sustainability motive	initialLimitWaste / organicWasteQty or 1 (if initialLimitWaste >organicWasteQty)

46	attitude_SustMotive	floating point	Updated value of sustainability motive	maxOrganicWaste / organicWasteQty or 1 (if maxOrganicWaste >organicWasteQty)
47	weightFin	floating point	Coefficient of strategic/profitability motive of attitude	random-normal value with mean = 0.57 and SD = 0.2
48	weightSust	floating point	Coefficient of sustainability motive of attitude	random-normal value with mean = 0.72 and SD = 0.2
49	attitude	floating point	Value of attitude	(weightFin * attitudeStrMotive) + (weightSust * attitude_SustMotive)
50	weightSN	floating point	Weight component/coefficient of SN	random-normal value with mean = 0.307 and SD = 0.2
51	weightPBC	floating point	Weight component/coefficient of PBC	random-normal value with mean = 0.362 and SD = 0.2
52	weightAttitude	floating point	Weight component/coefficient of attitude	random-normal value with mean = 0.214 and SD = 0.2
53	numParticipants	integer	Number of waste shippers that join the initiative, i.e., participants	Obtained from model
54	intention	floating point	Decision of waste shippers to join initiative	(weightPBC * pbc) + (weightAttitude * attitude) + (weightSN * sn)
55	limitOnWasteInput	boolean	To denote if there is a limit on waste that can be sent to biodigester	TRUE
56	initiativeJoined	boolean	To denote if initiative has been joined	FALSE
57	incentiveProvided	boolean	Incentive provided to waste shippers	FALSE
58	maxIncentives	boolean	To denote if all incentives have been provided	FALSE
59	AEParticipants	integer	Number of authorised entrants	Obtained from model
60	AUParticipants	integer	Number of authorised users	Obtained from model
61	claimant- Participants	integer	Number of claimants	Obtained from model
62	proprietor- Participants	integer	Number of proprietors	Obtained from model
63	attitudeCalc	integer	To denote whether initial value of intention is to be calculated or updated value	0 / 1
64	totalSumObtained	floating point	To store the total investment obtained from participants	Obtained from model

65	intentionThreshold	floating point	Threshold value of intention against which intention value of an agent is checked	Mean of all possible intention values, calculated for each incentive (refer Appendix <>)
66	costShare	floating point	Share of operational cost for each agent, based upon the amount of organic waste generated	(organicWasteQty / totalWasteGenerated) * cost
67	revenueShareSame	floating point	Share of revenue if all agents are to pay equally and receive equal revenue (payoff rule: equal share of investment/revenue)	revenue / initialNoOfParticipants, then updated to revenue / (numParticipants + 1)
68	revenueShareProportionate	floating point	Share of revenue if all agents are to pay or receive revenue in proportion to amount of organic waste generated (payoff rule: share of investment/revenue in proportion to amount of waste generated)	((organicWasteQty / totalWasteGenerated) * revenue)
69	revenueShare	floating point	Share of revenue to be received or paid by agent (based on payoff rule)	revenueShareSame or revenueShareProportionate
70	financialValueEqualShare	floating point	RoI when share of investment is equally divided among participants, used for determining payoff rule	(revenueShareSame - costShare) / shareInvestmentSame
71	sustainability- ValueEqualShare	floating point	Value of sustainability when agents can send equal amount of waste for processing	maxOrganicWaste / organicWasteQty or 1 (if maxOrganicWaste >organicWasteQty)
72	valueEqualShare	floating point	Value used to determine payoff rule, value associated with division of share/revenue when divided equally among participants	(weightFin * financialValueEqualShare) + (weightSust * sustainabilityValueEqualShare)
73	financialValueProportionalShare	floating point	RoI when share of investment is divided among participants based on the amount of waste generated by them, used for determining payoff rule	(revenueShareProportionate - costShare) / shareInvestmentProportionate
74	sustainability-ValueProportionalShare	floating point	Value of sustainability when agents can send all the generated waste for processing	1

75	valueProportional-Share	floating point	Value used to determine payoff rule, value associated with division of share/revenue based on amount of waste generated	(weightFin * financialValueProportionalShare) + (weightSust * sustainabilityValueProportionalShare)
76	formulatedRules	boolean	Variable to check if agent has already formulated rules	FALSE
77	amountPaid	floating point	Amount paid by the agent to join initiative	value of shareInvestment at the time agent joins the initiative
78	vote_share- InvestmentSame	integer	Votes for the payoff rule wherein share of investment and revenue are equally divided among participants	NA
79	vote_share- InvestmentProportionate	integer	Votes for the payoff rule wherein share of investment and revenue are divided based on the amount of organic waste generated by the agent	NA

Table E.1: Variables and their description

	Digestate generated	**Amount**	**Units**
i	1000 kg of foodwaste	840	kg
ii	3600 kg of foodwaste	3024	kg
iii	Digestate price	-5 to 2	€/kg

Table E.2: Digestate Data (Corden et al., 2019; Tonini et al., 2020)

	Biogas generated	**Amount**	**Units**
i	1000 kg of foodwaste	250	m^3
ii	Biogas calorific value (low)	19,7	MJ/m^3
iii	Biogas calorific value (high)	23,3	MJ/m^3
	Total heat produced		
iv	Lower limit	4925000000	J
v	Higher limit	5825000000	J
vi	Lower limit (in GJ)	4,925	/1000 kg of foodwaste
vii	Upper limit (in GJ)	5,825	/1000 kg of foodwaste
viii	Average limit (in GJ)	5,375	/1000 kg of foodwaste
ix	3600 kg of foodwaste	19,35	GJ
	Total heat generated:	20,97	GJ

Table E.3: Calculation for Biogas generated and Heat produced (ACM ConsuWijzer, 2020; Corden et al., 2019; Kaparaju & Rintala, 2013)

	Electricity generated	**Amount**	**Units**
i	1000 kg of food waste	250	m^3
ii	Calorific value of biogas	5,5	kWh/m^3
	Total electricity generated for 1000kg of food waste	1375	kWh
	Total electricity generated for 3600kg of food waste	4950	kWh

Table E.4: Calculation for total electricity generated (CBS, 2020; Corden et al., 2019)

F

Supporting Results and Analysis

Supporting graphs and information used for the data analysis are provided here.

F.1. Statistical Significance - Amsterdam Zuidoost Results

Joining Ratio (Amsterdam Zuidoost)	All incentives	Base case	Incentive 1 case	Incentive 2 case	Incentive 3 case
All incentives	1	0.74	0.65	0	0.01
Base case		1	0.86	0	0.03
Incentive 1 case			1	0.01	0.05
Incentive 2 case				1	0.68
Incentive 3 case					1

Table F.1: p-values for the Joining Ratio distributions obtained for the different incentive cases (Results for Amsterdam Zuidoost)

F.2. General Results

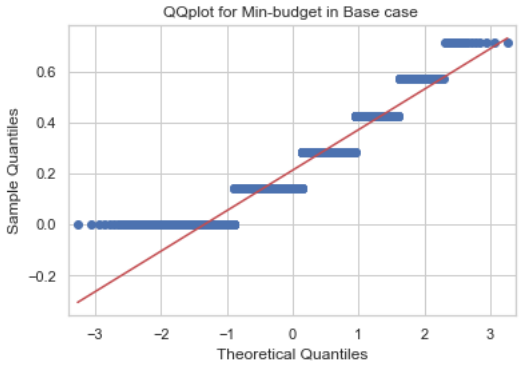
Joining Ratio (General Results	All incentives	Base case	Incentive 1 case	Incentive 2 case	Incentive 3 case
All incentives	1	0	0	0	0
Base case		1	0.51	0	0
Incentive 1 case			1	0	0
Incentive 2 case				1	0
Incentive 3 case					1

Table F.2: p-values for the Joining Ratio distributions obtained for the different incentive cases (General Results)

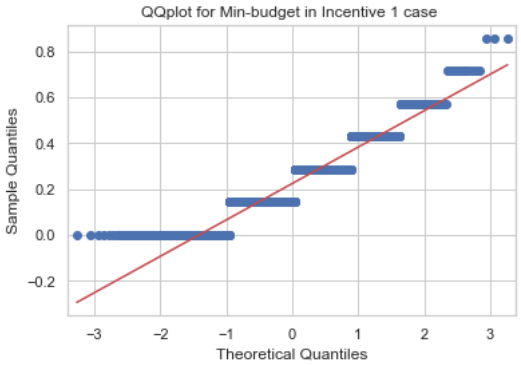
F.3. Property rights bundles and minimum waste (sustainability motive)

Box-plots were used to analyse the influence of the different property rights bundles for varying values of minimum waste on the Joining Ratio of the participants. As an overlap was observed in the output

values, the Kruskal-Wallis test was used to determine the statistical significance at 95% confidence interval. This test was used since the dependent variables are not normally distributed, as verified using the QQ plots, seen in the figures F.1 to F.3.

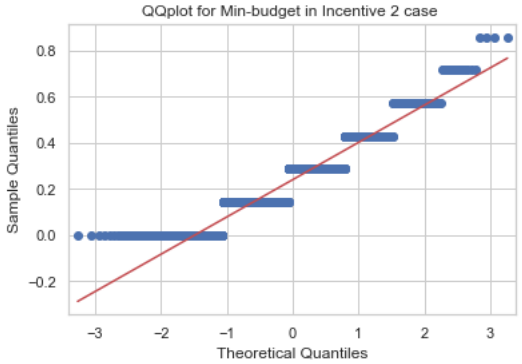


(a) QQ-plot for base case for varying values of minimum waste

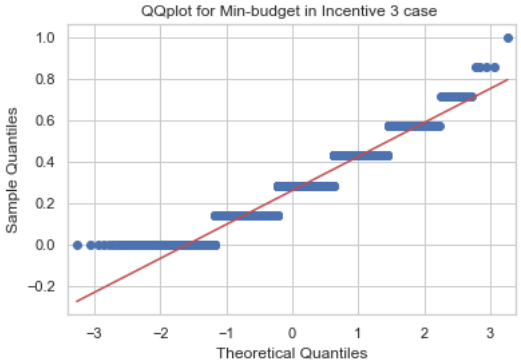


(b) QQ-plot for incentive 1 case for varying values of minimum waste

Figure F.1: QQ-plot for base case and incentive 1 case for varying values of minimum waste



(a) QQ-plot for incentive 2 case for varying values of minimum waste



(b) QQ-plot for incentive 3 case for varying values of minimum waste

Figure F.2: QQ-plot for incentive 2 case and incentive 3 case for varying values of minimum waste

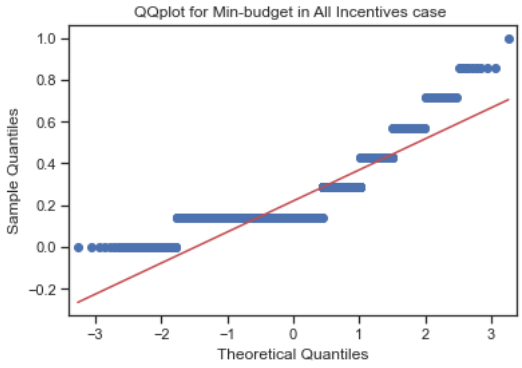
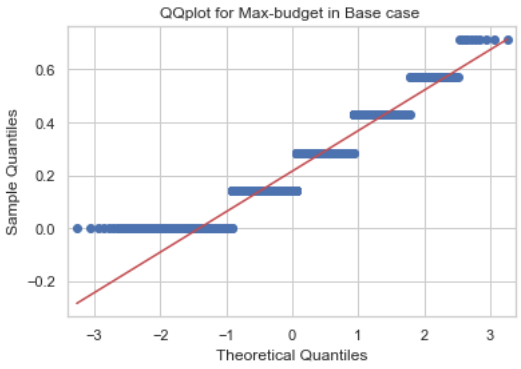


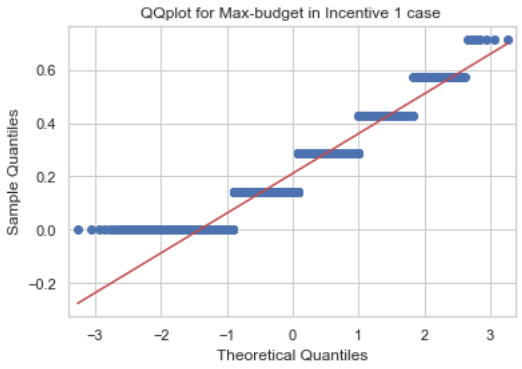
Figure F.3: QQ-plot for all incentive case for varying values of minimum waste

F.4. Property rights bundles and maximum waste (sustainability motive)

The QQ plots for the distributions and p-values obtained from the Kruskal-Wallis significance test are shown in figures F.4 to F.6.



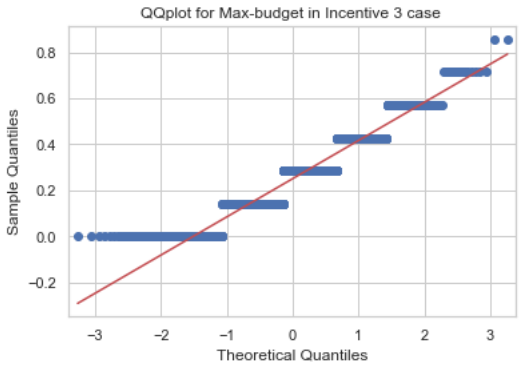
(a) QQ-plot for base case for varying values of maximum waste



(b) QQ-plot for incentive 1 case for varying values of maximum waste

Figure F.4: QQ-plot for base case and incentive 1 case for varying values of maximum waste

(a) QQ-plot for incentive 2 case for varying values of maximum waste



(b) QQ-plot for incentive 3 case for varying values of maximum waste

Figure F.5: QQ-plot for incentive 2 case and incentive 3 case for varying values of maximum waste

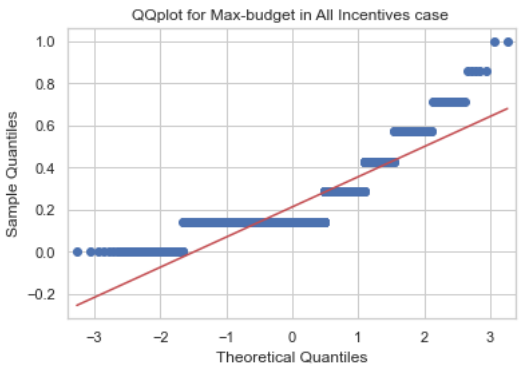
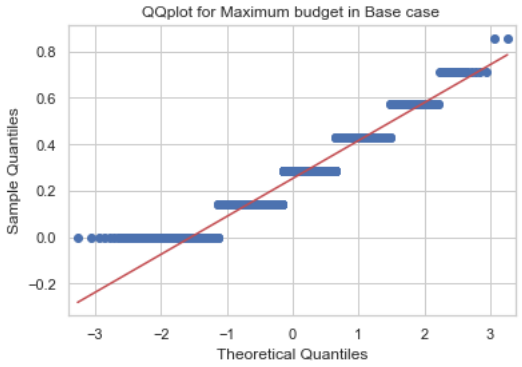


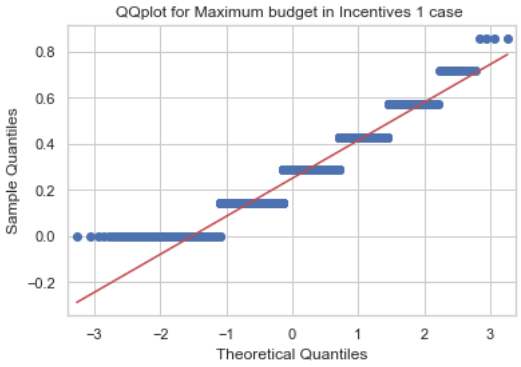
Figure F.6: QQ-plot for all incentive case for varying values of maximum waste

F.5. Property rights bundles and maximum budget

The QQ plots for the distributions and p-values obtained from the Kruskal-Wallis significance test are shown in figures F.7 to F.9.

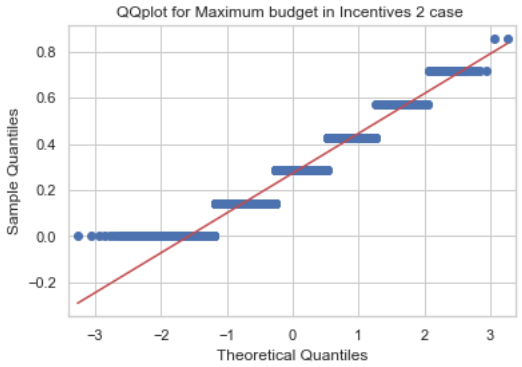


(a) QQ-plot for base case for varying values of maximum budget

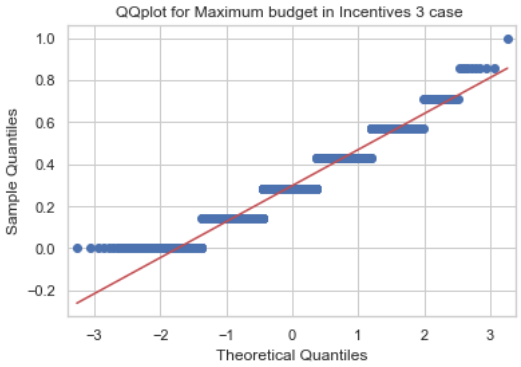


(b) QQ-plot for incentive 1 case for varying values of maximum budget

Figure F.7: QQ-plot for base case and incentive 1 case for varying values of maximum budget



(a) QQ-plot for incentive 2 case for varying values of maximum budget



(b) QQ-plot for incentive 3 case for varying values of maximum budget

Figure F.8: QQ-plot for incentive 2 case and incentive 3 case for varying values of maximum budget

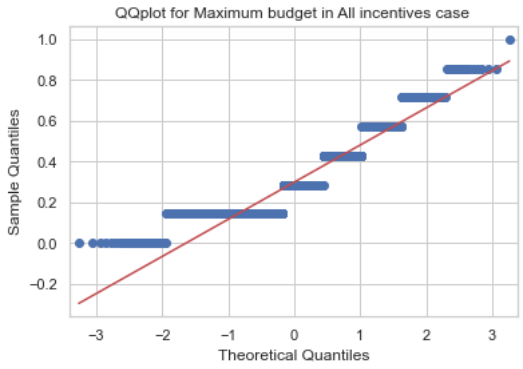
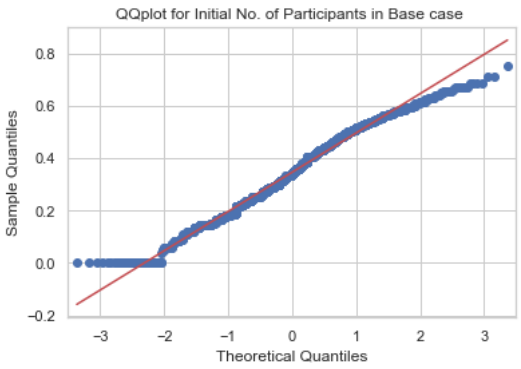


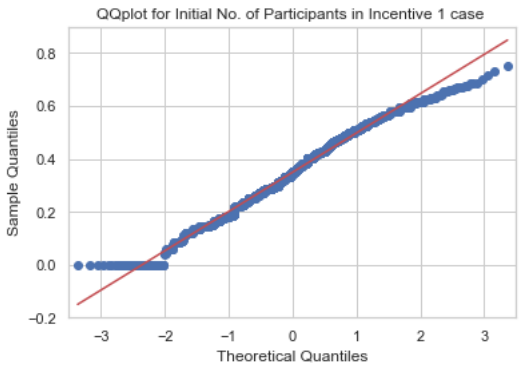
Figure F.9: QQ-plot for all incentive case for varying values of maximum budget

F.6. Property rights bundles and initial number of participants (initial subjective norm)

The QQ plots for the distributions and p-values obtained from the Kruskal-Wallis significance test are shown in figures F.10 to F.12.

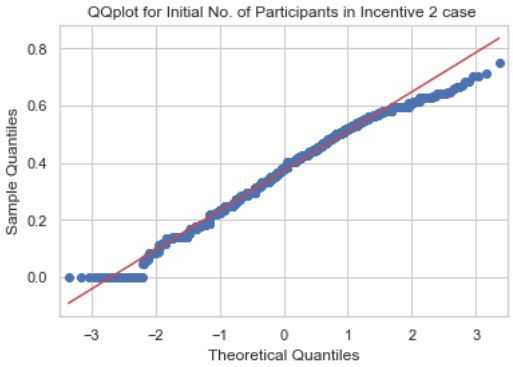


(a) QQ-plot for base case for varying values of initial number of participants

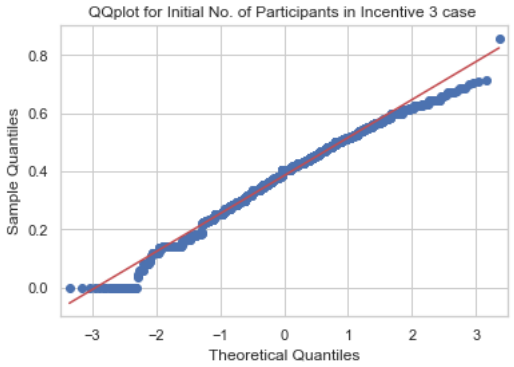


(b) QQ-plot for incentive 1 case for varying values of initial number of participants

Figure F.10: QQ-plot for base case and incentive 1 case for varying values of initial number of participants



(a) QQ-plot for incentive 2 case for varying values of initial number of participants



(b) QQ-plot for incentive 3 case for varying values of initial number of participants

Figure F.11: QQ-plot for incentive 2 case and incentive 3 case for varying values of initial number of participants

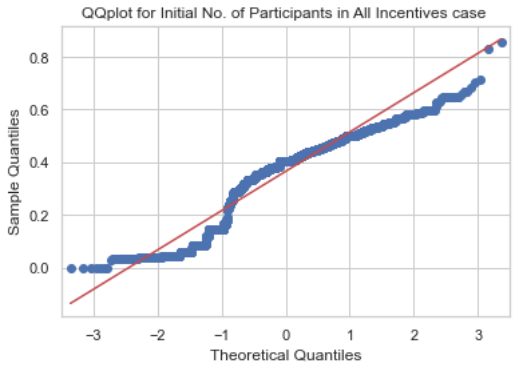


Figure F.12: QQ-plot for all incentive case for varying values of initial number of participants

Min Waste	Base - All Incentive	Base - Incentive 1	Incentive 1 - Incentive 2	Incentive 2 - Incentive 3
15	5.86,0.01	7.9, 0.00	0.11,0.74	1.70,0.19
20	0.01,0.89	5.14, 0.02	0.74,0.38	0,0.97
25	1.51,0.21	3.27, 0.07	0.04,0.84	7.94,0
30	3.68, 0.05	0.01,0.90	0.78,0.37	10.42,0
35	0.0,0.95	0.96, 0.32	9,0	0.39,0.52
40	1.63,0.20	2.87,0.08	0.30,0.58	1.41,0.23
45	4.55,0.03	0.80, 0.36	2.8,0.09	1.9,0.16
50	0.24,0.62	0.05, 0.80	1.07,0.30	1.86,0.09
55	0.42,0.51	0.01, 0.9	1.26,0.26	0.16,0.68

Table F.3: H statistic and p-values for the minimum waste for the different incentive cases wrt. base case

Max Waste	Base - All Incentive	Base - Incentive 1	Incentive 1 - Incentive 2	Incentive 2 - Incentive 3
60	0.01,0.89	2.23,0.13	1.89,0.16	0,0.95
65	0.04,0.82	2.22,0.13	0.01,0.90	0.75,0.38
70	10.71,0.00	2.84,0.09	4.28,0.03	0.09,0.75
75	2.20,0.13	0.41,0.51	3.17,0.07	0.48,0.48
80	0.54,0.46	0.04,0.82	0.51,0.47	0.01,0.89
85	2.41,0.12	1.19,0.27	1.17,0.27	6.5,0.01
90	0.13, 0.71	0.11,0.73	1.10,0.29	5.32,0.02
95	2.90,0.08	2.39,0.12	0.79,0.37	3.85,0.04
100	0.60,0.43	1.18,0.27	4.04,0.04	3.10,0.07

Table F.4: H statistic and p-values for the maximum waste for the different incentive cases wrt. base case

Max Budget	Base - All Incentive	Base - Incentive 1	Incentive 1 - Incentive 2	Incentive 2 - Incentive 3
200	2.18,0.13	0.28,0.59	3.38,0.06	2.84,0.09
225	5.54,0.18	0.04,0.83	0.10,0.74	1.43,0.23
250	0.74,0.38	1.15,0.28	230,0.12	3.35,0.06
275	1.50,0.21	0.19,0.66	1.05,0.30	1.06,0.30
300	4.09,0.04	0.01,0.90	1.36,0.24	2.77,0.09
325	16.57, 0.00	0.03, 0.84	4.24,0.03	4.65,0.03
350	7.8,0.00	4.10,0.04	8.02,0	2.63,0.10
375	17.40, 0.00	0.32,0.57	0.43,0.51	1.08,0.29
400	14.73,0.00	0.37, 0.53	0.08,0.77	1.91,0.16

Table F.5: H statistic and p-values for the maximum budget for the different incentive cases wrt. base case

Initial number of participants	Base - All Incentive	Base - Incentive 1	Base - Incentive 2	Base - Incentive 3
7	0.12, 0.72	0.31, 0.57	6.40, 0.01	10.27,0
12	7.14, 0	1.34, 0.24	3.43,0.06	19.9,0
17	10.58,0	0.24,0.62	29,0	32.52,0
22	11.28,0	0.22,0.63	14,0	57,0
27	60.60,0	6.89,0	44,0	92.30,0
32	116,0	0.21,0.64	15,0	47,0
37	90,0	0.07,0.77	32,0	47,0
42	7.68,0	0.25,0.61	7.43,0	25,0
47	6.87,0	2.23,0.13	0.12, 0.72	4, 0.04
52	2.17,0.13	1.09,0.29	0.33, 0.56	4.29, 0.03
57	35.59,0	2.05,0.15	0.02, 0.88	5.89, 0.01
62	46.88,0	0.30, 0.58	1.16, 0.27	0.51, 0.47
67	37.81,0	0.85,0.35	0, 0.93	0.69, 0.40

Table F.6: H statistic and p-values for the initial number of participants for the different incentive cases wrt. base case

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