Academic Paper for MSc Thesis

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September 2020

Abstract

This research studies the influence of property rights bundles as incentives on the participation of companies in the case of a decentralised waste processing initiative. Specifically, it attempts to understand the influence of property rights on the collective ownership of waste processing infrastructure. Previous research on property rights have been from an economic perspective, where its influence is discussed in the case of economic activities such as distribution of costs, benefits, risks, etc. The current research applies the literature on property rights to the case of an initiative which does not have economic profit as its objective. The Institutional Analysis and Development (IAD) framework is used to examine the case study, upon which the research is based so as to set it in a realistic context. The decision-making of the actors involved is captured using the Theory of Planned Behaviour (TPB), and property rights are evaluated using the security of tenure, and captured through the Perceived Behavioural Control of the TPB. An agent-based model is built to understand the role of property rights bundles in the case. It was found that property rights bundles with higher rights indeed incentivise the actors to participate. 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.

1 Introduction

The increasing amount of resource consumption and the need to manage the waste generated as a result has led to the need to manage waste more efficiently. The conventional waste disposal methods such as land-filling, are not favourable in this situation as it leads to an increase in carbon emissions and prevents the recovery of value out of products at the end of their life (Kosseva, 2013). The 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 waste in a responsible manner.

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 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). Commercial waste is managed in a free market scenario, wherein companies can have independent contracts with waste collectors and processors. This leads to increased emissions, noise, costs and traffic. A group of companies in the Amsterdam Zuidoost region have recognised these challenges and have established an initiative to process the waste locally.

However, decentralised waste processing poses economic barriers for its uptake and one of the means to address this is through collective ownership and management of the waste processing infrastructure. 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.

Incentives can be provided to address this, and this research focuses on institutional incentives to examine their influence on the investment in the waste processing infrastructure.

The research question defined is:

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

The question will be addressed with the help of theory on property rights and the Theory of Planned Behaviour (Ajzen, 1991) using which an agent-based model will be built.

2 Theoretical Background

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).

2.1 Property Rights Components

Property rights can be categorised into multiple types, based on the way the resource can be used. As perSchlager and Ostrom (1992), these components for the case of common-pool resources are:

1. Access rights – The rights to enter an area and enjoy the benefits without extracting the resources

2. Withdrawal rights – The rights to obtain products from a resource

3. Management rights – The rights to regulate internal use patterns and transform the resource by making improvements, in other words, to define the withdrawal rights

4. Exclusion rights – The rights to determine who will be authorised to access, withdraw from, or manage the resource

5. Alienation rights – The rights to sell, transfer or lease any of the rights defined above

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.

2.2 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 shared among various users: they can be held by an individual, shared or collectively held by a group or multiple groups, villages, governmental and non-governmental organisations (Marschke, Armitage, Van An, Van Tuyen, & Mallee, 2012).

The bundles of rights 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

For the case of the initiative, these bundles are provided in table 1.

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 1: Property rights bundles in the case of the initiative

2.3 Sources of rights

These rights are required to be recognised by an authority before they are considered legal (Sikor & Lund, 2009). On the basis of type, they are divided into (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).

2.4   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 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 (Meinzen-Dick, 2000). 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) excludability, ii) duration, iii) robustness, and iv) assurance, or strength of the rights. These are defined below:

- 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). 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).

- 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.

3   Institutional Analysis and Development (IAD) framework

The Institutional Analysis and Development (IAD) framework, developed by Ostrom (2009) is used in this research to identify the components that are at play in the institutional arrangement which is being analysed. The external variables and action situation, along with the interactions, outcomes and evaluative criteria for their assessment are discussed.

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.

3. Rules-in-use: 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 which will determine how the costs and benefits are allocated. 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 are provided. The agents have a fixed amount of budget, generate organic waste, and possess the characteristics of attitude, perceived behavioural control and subjective norm, and use these to determine intention.

3.1 Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB) is a psychological model used to explain the behaviour of individuals. 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). It is used in this research for the decision-making of agents.

1. Subjective norm: 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).

2. Attitude: 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 this research it is considered to be composed of the strategic motives and sustainability motives (Brønn & Vidaver-Cohen, 2009).

3. 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).

3.2 Relation between Property Rights and the Theory of Planned Behaviour

In this research, the connection between these two aspects has been studied with the help of the TPB (Ajzen, 2002). The aspects of the 'security of tenure' attribute with respect to the context of Amsterdam Zuidoost are given below:

- 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 it is likely that the institutions operational in the initiative are applicable to all the participants equally. Thus the strength will be the same for all participants, 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.

For the case of this initiative, the discussion above is summarized in Table 2, with 1 marked against those aspects which are present for a given bundle. The average of these values denotes the value of PBC (specifically, knowledge readiness of the PBC) for the company.

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

Table 2: Property rights bundles and the aspects of property rights associated with each for the Amsterdam Zuidoost initiative

4 Modelling

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.

4.1 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.

4.2 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.

4.3   Process Overview and Scheduling

The processes that take place in the model, and the order of execution is described.
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.
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 $(= totalCapacity/newNumberOfParticipants)$.

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.

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

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).

4.4 Initialization and Input data

1. Values related to the agents: based on TPB, discussed in appendix (Section: Calculation of intention values).

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 (Refer Appendix for calculations)

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 (zero) 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

4.5 Sub models

The sub-models used in the main model are those used to calculate the coefficients of the variables in the Theory of Planned Behaviour, coefficients of the factors of the attitude variable, amount of organic waste generated and calculation of intention threshold. These are discussed in detail in appendix.

4.6 Verification and Sensitivity Analysis

The model verification step is performed to make sure that the model narrative has been translated correctly into the model code. As suggested by van Dam, Nikolic, and Lukszo (2013), the model was verified by: Recording and Tracking Agent Behaviour, Single Agent Testing, Interaction testing in a minimal model and multi-agent testing. Sensitivity analysis was performed for the standard deviation of weight coefficients of Theory of Planned Behaviour variables, standard deviation of waste and the maximum budget.

Standard Deviation - Weight Coefficients
The weight coefficients are considered to be random-normally distributed. The mean of the value for the input function is taken from literature (Ham, Pap, & Stimac, 2018), but the value for standard deviation was not known. The analysis was conducted for standard deviation values of 0.2, 0.8 and 1.5. Although the difference is low, we can state that the model is slightly sensitive to the values of coefficients of the TPB variables.
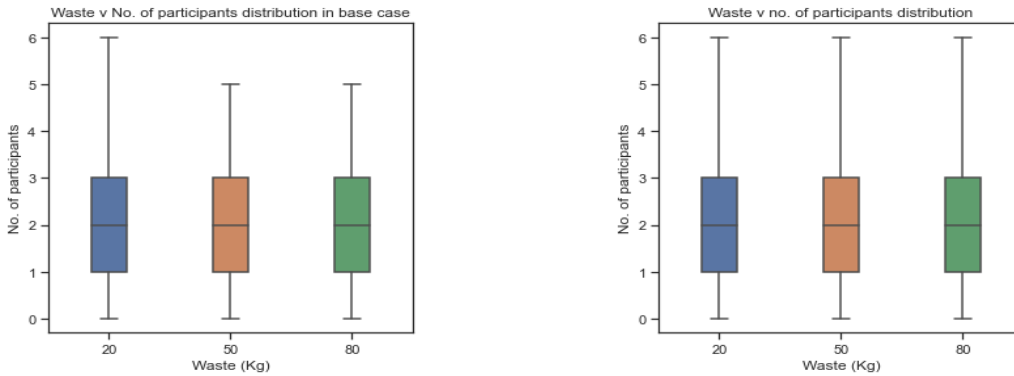
(a) Variation in number of participants when the standard deviation of waste is varied in the base case

(b) Variation in number of participants when the standard deviation of waste is varied

Figure 1: Variation in number of participants for sensitivity analysis of standard deviation of waste

Standard deviation - Waste
Sensitivity analysis was conducted for the standard deviation of weight coefficients, as this value was not obtained from literature. The analysis was conducted for the values 20kg, 50kg and 80kg. From the graphs, the choice of value of standard deviation does not have a significant influence on the results.

Maximum Value of budget
Due to lack of data, the value of maximum budget 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. It was found that the initiative starts in the case of increasing incentives when the value is EUR200 (Figure 3b).

4.7 Experimentation & Validation

In order to understand the influence of property rights bundles in varying conditions, certain experiments that can help provide further these insights were designed and conducted. These experiments took into account model variables minimum amount of waste that can be generated, maximum amount of waste that can be generated, maximum budget and initial number of participants. Four experiments were run, with atleast 15 repetitions for each. The Key Performance Indicators (KPIs) used were:
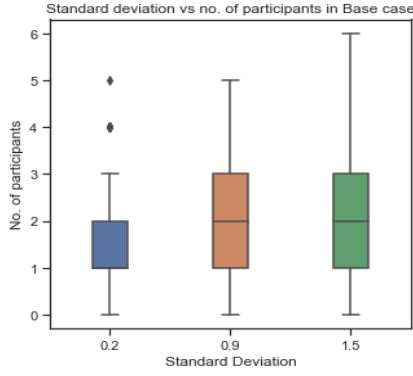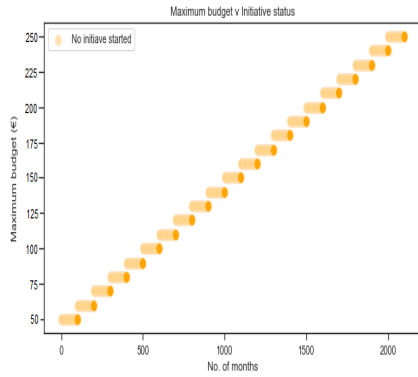
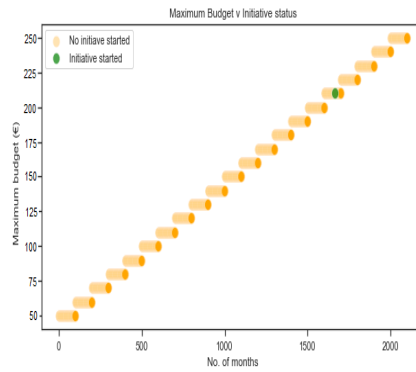(a) Variation in range of number of participants against the SD of weight coefficients in the base case
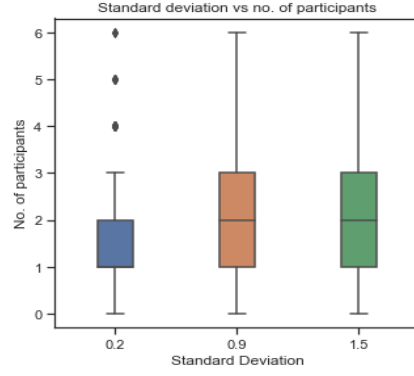
(b) Variation in range of number of participants against the SD of weight coefficients in the increasing incentives case

Figure 2: Variation in number of participants for sensitivity analysis of standard deviation of weight coefficients

(a) Number of months (ticks) v/s Maximum Budget for base case

(b) Number of months (ticks) v/s Maximum Budget for the increasing incentives case

Figure 3: Variation in number of participants for maximum budget value

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.

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.

Validation of the results was done with a case study participant. It was confirmed that the property rights bundle of a proprietor or an owner were the more desirable roles.

5 Results

5.1 Results - Amsterdam Zuidoost

The agent-based model built for this research was calibrated for the case of Amsterdam Zuidoost.

Figure 4 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
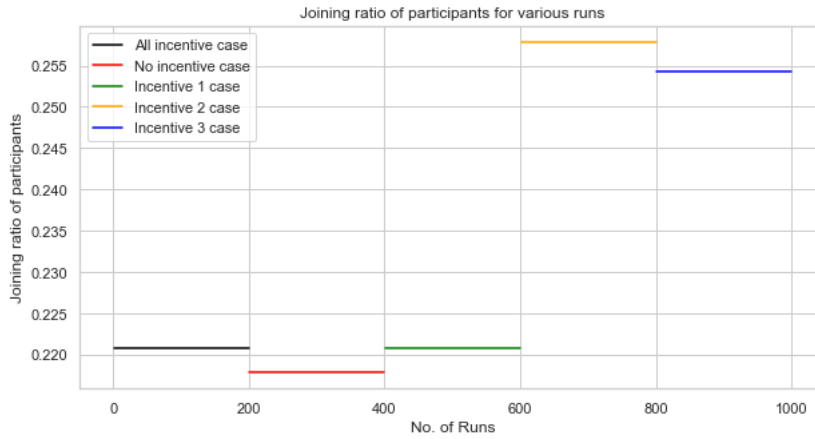
Figure 4: Joining Ratio of participants for Amsterdam Zuidoost

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.

The confidence interval was chosen to be 95%, and the statistical significance between distributions was compared with the base case. Table **??** 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.

In all the cases of incentives for the case of Amsterdam Zuidoost, depicted in figure 5, 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.
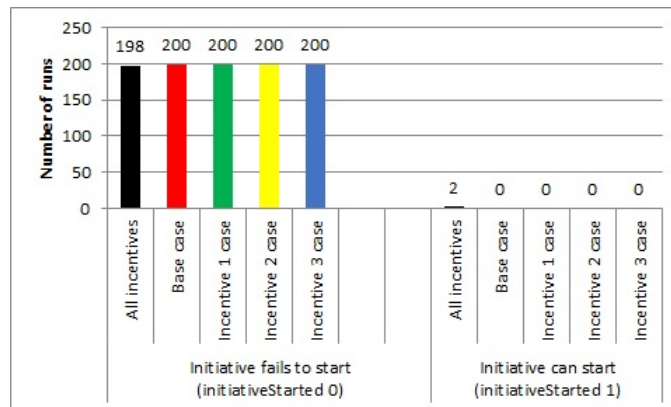

Figure 5: Number of times the initiative starts for Amsterdam Zuidoost

5.2   Results - General

Figure 6 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.
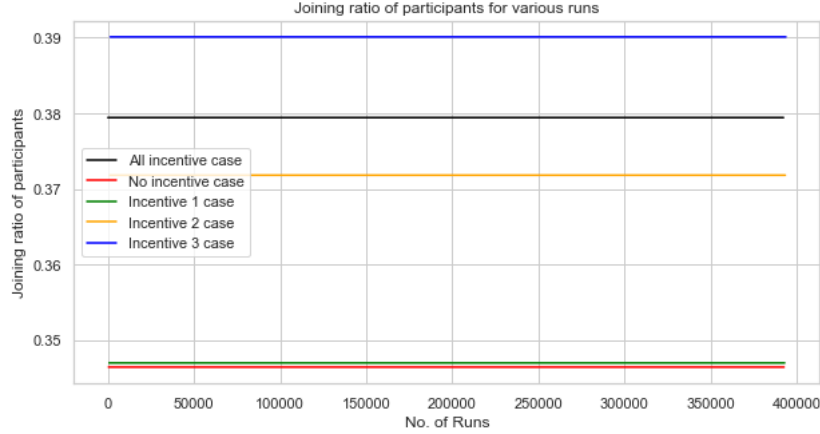
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Figure 6: Number of runs v/s Ratio of participants joining (mean value)

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. 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.

For the four hypotheses tested, it is found that all of them fail to be rejected due to lack of conclusive evidence. The results for the hypothesis related to property rights bundles and initial number of participants is provided here.

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

Figures 7 to 11 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).

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 for all values except for two. On vertically comparing the plots in the figures 7 and 11, it is observed that the results are not consistent for all values of initial number of participants, the hypothesis is rejected.
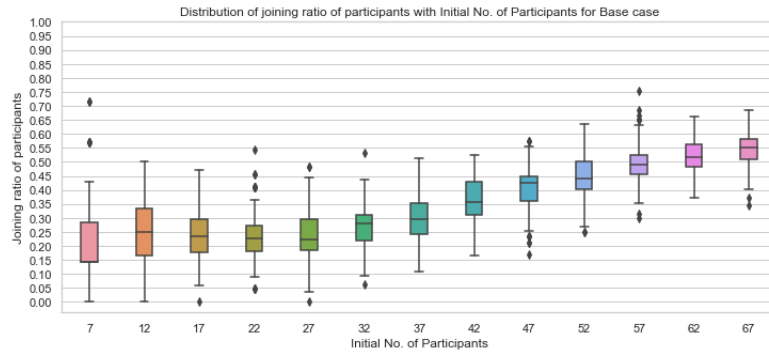
Figure 7: Joining Ratio for Base case (initial number of participants)

2. Base case and incentive 1 case - Statistical significance is seen for only one value of initial number of participants. No conclusions are derived in this case due to lack of sufficient data points.

3. Base case and incentive 2 case - From figures 7 and 9, 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 - From figures 7 and 10, 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.
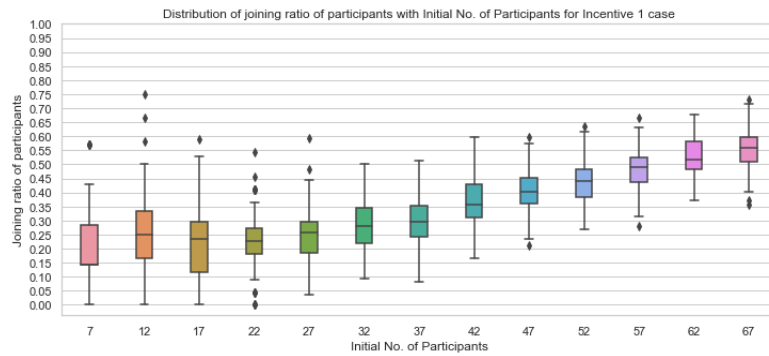

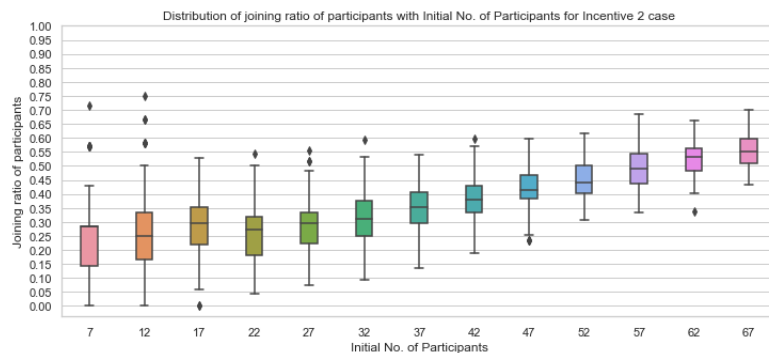Figure 8: Joining Ratio for incentive 1 case (initial number of participants)

Figure 9: Joining Ratio for incentive 2 case (initial number of participants)
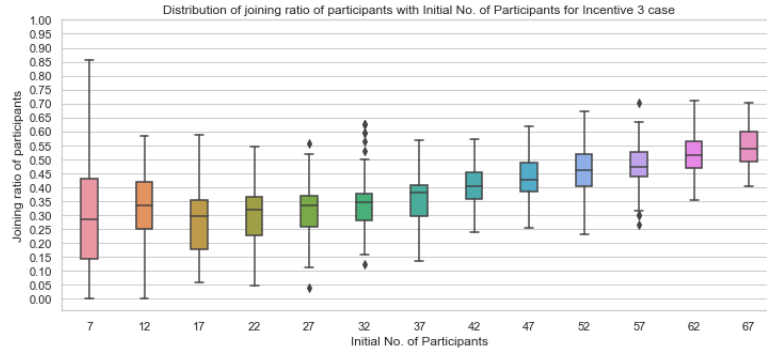
Figure 10: Joining Ratio for incentive 3 case (initial number of participants)
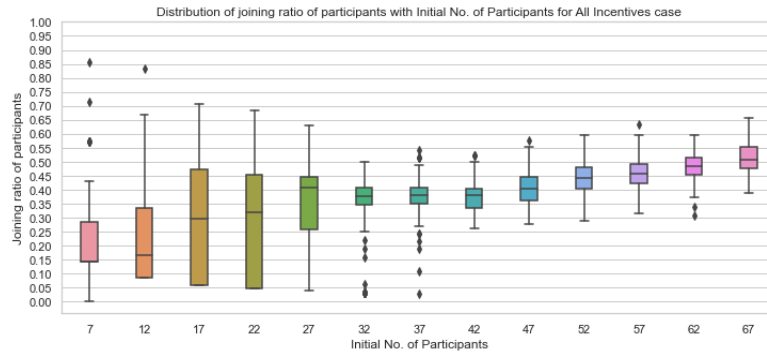

Figure 11: Joining Ratio for all incentives case (initial number of participants)

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.

6 Conclusion

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.

6.1 Recommendations for Future Work

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

Future Research The current research focused on the property rights bundles of Authorised User, Authorised Entrant, Claimant and Proprietor. The Owner bundle was left out of scope due to time and simplicity constraints. It is likely that including the owner bundle in future versions of the model will provide richer insights on the incentivising influence that property rights bundles have. Furthermore, only

the payoff rule has been considered in the research, a choice made due to time constraints. Expanding the scope to include other rules would also add to the scientific value of the research.

Secondly, 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.

For participants in Amsterdam Zuidoost 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. 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.

Appendix

Calculation of Byproducts Values and Prices

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

Table 3: 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 4: Calculation for Biogas generated and Heat produced (ACM ConsuWijzer, 2020; Corden et al., 2019; "Generation of heat and power from biogas for stationary applications: Boilers, gas engines and turbines, combined heat and power (CHP) plants and fuel cells", 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
	Electricity Price	Values from (CBS, 2020)	EUR/kWh

Table 5: Calculation for total electricity generated (CBS, 2020; Corden et al., 2019)

Sub models

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 **?**. 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 (2020), 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. 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.

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.

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 is calculated as (Chu & Chiu, 2003): (weight(PBC) * PBC) + (weight(Attitude) * attitude) + (weight(SN) * SN). 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 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, calculated as: totalCapacity/initialNoOfParticipants The value of sustainability motive will be: 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: 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 Return on Investment earned by participating in the project. This is calculated as: ((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 PBC

The value of PBC is dependent upon the type of property rights held by the agent. The overall value is determined by the components: strength, robustness, duration and excludability of the property rights (as defined in section 3.4). Each of these components holds equal weight in determining the overall average value of PBC.

	pbc_excludability	pbc_robustness	pbc_strength	pbc_duration
Authorised Entrant			1	
Authorised User			1	
Claimant		1	1	1
Proprietor	1	1	1	1

References

ACM ConsuWijzer. (2020). *How much do I pay for my heat?* Retrieved 2020-09-25, from https://www.consuwijzer.nl/stadsverwarming-en-blokverwarming/warmtetarieven

Ajzen, I. (1991). The Theory of Planned Behaviour. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211. doi: 10.1016/0749-5978(91)90020-T

Ajzen, I. (2002). Perceived behavioral control, self-efficacy, locus of control, and the theory of planned behavior. *Journal of Applied Social Psychology*, *32*(4), 665–683. doi: 10.1111/j.1559-1816.2002.tb00236.x

Arnot, C. D., Luckert, M. K., & Boxall, P. C. (2011). What is Tenure Security? Conceptual Implications for Empirical Analysis. *Land Economics*, *87*(May), 297–311.

Botetzagias, I., Dima, A. F., & Malesios, C. (2015). Extending the Theory of Planned Behavior in the context of recycling: The role of moral norms and of demographic predictors. *Resources, Conservation and Recycling*, *95*, 58–67. Retrieved from http://dx.doi.org/10.1016/j.resconrec.2014.12.004 doi: 10.1016/j.resconrec.2014.12.004

Brønn, P. S., & Vidaver-Cohen, D. (2009). Corporate motives for social initiative: Legitimacy, sustainability, or the bottom line? *Journal of Business Ethics*, *87*(SUPPL. 1), 91–109. doi: 10.1007/s10551-008-9795-z

CBS. (2020). *Average energy prices for consumers.* Retrieved 2020-09-25, from https://opendata.cbs.nl/#/CBS/en/dataset/84672ENG/table?dl=3E889

Chu, P. Y., & Chiu, J. F. (2003). Factors influencing household waste recycling behavior: Test of an integrated model. *Journal of Applied Social Psychology*, *33*(3), 604–626. doi: 10.1111/j.1559-1816.2003.tb01915.x

City of Amsterdam. (2020). *Commerical Waste.* Retrieved from https://www.amsterdam.nl/en/waste-recycling/commercial-waste/

Corden, C., Bougas, K., Cunningham, E., Tyrer, D., Kreißig, J., Zetti, E., ... Crookes, M. (2019). Digestate and compost as fertilisers: Risk assessment and risk management options. (February), 121,128, B2, D13. Retrieved from https://ec.europa.eu/environment/chemicals/reach/pdf/40039 Digestate and Compost RMOA - Final report i2_20190208.pdf

European Parliament and Council. (2008). *Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives (Waste framework.* Retrieved from http://ec.europa.eu/environment/waste/framework/ doi: 2008/98/EC.; 32008L0098

Gemeente Amsterdam. (2020). Uitvoeringsprogramma afval en grondstoffen concept B & W versie. (april).

Generation of heat and power from biogas for stationary applications: Boilers, gas engines and turbines, combined heat and power (CHP) plants and fuel cells. (2013). , 404–427.

Gordon, S. (n.d.). *The Normal Distribution* (Tech. Rep.).

Grimm, V., Railsback, S. F., Vincenot, C. E., Berger, U., Gallagher, C., Deangelis, D. L., ... Ayllón, D. (2020). The ODD protocol for describing agent-based and other simulation models: A second update to improve clarity, replication, and structural realism. *Jasss*, *23*(2). doi: 10.18564/jasss.4259

Ham, M., Pap, A., & Stimac, H. (2018). Applying the Theory of Planned Behaviour in Predicting the Intention to Implement Corporate Social Responsibility. *Innovation Management and Education Excellence Through Vision 2020, Vols I -Xi*(November), 6544–6553.

Kosseva, M. R. (2013). Introduction: Causes and Challenges of Food Wastage. In M. R. Kosseva & C. B. T. F. I. W. Webb (Eds.), *Food industry wastes - assessment and recuperation of commodities* (pp. xv–xxiv). San Diego: Academic Press. Retrieved from http://www.sciencedirect.com/science/article/pii/B9780123919212000196 doi: https://doi.org/10.1016/B978-0-12-391921-2.00019-6

Marschke, M., Armitage, D., Van An, L., Van Tuyen, T., & Mallee, H. (2012). Do collective property rights make sense? Insights from central Vietnam. *International Journal of the Commons*, *6*(1), 1. doi: 10.18352/bmgn-lchr.334

McGinnis, M. D. (2011). Updated Guide to IAD and the Language of the Ostrom Workshop: A Simplified

Overview of a Complex Framework for the Analysis of Institutions and their Development. *Policy Studies Journal*, *39*(1), 163–177.

Meinzen-Dick, R. (2000). Property Rights and Maintenance of Irrigation Systems. *Division 45 Rural Development.*(6), 37.

Meinzen-Dick, R. (2014). Property rights and sustainable irrigation: A developing country perspective. *Agricultural Water Management*, *145*, 23–31. doi: 10.1016/j.agwat.2014.03.017

Meinzen-Dick, R., & Mwangi, E. (2009). Cutting the web of interests: Pitfalls of formalizing property rights. *Land Use Policy*, *26*(1), 36–43. doi: 10.1016/j.landusepol.2007.06.003

Musole, M. (2009). Property rights, transaction costs and institutional change: Conceptual framework and literature review. *Progress in Planning*, *71*(2), 43–85. doi: 10.1016/j.progress.2008.09.002

Ng, K. S., Yang, A., & Yakovleva, N. (2019, aug). Sustainable waste management through synergistic utilisation of commercial and domestic organic waste for efficient resource recovery and valorisation in the UK. *Journal of Cleaner Production*, *227*, 248–262. doi: 10.1016/j.jclepro.2019.04.136

Ostrom, E. (2009). Collective Action Theory. In C. Biox & S. C. Stokes (Eds.), *The oxford handbook of comparative politics* (chap. Collective).

Ostrom, E. (2010, jun). Beyond markets and states: Polycentric governance of complex economic systems. *American Economic Review*, *100*(3), 641–672. doi: 10.1257/aer.100.3.641

Panepinto, D., & Zanetti, M. C. (2018, mar). Municipal solid waste incineration plant: A multi-step approach to the evaluation of an energy-recovery configuration. *Waste Management*, *73*, 332–341. doi: 10.1016/j.wasman.2017.07.036

Pfaltzgraff, L. A., De Bruyn, M., Cooper, E. C., Budarin, V., & Clark, J. H. (2013, jan). *Food waste biomass: A resource for high-value chemicals* (Vol. 15) (No. 2). Royal Society of Chemistry. Retrieved from www.rsc.org/greenchem doi: 10.1039/c2gc36978h

Rezzadori, K., Benedetti, S., & Amante, E. R. (2012, oct). *Proposals for the residues recovery: Orange waste as raw material for new products* (Vol. 90) (No. 4). Elsevier. doi: 10.1016/j.fbp.2012.06.002

SAGE Research Methods. (2010). *Normal Distribution.* Retrieved from https://methods-sagepub-com.tudelft.idm.oclc.org/reference/encyc-of-research-design/n276.xml

Scalco, A., Ceschi, A., & Sartori, R. (2018). Application of psychological theories in agent-based modeling: The case of the theory of planned behavior. *Nonlinear Dynamics, Psychology, and Life Sciences*, *22*(1), 15–33.

Schlager, E., & Ostrom, E. (1992). Property-Rights Regimes and Natural Resources : A Conceptual Analysis. *, 68*(3), 249–262.

Sikor, T., & Lund, C. (2009). Access and property: A Question of Power and Authority. *The Politics of Possession: Property, Authority and Access to Natural Resources*, *40*(1), 1–22. doi: 10.1002/9781444322903.ch1

Teraji, S. (2008). Property rights, trust, and economic performance. *Journal of Socio-Economics*, *37*(4), 1584–1596. doi: 10.1016/j.socec.2007.06.008

Tonini, D., Wandl, A., Meister, K., Unceta, P. M., Taelman, S. E., Sanjuan-Delmás, D., ... Huygens, D. (2020, sep). Quantitative sustainability assessment of household food waste management in the Amsterdam Metropolitan Area. *Resources, Conservation and Recycling*, *160*, 104854. doi: 10.1016/j.resconrec.2020.104854

van Dam, K. H., Nikolic, I., & Lukszo, Z. (2013). *Agent-Based Social Systems Volume 9 Editor in Chief : Series Editors : ABSS – Agent-Based Social Systems* (Vol. 9).

Wade, R. (1987). The management of common property resources: collective action as an alternative to privatisation or state regulation. *Cambridge Journal of Economics*, *11*(2), 95–106. doi: 10.1093/oxfordjournals.cje.a035024