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Institutional Effects:
Enforcement through the Internet of Things

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ABSTRACT

This study examines whether enforcement through a specific ICT-application, known as the *Internet of Things (IoT)*, affects the institutions in public spaces that it enforces. Little remains known about the effects and abilities of ICT to cope with street-level complexity. Existing research suggests that the use of ICT for the application of rules induces digital rigidity. This study addressed the question '(How) does the integration of IoT in the enforcement of an institution lead to change in the institution's operation?' The question was approached by conducting a small-N intertemporal case study, in which an institution was compared before and after IoT was integrated in the enforcement of the institution. It was chosen to examine the institution of paid parking, and the Municipality of Amsterdam was selected as a case, since it was an early adopter with regard to using IoT in the enforcement of paid parking. The analysis focused on the institution on the operational level, including both the written rules and how these were enforced by inspectors. By means of a co-variational analysis, covariance was found between the integration of IoT in the enforcement and change in the enforced institution. Identified changes revolve around the establishment of a digital connection between physical objects and user data, on the one hand, and more rigid interpretations of rules on the other. Propositions derived from the e-government literature were tested and found to provide explanations for the found covariance regarding more rigid interpretations.

Keywords: ICT, Internet of Things, institutional change, enforcement, e-government

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1 INTRODUCTION

1.1 Towards smart enforcement?

Information and communication technologies (ICTs) continue to shape social life. Everyday activities that used to take place in physical spaces, have moved to cyberspaces, enabled by ICT. Think of online shopping, online banking, web lectures (MOOCs), playing scrabble with your aunt via a smartphone app, and applying for a permit through your municipal web portal. These examples illustrate a shift of everyday activities to cyberspace. Yet, ICT is also bringing digital devices to physical spaces, by what is known as the *Internet of Things (IoT)*. The concept of IoT comprises a particular use of ICT that focuses on a network of physical things, like phones, cameras and vehicles. These devices are "all communicating and sharing information based on stipulated protocols in order to achieve smart reorganizations, positioning, tracing, (...) [and] process control" (Patel, et al., 2016, p. 6122).

The use of IoT is associated with the word *smart*. IoT is used on a household level referred to as *smart homes*. Conventional household appliances become smart by equipping them with computational power, sensors and network access. Examples of smart home appliances include vacuum- and lawn mower robots, autonomous lighting, and heating. The homeowner controls the house by setting up so-called if-then rules. These rules tell the smart home system to perform certain actions when specific events are detected. These events include for example time events, location events (geofencing), as well as events detected by sensors like motion, light, and temperature. Devices within the smart home network share data to coordinate actions. This allows for example the lights to turn on in the living room when a motion sensor in that room detects movement, or turn off when no movement is detected for 10 minutes. Thus, IoT renders the smart home capable of performing automated tasks, triggered by data extracted from the physical world, such as the homeowner's behavior (e.g. movement). This serves the homeowner, since it takes away some process control. After all, the homeowner no longer has to decide whether it is necessary to turn off the light when leaving the room.

Similar to the logic of smart homes, IoT can be used on a city level to detect events in the physical world, and subsequently trigger actions on the basis of rule sets. For example, underground waste containers that automatically notify the disposal services when sensors detect that the container is full. Cities that use ICT as a "digital nervous system" are regarded as *smart cities* (Hall et al., 2000, p. 1; MIT, 2019). Although the term smart city dates back to the 1990s, the emergence of IoT has contributed to its realization (Schaffers et al., 2011; Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014). Scholarly attention was drawn to the smart city phenomenon, when near the end of the first decade of the 2000s, it was observed that smart city programs started to emerge (Nam &

Pardo, 2011, p. 284). In 2012, the number of cities with smart city programs had already reached 143 cities worldwide (Lee & Hancock, 2012).

Since the principle of IoT is that sensors observe behavior and subsequently trigger actions, it can also be used to detect unwanted behavior. On a household-level the smart home might trigger an alarm when motion is detected in the house, while the GPS-location of all family members indicate that they are not at home. China's Social Credit System, illustrates the use of IoT for enforcement purposes on a state-level (Pető & Tokody, 2019). However, this application is not limited to China's state level, nor a household-level. It can also be used at a city level. Since 2010, some Dutch Municipalities have experimented and incrementally implemented IoT arrangements in the enforcement of paid parking. This includes parking machines with internet access, smartphone applications to make payments and register license plate numbers, as well as scanning-systems that are driven around the city to detect parked cars that lack a valid parking right.[1]

1.2 Problem definition and research question

The emergence of IoT within public administrations adds to a larger trend of ICT integration within public administrations, known as *e-government* (Dawes, 2008, p. 68). The existing e-government doctrine concentrates inter alia on the distribution of public services (Bekkers & Homburg, 2007; Twizeyimana & Andersson, 2019). The use of ICT for the distribution of public services is characterized by a reduction of vis-à-vis interaction between citizens and public service workers. This manifested itself through a replacement of window clerks by online portals and digital forms, as well as a replacement of adjudicating officials that were responsible for deciding on granting e.g. permits, welfare benefits and tax declarations, by computer systems (Bovens & Zouridis, 2002).

A point raised by several scholars addresses the issue whether computerized decision-making is able to sufficiently take special circumstances of individual cases into account (cf. Bovens & Zouridis, 2002; Kallinikos, 2005; Cordella, 2007; Cordella & Tempini, 2015). Computerized decision-making is in particular suitable for rules that follow clear if-then structures and rely on numerical parameters (Busch & Hendriksen, 2018, p. 21). Bovens and Zouridis (2002, p. 182) argue that the use of ICT for the assessment of cases, reduces the possibility of interpreting rules in respect of facts and circumstances, thereby inducing a form of digital rigidity.

With regard to enforcement through IoT, it is not the adjudicating officials that are replaced by computer systems, but the enforcement agents (inspectors and police officers). Yet, little remains known about the effects, reliability and capabilities of IoT, to cope with the complexities of the street-level reality of public spaces. Not all rules and regulations comprise clear defined numerical

[1] See chapter five.

parameters. Hence, several questions remain: whether enforcement through IoT is sufficiently able to observe behavior, whether legal prescripts can be adequately interpreted, or whether regulation and/or its enforcement are adapted to computer-interpretable parameters instead. Little remains known about what this means for the broader institution that the enforcement is set to uphold. To approach this puzzle, this study is guided by the following research question: '(How) does the integration of IoT in the enforcement of an institution lead to change in the institution's operation?'

1.3 Relevance

From an academic perspective, this study is relevant, because it contributes to the existing e-government literature, that is, the knowledge about the effects of the integration of ICT in public administrations. The contribution lies in the application of e-government concepts in the context of IoT. As noted at the beginning of this chapter, ICT has brought about a shift from physical space to cyberspace. E-government research has been focused on this shift within an administrative context. Yet, as pointed out earlier, IoT is different as it does not entail a shift from physical space to cyberspace. It rather involves the emergence of digital devices in public physical spaces. Therefore, it is relevant to study whether the applicability of e-government knowledge extends to IoT.

The societal relevance of this study is that it provides potentially policy relevant knowledge about the effects of IoT for enforcement purposes, such as indications of factors that may or may not make enforcement through IoT suitable. Moreover, as technologies evolve the urgency increases for an adequate understanding of the opportunities and limitations of IoT for policy enforcement. It is expected that with the emergence of 5G wireless internet, the use of IoT in public spaces will increase (Postma, 2019; OECD, 2019). Furthermore, enforcement through IoT is not limited to the domain of paid parking. for example, in the Netherlands, some municipalities intent to include other domains like: the detection of illegally disposed garbage, graffiti, stray bicycles, illegal construction work on monumental real estate, the tracking of confused or wanted persons, and enforcement of advertisement taxation[2] (NOS, 2019).

1.4 Introduction of method

In order to find an answer to the research question, this study compares an institution before and after it is enforced through IoT, focusing on the institution of paid parking. Comparing the institution before and after the integration of IoT, allows to infer causality between the use of IoT and institutional change. The research design consists of a small-N intertemporal case study and employs a co-variational analysis. As a case, the Municipality of Amsterdam is selected, because it is

[2] *Gemeenteblad* 2019, 290031.

an early adopter of IoT in the enforcement of paid parking. To assess covariance, it is analyzed whether the institution's operation before the integration of IoT is different from the institution's operation after the integration of IoT. The analysis focuses on the operational level of the institution. A broad understanding of institutions is used, which involves that the analysis not only examines the written rules, but also prescribed courses of action to comply with these rules, and how these rules are enforced in practice. Data about the written rules is collected in the form of regulations; data about the prescribed courses of action and enforcement is collected in the form of case reports and court cases. Three databases are used: (1) Decentrale.regelgeving.overheid.nl, (2) Ombudsmanmetropool.nl, and (3) Rechtspraak.nl.

1.5 Reading guide

This thesis has seven chapters. In chapter two I set out a theoretical framework to provide an understanding about the concept of institutions and the need for enforcement. Thereafter I explain the connection with e-government, and further elaborate on relevant academic work within this discourse. Based on the e-government literature, I conclude the chapter with propositions that provide plausible explanations for institutional change. In chapter three I present the research design and explain choices with regard to the research scope. In the fourth and fifth chapter I set out how the institution was shaped and enforced, before and after the integration of IoT in the enforcement of the institution. Then, in the sixth chapter I present the analysis, which involves a comparison of both cases to determine whether institutional change occurred. As already noted, this does not merely focus on the written rules of the institution, but also on the prescribed courses of action and how the rules are enforced. After the assessment of institutional change, I continue the chapter by reflecting on the propositions from chapter two, and see whether these indeed provide an explanation for the existence of institutional change, or lack thereof. In the final chapter I present my conclusions, reflect on limitations of this study and outline opportunities for future research.

2 THEORY

2.1 Introduction

This chapter provides an initial understanding of how the integration of IoT in the enforcement of an institution might affect the institution. Thereto, the next paragraph discusses the effects of ICT in domains where ICT has already been integrated. As noted in the first chapter, IoT is a subtype of ICT, so it makes sense to discuss how the general use of ICT has affected public administrations. The paragraph thereafter sets out the domain of interest of this study, namely the domain of enforcement of institutions. Then, the final paragraph formulates propositions on how the integration of IoT in the enforcement of institutions, affects institutions.

2.2 E-government

The integration of ICT in public administrations has become known as e-government, which stands for electronic government. The term is sometimes used interchangeably with *e-governance*, yet it is argued that the latter should be used to denote a broader concept not limited to the public domain (Palvia & Sharma, 2007). To prevent semantic confusion, the term e-government is used hereafter.

The literature on e-government is fragmented, as the concept attracted attention from various disciplines, including Computer Science, Information Systems, Public Administration and Political Science (Heeks & Bailur, 2007). Depending on the discipline, researchers focus on different aspects of ICT integration in public administrations. For example, computer scientists study network architectures (Ebrahim & Irani, 2005), whereas political scientists concentrate on concepts like *e-participation* and *e-democracy*, while researchers in the field of Public Administration explore topics such as the effects on citizen-administration interaction and improving administrative efficiency (Jansson & Erlingsson, 2014). Hereafter, relevant academic work within the domain of Public Administration is further discussed.

A much-cited definition, relevant to Public Administration researchers, regards e-government as: "the use of information and communication technologies, especially internet and web technology, by a public organization to support or redefine (...) relations with stakeholders (...)" (Bekkers & Homburg, 2005, p. 6). Adding to that, e-government is often explained in the context of the provision of public services, in particular: *information*, *communication* and *transaction services* (Bekkers & Homburg, 2007). Although the implementation of ICT in the distribution of these services is explained in terms of economic motives, like effectiveness and efficiency, research also focused on non-output related aspects resulting from the changing nature of the way public services are distributed (Jansson & Erlingsson, 2014, pp. 293–4; Homburg & Bekkers, 2005). These non-output related aspects are hereafter further discussed.

First, information services relate to the disclosure of information by public administrations. ICT has brought about a change in the way that such information is disclosed, manifested in the replacement of window clerks by websites. Tolbert and Mossberger (2006) found that citizens who visited websites of their local governments, perceived their local governments as more responsive, which in turn increased their trust in local governments.

Second, communication services concern channels for asking questions to citizens' public administration, for example about programs and the scope of specific rules (Bekkers & Homburg, 2007). E-government developments regarding these services include online chat services and discussion forums to facilitate citizen participation. The term *Web 2.0* refers to such ICT-enabled two-way interactions (Jansson & Erlingsson, 2014). It is argued that the use of social media by public administrations promotes transparency and is negatively associated with the level of corruption (cf. Andersen et al., 2011; Bertot, Jaeger & Grimes, 2012; Elbahnasawy, 2014).

Finally, transaction services refer to public services that deal with administrative decision-making, such as the processing of requests and intakes. Think for example of allocating social benefits, issuing licenses, granting permits, determining the height of a tax assessment, and imposing fines (cf. Bekkers & Homburg, 2007, p. 375; Thomas & Streib, 2003, p. 98; Bovens & Zouridis, 2002). With the rise of the welfare state, the amount of decisions that public administrations had to process increased, leading up to large executive agencies (Bovens & Zouridis, 2002, p. 175). Within these executive agencies, public-service workers fulfill a crucial role, because in practice "it is the welfare workers, adjudicating officials, tax inspectors, and police officers who (…) decide to grant a benefit payment, lay down the conditions attaching to a permit, and determine the amount of an assessment or fine" (Bovens & Zouridis, 2002, p. 175). A lot of these workers that are involved in transactions services could be considered frontline workers or so-called *street-level bureaucrats*. This concept denotes public-service workers whose job requires interaction with citizens on a regular basis, while having significant discretion in their decision-making that can substantially influence their clients' lives (Lipsky, 1969, p. 2). Discretionary power arises because legislators cannot oversee the complexity of reality, and therefore cannot provide sufficiently detailed rules and regulations. As a result, street-level bureaucrats constantly face choices in respect of the interpretation of rules for each individual case (Bovens & Zouridis, 2002; Lipsky, 1980).

The integration of ICT for transaction services transformed public administrations, raising normative-administrative questions with regard to the discretionary power of the public workers, that characterized the delivery of these services. Two transformations are identified.

The first transformation involves the use of ICT on an organizational level, referred to as *e-bureaucracy*. This encompasses the use of ICT to “support the fundamental organizational functions of coordination and control (...) that prescribe how to coordinate the activities of the organization and how to deliver the services” (Cordella, 2007, p. 273). This idea touches on the concept of *screen-level bureaucracy*, coined by Bovens and Zouridis (2002, p. 178). ICT is used within screen-level bureaucracies for the formalization and standardization of assessment processes, as well as the input side of the decision-making process through templates and forms. This restricts discretionary power, as the role of the case-worker is reduced to processing the forms filled in by clients into a computer.

A second transformation involves the use of ICT on an operational level, in the sense that computers are used to produce decisions; and by that, decreasing or eliminating the need for human decision-making, in particular with regard to tasks that follow schematic rulesets and for which numerical data is available (Busch & Hendriksen, 2018, p. 21). Again, this matches a concept coined by Bovens and Zouridis (2002), namely that of *system-level bureaucracy*. The authors describe this concept as a public administration in which computers produce decisions based on programmed decision-models (algorithms). Input for decision-models is provided directly by citizens through digital application forms. This way, no human intervention is required. Some researchers argue that this shift from human decision-making to computerized decision-making supports democratic values, since computer systems and algorithms only include predefined sets of variables, which “serves the principle of impersonality, equality and fairness” (Cordella, 2007, p. 273; also see Kallinikos, 2005; Cordella & Tempini, 2015). Yet, Bovens and Zouridis (2002) argue that discretion has not dissolved in its entirety. They point out that discretion still exists, since rules and regulations still require to be translated in computer readable algorithms. It is now in the process of software architecture and coding where discretionary power manifests itself. As system engineers make choices about the interpretation of legal prescripts, the separation between carrying out policy and making policy fades (Bovens & Zouridis, 2002, p. 182).

2.3 Institutions and enforcement

The previous paragraph discussed effects of the integration of ICT in public administrations, in respect of information, communication and transaction services. This paragraph continues by outlining the domain of enforcement of institutions. Hereafter, it is explained what institutions are, why they are needed, and why they need to be enforced.

The concept of *institutions* knows a myriad of definitions. A common quality of some of these definitions is that they address the aggregation of prescripts that determine what actions people choose to take in social situations. For example, Ostrom (2005, p. 3) defines institutions as "prescriptions that humans use to organize all forms of repetitive and structured interactions (...). Individuals interacting within rule-structured situations face choices regarding the actions and strategies they take, leading to consequences for themselves and for others." According to Streeck and Thelen (2009, p. 9), institutions "typically involve mutually related rights and obligations for actors, distinguishing between appropriate and inappropriate, right and wrong, possible and impossible actions and thereby organizing behavior into predictable and reliable patterns." While North (1991, pp. 97–8) defines institutions as "humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, and property rights)" or simply "the rules of the game."

Several theories explain why people devise institutions. These theories are based on paradigms with different assumptions about human behavior.[3] One of these paradigms is further discussed and concerns the rational choice paradigm. This paradigm regards humans as amoral calculators, that is, rational self-interested individuals motivated to optimize their personal utility (see Shepsle & Bonchek, 1997, p. 17; Goorden, 2003, p. 112). Under circumstances the choices that people make as self-interested individuals, can result in a suboptimal outcome for all individuals as a collective. The inability for individuals to effectuate optimal collective outcomes is what economists refer to as market failure (Randall, 1983, p. 131). Market failures originate from non-exclusion, meaning that individuals cannot be excluded from costs or benefits arising from activities undertaken by others (see Baldwin, Cave & Lodge, 2012, p. 128). Two problems are identified. A *free-rider problem* on the one hand, and a *tragedy of the commons* on the other. The free-rider problem is related to non-exclusion from benefits of *public goods* (Ostrom, 2005, p. 24). Exemplary public goods concern the dikes in the Netherlands. All individuals living in a neighboring village benefit from the protection of the dike. Those people who do not contribute to the dike, cannot (easily) be excluded from the benefit of being protected by the dike. It is assumed that rational individuals decide not to contribute to the public good, as they anticipate that others will still produce it, while they will still benefit. Yet, when each individual follows this strategy the public good is not produced, leaving each individual without the benefit.

As for tragedies of the commons, they can occur in respect of non-exclusion from costs of *common-pool resources* (see Hardin, 1968; Fischer, 1981). The use of common-pool resources by one individual comes at the costs of use of the common-pool resources by another. Because rational individuals weigh their actions on factors that determine their personal utility – not the effects on others – they are inclined to overuse the common-pool resources. Now, when all individuals follow

[3] It falls outside the scope of this study to discuss these. Therefore, I refrained from discussing the rational choice paradigm, since I consider this perspective the most relevant for this study.

this strategy the collective overuse can deplete the common resource, leaving everyone worse off (Ostrom, 2005, p. 24). Examples include overfishing and overgrazing.

Both the free-rider problem and the tragedy of the commons, arise because people choose their course of action as individuals, instead of as a collective. However, these collective action problems can be overcome through institutions that place constraints on social behavior, usually devised by a government. The term *governance* refers to "the processes and institutions, both formal and informal, that guide and restrain the collective activities of a group. *Government* is the subset that acts with authority and creates formal obligations" (Keohane & Nye, 2000, p. 12). Governments can for example devise formal rules and regulation to oblige people to contribute to public goods. As regards common-pool resources, *property rights* can be used to allocate benefits of the common-pool resources to individuals. For example, governments can permit only a limited number of people through a permit system (Hahn & Hester, 1989). That way, the costs and benefits are assigned to specific individuals. Considering the conception of humans as rational self-interested individuals, owners of property rights have no incentive to deplete their allotted resource, since it would reduce their individual utility. Ideally, the property rights are transferable and transaction costs are low, so that the property rights can be (re)distributed to individuals for who the utility is highest (Coase, 1960).

For institutions to be meaningful, the rules they impose on individuals need to be enforced (Roland, 2004, p. 111). The concept of enforcement refers to an intervention encompassing sanctions, usually by a government, to compel individuals to act in accordance with the rules (cf. KCJW, 2018; Park & Allaby, 2016; Lodge & Wegrich, 2012; Kleinfeld, 2011; Hofmann, Rowe & Türk, 2011). Enforcement is carried out by inspectors, whose task is twofold: (1) they *detect* wrongdoers, and (2) they *sanction* accordingly, thereby restricting the freedom of individuals to deviate from the rules (De Boer, 2019, p. 381). Rational deterrence theory suggests that costs of the sanction need to be higher than the benefits of violating the rule (Ritchey & Nicholson-Crotty, 2011). Otherwise, the benefits would outweigh the costs. Hence, it would still be rational to violate the rule. The expected costs of a violation are assumed to follow from a combination of the probability of being detected, and the height of the sanction level (Mendes & McDonald, 2001; Tittle, 1969). Enforcement of rules and regulations is sometimes understood as a game between inspectors and inspectees. In this game the role of inspectors is to promote norm-compliant behavior among inspectees, while inspectees react by improving their behavior or by frustrating the undertakings of inspectors. In turn inspectors can react to the behavior of the inspectees, which brings about an interaction process between and among inspectors and inspectees (De Bruijn, Ten Heuvelhof & Koopmans, 2007).

2.4 Propositions for institutional change

In the previous paragraph the concept of institutions has been explained as rules and property rights that restrict the actions of individuals. It follows that change in the institution's operation involves change in the rules and property rights, that consequently brings about a change in restrictions on the actions of individuals. However, this is not to say that change in the restrictions exclusively results from changes in the (written) rules and property rights. Research with regard to transaction services explains how the integration of ICT in decision-making processes could result in rigid interpretations of the rules. More rigid interpretations could involve a form of institutional change, because it could de facto bring about a change in the restrictions on the actions of individuals. This line of thought could also apply with regard to the integration of IoT in the enforcement. After all, whereas adjudicating officials make decisions in respect of applications for grants and permits, inspectors make decisions in relation to the assessment of violations. However, there is also a difference, since adjudicating decisions are based on input *supplied by citizens* (by way of applications), whereas the input for decisions on sanctions is *collected through IoT*. Consequently, the input for decisions has to be adjusted to information that can be captured by IoT sensors. This involves not only that legal prescripts have to be translated to computer-interpretable algorithms, it also involves that *behavior* is operationalized in terms that can be detected by sensors. Hence, three propositions can be formulated:

Proposition 1: Organizational standardization. The use of ICT for organizational standardization through predefined forms and indicators constrains the interpretation of inspectors, and consequently the outcome of what are considered violations (see Bovens & Zouridis, 2002). This constitutes a change in what is considered right and wrong, possible and impossible and thereby results in institutional change at the operational level (see Streeck & Thelen, 2009, p. 9).

Proposition 2: Computer-interpretable prescripts. The process of translating legal prescripts into computer-interpretable scripts entails that software engineers have to make choices regarding the interpretation of terms. This applies in particular to context dependent terms like 'reasonableness' and 'fairness' (see Bovens & Zouridis, 2002; Busch & Hendriksen, 2018). Legislators may use such terms to account for facts and circumstances,[4] thereby allowing for *different* interpretations in *different* situations. A computer, however, does not have discretionary abilities, so system engineers need to specify exact values. Consequently, prescripts need to be interpreted in advance. For example, if a legal prescript states that someone should be granted a 'reasonable time', then the engineer needs to tell the computer exactly how long this time is and in terms that a computer can understand, like days, hours, ..., milliseconds.[5] The implication of having

[4] In the Netherlands, conjugations of the words 'reasonableness' and 'fairness' can be found 70 times in the 'Algemene wet bestuursrecht' [General Administrative Law Act].

[5] See e.g. Algemene wet bestuursrecht, article 3:18, 3:48.

to specify an exact value in advance, is that the *same* value is used for *different* situations. With the interpretation of a legal prescript no longer being tailored to a specific situation, the application of the rule could become more restrictive in some situations and less restrictive in others. [6] This encompasses institutional change, as it brings about a change in restrictions.

Proposition 3: Sensor detectable indicators. Detecting behavior through IoT sensors instead of through (human) inspectors, entails that behavior needs to be operationalized in a way that can be detected by the sensors.[7] This process could involve choices with regard to the selection of (derivative) indicators to model the actual behavior. Then, these choices could entail a form of institutional change, as the modelled behavior could differ from the behavior that the institution intends to address. A model that is based on a broader understanding of certain unwanted behavior, will register more violations, than a model with a narrow understanding of the unwanted behavior. For this reason, the indicators that are used to interpret the behavior through sensors, could determine which behavior is included in the restrictions of the institution. Hence, the use of IoT sensors can bring about a change in restrictions.

In sum, based on the literature that was set out in this chapter, three mechanisms have been identified that could explain how the integration of IoT leads to change in an institution's operation: (1) organizational standardization, (2) computer-interpretable prescripts, and (3) sensor detectable indicators. For all three mechanisms the effect of IoT on the institution's operation is mediated by changing interpretations of legal prescripts and/or the behavior that is the subject of the prescript. Subsequently, these changes in interpretations are presumed to bring about a change in the scope of the restrictions of an institution, and with that, a change in the institution's operation, as referred to in the research question. In the sixth chapter, the findings are analyzed in respect of the three propositions that were formulated in this chapter.

[6] Depending on the value of the interpretation in relation to the distribution of values of previous interpretations.
[7] The first chapter of this thesis mentioned an example application of a smart home. The example included having the lights automatically turned on when people are present, based on movement captured by a motion sensor. It also mentioned that the lights would be turned off, when during a period of 10 minutes no motion is detected. Now imagine someone sitting really still for 10 minutes, the motion sensor would not detect movement and turn off the lights. This is because it is in fact not 'presence' that is detected, but 'movement'. Presence is a complex concept, that could mean different things (e.g. physical presence, conscious presence or online presence). Although movement signifies presence, it remains a derivative indicator.

3 RESEARCH DESIGN

3.1 Introduction

This chapter describes how the research question is approached. Hereafter, the first paragraph outlines the overall research approach, which explains the logic of the study and why it was chosen in relation to the research question. The next paragraph elaborates on the choices regarding the demarcation of the research scope; followed by the operationalization of the variables. Both paragraphs narrow down the empirical scope and provide analytical starting points. The subsequent paragraph sets out the method of analysis, explaining and accounting for confounding variables, case selection and data collection. The chapter concludes with a reflection on the research design in respect of validity and reliability.

3.2 Overall research approach

The purpose of this study is to find out if the integration of IoT in the enforcement of an institution, leads to changes in that institution's operation. Independent variable *x* denotes *the integration of IoT in the enforcement of an institution*, while dependent variable *y* represents *the operation of the enforced institution*. To examine whether an effect exists between the dependent and independent variable, it is chosen to conduct an intertemporal case study, which is a type of small-N study (Blatter & Haverland, 2012). The study follows quasi-experimental logic with two cases. These cases are derived from a single unit of analysis at different times. The timeframes are chosen deliberately in a way that the value of the independent variable is different for both cases. This way the independent variable acts as the treatment. In the *before-case*, IoT (i.e. the treatment) is not integrated in the enforcement of the institution, while in the *after-case*, IoT has been integrated in the enforcement of the institution. Comparing the institution before and after the integration of IoT, allows to infer covariance between the integration of IoT and observed change in the institution's operation. Falsification is also possible, if the institution is found not to have changed, then there is reason to reject the idea of covariance among these variables. However, if there is a difference in the institution before and after the integration of IoT, and all else remained equal, it is plausible that covariance exists between the integration of IoT and the institutional change (Blatter & Haverland, 2012, p. 40).

To reduce the risk of erroneously assuming covariance between the independent and dependent variable, other variables that are likely to cause variance in the dependent variable need to be controlled for. Two of these so-called confounding variables are identified: the Gemeentewet [Municipality Law] and the municipal administration's political affiliation. These are further discussed later on in this chapter. With an intertemporal case study, controlling for confounding variables is achieved by selecting a before- and after-case that have similar values on confounding variables. After all, if the value of a confounding variable remains unchanged, it can be ruled out as an explanatory factor of change in the dependent variable. The advantage of an intertemporal case study, over other types of case studies, is that it provides a high level of certainty about potential confounding factors remaining equal. This is because both cases are derived from the same unit of analysis at different moments in time.[8] Hence, an intertemporal case study is an appropriate approach to the research question.

3.3 Research scope: the institution of paid parking

This paragraph elaborates on the choices regarding the demarcation of the research scope. For reasons of feasibility this study is limited to the Netherlands. Furthermore, it is chosen to focus on the *institution of paid parking*, which is enforced with the use of IoT in some Dutch Municipalities. Public parking spaces are the common-pool resource and a tragedy of the commons occurs when too many individuals attempt to use the parking spaces, making it difficult for everyone to obtain a parking space and thereby contributing to traffic congestion (Feng, 1986). The institution of paid parking is set out in the Gemeentewet, and involves that municipalities may impose a tax on the use of public parking spaces.[9] The right to use a parking space can be understood as a property right. Because the tax reduces the utility, some people prefer other means of transportation. The collective outcome is more efficient, because of optimized traffic flows and availability of parking spaces (Feng, 1986, pp. 151, 178).

In the Netherlands, the term *parking* is defined in the Gemeentewet [Municipality Law] as having a vehicle stand still for a consecutive period of time, other than for the time required and used for the immediate (un)boarding of goods or people.[10] When a vehicle is parked on a public space for which paid parking applies, a tax obligation arises, which may be met by any person who is willing to comply. Complying with the obligation requires appropriately activating a parking meter or a parking machine at the start of parking, and in accordance with instructions prescribed by the municipality.[11] The municipality also appoints inspectors, who are tasked with verifying whether obligations are complied with.[12] If an inspector assesses that a car is parked, but the tax

[8] Alternatively, a cross-sectional comparison (comparing several cases at the same moment of time) was also considered. However, this option was abandoned because it requires the examined cases to be similar with regard to confounding factors. Since the use of IoT is still largely maturing, it remains uncertain whether cases are in fact comparable. Therefore, it was chosen to conduct an intertemporal case study.
[9] Gemeentewet, art. 225.
[10] Gemeentewet, art. 225.
[11] Gemeentewet art. 234 (2a).
[12] Gemeentewet art. 231 (2b).

obligation is not complied with, an additional tax assessment may be issued to sanction the violation.[13]

To be able to analyze the institution of paid parking it is necessary to determine what it is exactly that constitutes the institution. Thereto, vertical and horizontal demarcation are appropriate. Hereafter the vertical demarcation is discussed first, which concerns the identification of different analytical levels of the institution, and selecting at which level of analysis to study the institution. Thereafter, the horizontal demarcation is set out. This involves choosing between a narrow or broad understanding of institutions.

With regard to the vertical demarcation, Ostrom (2005, pp. 58–60) argues that institutions are nested in other institutions, allowing for the identification of different analytical levels. Such levels may include: a meta-constitutional, constitutional, collective choice and an operational level. Each level shapes institutions on another level, culminating in operational rules. These operational rules directly affect the behavior of individuals, for example rules regarding how much, when, and with what technology the common-pool resources are used (Ostrom, 2005, pp. 58, 60). Applied to the institution of paid parking, the rules on the operational level would determine how paid parking spaces as common-pool resources are utilized and with what technology. This is also the level where the enforcement through IoT is likely to take place. Hence, it makes sense to select the operational level as the level of analysis.

Subsequently, it needs to be determined how this level of analysis relates to the empirical reality. That is, identifying the operational level of the institution of paid parking in the Netherlands. Several analytical levels can be identified: the framework of the institution is set out at the *Parliamentary level* and passed down in formal legislation (Gemeentewet).[14] This law allows municipalities to levy taxes for the purpose of structuring public parking. From there, it is up to policy arenas at the *municipal level* to decide on whether to invoke this power via a prescribed tax regulation.[15] Although the Gemeentewet provides a framework that municipalities must adhere to, the framework also leaves room for discretion. If the power is invoked, a municipality must devise *further rules*.[16] Seeing these levels, it seems that the 'further rules' that municipalities must devise involve the operational rules. Therefore, the regulation(s) that contains these further rules involve the empirical interpretation of the rules on the *operational level*. These regulation(s) will be included in the analysis.

As for the horizontal demarcation, it needs to be decided whether to follow a narrow or a broad understanding of institutions. A narrow understanding limits institutions to formal written rules, while a broad understanding distinguishes between written rules and their operational

[13] See Appendix B: Fig. 1.
[14] Gemeentewet, art. 225.
[15] Gemeentewet, art. 216.
[16] Gemeentewet art. 225.

enactment (Streeck & Thelen, 2009, p. 13). On the one hand, a narrow understanding makes the process of assessing institutional change more tangible, because it assumes that the written rules are how the institution works in reality. On the other hand, it ignores institutional change that occurs outside of the formal written rules (see e.g. Hacker, 2004). Considering that a narrow understanding does not account for institutional change resulting from changing interpretations of concepts. Since the propositions from chapter two, suggest that an effect of IoT on the institution's operation is mediated through changing interpretations, a broad understanding must be used. That is why besides the written rules it is also analyzed how those rules are acted upon, and how they are enforced. After all, how the rules are acted upon and how they are enforced represent how the rules are interpreted and actualized by inspectees and inspectors.

In summary, based on the vertical and horizontal demarcation, the analysis focuses on the operational level of the institution of paid parking in the Netherlands, following a broad understanding of institutions. The empirical focus includes (1) the rules as they are elaborated in municipal regulation(s); and (2) the rules as they are acted upon and enforced in practice.

3.4 Operationalization

This paragraph discusses how the value of the independent and dependent variable is measured. Independent variable *x* represents *the integration of IoT in the enforcement of an institution*. To determine the value of this variable, it needs to be measured whether IoT is integrated in the enforcement. In 2019, the OECD[17] emphasized the need for an instrument that enables to measure the *extent* to which IoT is established in specific policy domains. However, such an instrument is still lacking, as definitions are still developing along with technologies, protocols and application levels (OECD, 2019, pp. 108–111). Nevertheless, for the purpose of this study it suffices to determine *that* IoT is integrated in the enforcement, without determining the *extent* by which it is integrated. It is chosen to measure the existence of IoT on the basis of existing research in respect of IoT architecture on a (smart) city level.

Zanella et al. (2014) provide an architecture for IoT on a city level, which the authors refer to as "urban IoT", and which suits the context of this study. Based on their conceptualization of urban IoT, four constituents are identified: (1) IoT nodes, (2) a control center, (3) interfaces, and (4) a network (see Table 3.1).[18] IoT nodes consist of devices that generate data in the physical world. They represent the *things* in the Internet of Things. Examples include "surveillance cameras, monitoring, sensors, actuators, displays, and vehicles" (Zanella et al., 2014, p. 22). The data that is generated by the IoT nodes is stored and processed in a control center, which could be a backend

[17] Organisation for Economic Co-operation and Development.

[18] It is not to say that only centralized network architectures constitute IoT. However, Zanella et al. (2014) note that a network without a coordinating node – a decentralized architecture – is less suited in a smart city context.

server. Interfaces are used to interact with the system, which could involve websites that may be accessed by smartphones or computers. Finally, there needs to be a network encompassing one or more gateways, allowing for data exchange between connected nodes including the control center (Zanella et al., 2014). The network relies on a form of Internet Protocol (IP), which is the *internet,* in the Internet of Things.

Within this study, the existence of IoT is assessed by determining whether these four constituents of IoT are present in the enforcement of paid parking. Examples of each of the constituents are mentioned in Table 3.1 and act as potential observations. Since the examples are not exhaustive, other instances could also be valid. Such other instances can be observed in accordance with the function of the constituent. To attribute the constituent to the enforcement, it needs to enable or contribute to the detection of violations. The existence of IoT in the enforcement can be concluded [x = true] when all constituents of IoT are present. Descriptions of the enforcement in the before- and after-case enable the observation of the constituents.

Table 3.1: Urban IoT

Constituents	Function	Examples
IoT nodes	Generate data	**Devices:** surveillance cameras, monitoring, sensors, actuators, displays, vehicles
Control center	Electronic data storage and processing	**Backend servers**: database management systems, enterprise resource planning systems
Interfaces	Interacting with the system	**Websites**, generally accessible through smartphones, tablet PCs, or laptops
Network	Gateway to interconnect end devices to the control center	**Internet:** IPv4, IPv6, 6LoWPAN; in combination with UMTS (3G), LTE (4G), NFC, RFID, BLE as link layer technologies

Adapted from Zanella et al. (2014).

Dependent variable y denotes *the operation of the enforced institution*. The goal is to assess whether the operation of the enforced institution from the after-case is different from the before-case. Thereto, the measurement is based on ADICO syntax, which is part of the Institutional Analysis and Development (IAD) framework (see Ostrom, 2005). This framework is designed to analyze institutional change, especially on an operational level.

The acronym 'ADICO' comprises five components: (1) ATTRIBUTES, (2) DEONTIC, (3) A*I*M, (4) CONDITIONS, and (5) OR ELSE. The components have the following meanings: ATTRIBUTES are capacities or properties of individuals in a group that determine whether the institutional statement applies to them. In other words, they designate a subset of participants in a larger group of participants. The DEONTIC expresses the modality of the statement. It determines whether an institutional statement *permits*, *obliges*, or *forbids* something, which can often be observed in words such as may, must, and must not. The A*I*M consists of *actions* or *outcomes* to which the deontic is assigned. It concerns things that may, must or must not be carried out (actions) or realized (results). CONDITIONS specify *circumstances* under which it is permitted, obligatory or forbidden to carry out the actions. Finally, the term 'OR ELSE' refers to consequences that the institution assigns to violations of the rule (Ostrom, 2005, pp. 139–152). Table 3.2 contains an overview with examples. The ADICO components are building blocks for institutional statements, which express rules of the institution. Here the word 'rule' includes both restrictions and rights, because the existence of a 'right' for one person, involves a restriction for another (Ostrom, 2005, p. 145).

Institutional statements based on ADICO syntax support a structured identification of rules. That way, the same rule can be compared systematically, at different moments in time, which makes it an appropriate instrument for an intertemporal case study. Adding to that, the observation of ADICO components is not limited to written rules. It can also draw on other sources of the institution's rules, such as how the rules are acted upon and enforced in practice. For example, it allows to include the interpretation of a condition by an inspector. That way, the influence of the enforcement is accounted for in the institutional statements, which therefore provides an adequate understanding of the rules for the purpose of this study.

Since institutions consist of multiple rules, it follows that multiple institutional statements may need to be formulated. As a result, the value of dependent variable *y* does not comprise a single statement but an array of institutional statements. In chapter four and five the before- and after-case are set out respectively. At the end of each case the found rules are captured in institutional statements. The institutional statements are based on both written rules (municipal regulation(s)) and how these rules work in practice (how they are acted upon and enforced). This approach allows for a systematic analysis of the rules in chapter six. The next paragraph sets out the method of analysis and includes a description of the empirical materials that constitute the input for the measurement of both variables.

Table 3.2: ADICO syntax

Components	Function	Examples
ATTRIBUTES	Designate a subset of participants	U.S. citizens over 18 years of age, senators, microwave-users
DEONTIC	Express modality	May, must, must not, should, should not
A*I*M	Assign actions that need to be taken, or results that need to be obtained	Voting, damage property, clean the microwave
CONDITIONS	Define application	Spatial jurisdiction, time, events
OR ELSE	Consequence of violation	Sanctions: imposing a fine, incarcerating a citizen, taking someone's livestock

Adapted from Ostrom (2005, pp. 139-152).

3.5 Method of analysis

Through a co-variational analysis, it is examined whether it is plausible that covariance exists between independent variable *x* and dependent variable *y*. As one might expect, covariance requires concurrent variance in both variables. Thus, the values of the independent variable from the before- and after-case must be different $[x_0 \neq x_1]$. The same applies to the dependent variable $[y_0 \neq y_1]$.

As explained in the previous paragraph, *x* is measured as a dichotomous variable. In the before-case IoT is *not* integrated in the enforcement of paid parking $[x_0$ = false], while in the after-case IoT *is* integrated in the enforcement $[x_1$ = true]; $[x_0 \neq x_1]$. With regard to *y*, it holds an array of elements for which $[i]$ denotes the index number. Each element contains an institutional statement, which in turn has five values for each of the ADICO parameters. Two types of change in *y* can occur. First, the configuration of elements can change. For example, if a rule would be abolished in the after-case, the element in the array that held that rule would no longer exist in the array $[y_0 \neq y_1]$. Second, a change within an element can occur. The element would exist in both cases, but have different values for its ADICO parameters $[y_{0[i]} \neq y_{1[i]}]$; $[y_0 \neq y_1]$.

Under the condition of *ceteris paribus*, variance in the value of the independent variable could be associated with variance in the value of the dependent variable $[x_0 - x_1 \rightarrow y_0 - y_1]$ (see Blatter & Haverland, 2012, p. 33; Toshkov, 2016, p. 263). As for the condition of ceteris paribus, it is theoretical and in the empirical world we can only aim to approximate it. As stated at the beginning of this chapter, this is achieved by selecting a case for which the values of confounding variables have not changed between the before- and after-case. The Gemeentewet and the political affiliation of the municipal administration are identified as confounding variables and further discussed in the next section that addresses the case selection. Finally, Table 3.3 presents the truth table with an overview of the relevant variables of this study.

Table 3.3: Truth table

Variable	Variable description	Case 1	Case 2
Control variable	Gemeentewet [a]	a	a
Control variable	Municipal administration	b	b
Independent variable *x*	IoT in enforcement	FALSE	TRUE
Dependent variable *y*	Operation of institution	c	≠c

Adapted from Blatter and Haverland (2012); [a] Containing the legal framework for paid parking.

Case selection

An informed discussion on this subject calls for a case that has advanced in the implementation of IoT in policy enforcement. Since the operational rules and enforcement are devised by municipalities, a municipality must be selected as a case. At the end of 2019, 13 Dutch municipalities were found to have integrated IoT in the enforcement of paid parking. It is chosen to focus on the Municipality of Amsterdam.[19] Since 2010, this municipality has been experimenting with digital arrangements for the enforcement of this policy, making it one of the first municipalities to experiment and adopt IoT in its parking enforcement. Therefore, the implementation of IoT has had a relatively long time to mature, which makes it an adequate case to measure an effect. Adding to that, Amsterdam plays a role as one of the world's leading smart cities (Manville et al., 2014).[20] As noted earlier, the use of IoT for enforcement purposes fits well within the discourse of smart cities. Selecting a case that relates to this concept might also contribute to a better understanding of the connection between these concepts.

The intertemporal case study design requires the case to be split up into a before-case and an after-case, with different values for independent variable *x*. Thus, timeframes need to be set for both cases. Shorter time frames usually provide a higher level of validity, as with a shorter time frame, it is more likely that many variables are kept constant, which contributes to the approximation of ceteris paribus (see Blatter & Haverland, 2012, p. 38). However, too narrow time frames are a risk to validity, since independent variable *x* could already be in the process of changing. As for the case of Amsterdam, the integration of IoT in the enforcement can be divided into several stages. The experimental phase spanned the period between 2010 and 2012, and it is characterized by small scale pilots. The following period, 2013–2015, can be described as a hybrid phase. The use of IoT for enforcement purposes was officially implemented, but it was only used to pinpoint potential violations. Inspectors would still go to each car to assess the situation and sanction accordingly. Finally, 2016 marked the beginning of the maturation phase, as routine on-site assessments were discontinued. From these phases the maturation phase (2016–2019) is chosen as the after-case, since it is the most representative of enforcement through IoT. The period between 2006 and 2009 is chosen as the before-case, because it is just before the start of the experimental phase in 2010.

[19] Amsterdam is a densely populated city and the capital of the Netherlands. Per km^2, Amsterdam has on average 1.415 cars, 6.020 addresses, and 5.160 inhabitants, which are respectively 568%, 304% and 1.012% of the Dutch national average (AlleCijfers, 2019). The city has a history of traffic nuisance (see e.g. Polygoonjournaal, 1970). In March 1964, the first paid parking machines were installed to reduce parking pressure in the city center (Oehlen, 2014). In 2019, paid parking applies to around 150.000 parking spaces (EPS, 2019).

[20] Amsterdam is found in the top 15 of international smart city rankings (cf. Bris et al., 2019, p. 18; Eden Strategy Institute, 2018, p. 46).

When it comes to the approximation of ceteris paribus the cases need to be similar on confounding variables. Confounding variables contribute to an observed change in the dependent variable (y), that would in turn be erroneously attributed to the independent variable (x). Therefore, alternative variables that might produce institutional change on the operational level (y), should be controlled for. Since institutions are shaped by other institutions on more fundamental levels (Ostrom, 2005), changes resulting from more fundamental levels need to be controlled for. A first confounding variable concerns the legal framework set out in the *Gemeentewet*, because it is likely that changes in the Gemeentewet affect the institution on the operational level. This change would then be mistakenly attributed to the introduction of IoT. However, the version history shows no substantial change.[21] Hence, an effect on institutional change from this more fundamental level is ruled out. As for the municipal level, a possible confounding variable concerns the *municipal administration*. After all, the institution might change as a result of shifting preferences. To control for this, it was checked whether notable shifts in the municipal coalition parties occurred. Looking at the coalition parties creates an impression of continuity rather than disruption. Two parties, PvdA and GroenLinks, have been coalition parties for at least some time of each of the identified phases. Therefore, there is no reason to assume that a disruption in political preferences induced institutional change from the municipal level.[22]

Finally, for the operational level itself, some comments are appropriate relating to changes in the organizational apparatus of the enforcement. When Amsterdam started experimenting in 2010, it aimed to outsource the enforcement to market parties at some future point to improve efficiency. Thereto, the enforcement activities were disentangled from *Dienst Stadstoezicht* [the city enforcement agency] and transferred to a newly established private entity called Cition. Cition remained owned by the municipality and was subsidized to further develop enforcement technology (Rekenkamer Amsterdam, 2014). In 2016, Cition was disbanded and the enforcement of paid parking was outsourced to Egis, a French engineering company, that mandatorily took over most of the employees of Cition (Parool, 2015). It is arguable whether these organizational changes contribute to a confounding effect. The organization that takes over the enforcement could establish new procedures, involving changed interpretations of rules. Seeing that the propositions from chapter two presume that an effect is mediated through changing interpretations of rules, the establishment of new interpretations could be confounding. At the same time, these changing interpretations would not be confounding, but part of the effect. This is because the organizational reforms were aimed at promoting a more efficient enforcement through technological advancements. The fact that the municipality subsidized technologic innovation by Cition, and the fact that Egis is an engineering company, substantiate this line of thought.

[21] *Stb*. 2014, 581 33976 (10-12-2014); In 2015 two textual adjustments were made.

[22] See Appendix A: Table 1.

For this reason, it was chosen not to consider the changes in the organizational apparatus as a confounding factor. Consequently, only the Gemeentewet and the municipal administration are identified and controlled for as confounding variables.

Data collection strategy

Building on the previous paragraphs, data needs to be collected about: (1) the rules as they are elaborated in municipal regulation(s); and (2) the rules as they are acted upon and enforced in practice. First, *Municipal regulation(s)* is retrieved from a governmental online database that stores decentral regulation.[23] When variations of regulation exist, the oldest regulation is used in the before-case (closest to 2007), because it limits the risk of using regulation that anticipates the experimental phase of 2010. It is therefore more likely to provide a valid description of the situation before implementing IoT. On the other hand, the most recent instance of a regulation is selected in the after case, since this is the most matured representation of the operational rules enforced through IoT.

Second, to gain an understanding of how the rules are acted upon and enforced, it is chosen to collect data by way of *court cases,* c*omplaint reports*, and information from stakeholder *websites*, Court cases are retrieved from a jurisprudence database.[24] This database allows to include parameters in its queries, which is set to filter for: administrative law, the Court of Amsterdam, and the Court of Appeal of Amsterdam. Time frames of the queries are set to match the time frames of both cases. As a search key 'additional tax assessment parking tax' is used.[25] To prevent misunderstanding, it is not the legal judgments that are of interest. Instead, court cases sum up facts and events that have taken place between a plaintiff and a defendant. Therefore, these cases provide descriptions of how the rules are effectuated in practice. The same logic applies to *complaint reports* from the Ombudsman Metropool Amsterdam. The Ombudsman is an independent agency that protects civil rights and mediates between citizens and their public administration. It has an online database, holding reports with detailed descriptions of complaints and the situations that gave rise to them. Anonymized mediation sessions in which involved citizens and government officials explain 'their side of the story' are also included in these reports.[26] This database also allows to include parameters in their queries, which are again set to the time frames corresponding to both cases. An additional search tool further enables to select keywords through semantic clustering. Keywords include: enforcement, parking, additional tax assessment, and fine. Finally, *websites* of involved stakeholders are examined (as they were in 2019), in particular the website of the

[23] Decentrale.regelgeving.overheid.nl.
[24] Rechtspraak.nl.
[25] The Dutch terms respectively translate to 'Bestuursrecht', 'Rechtbank Amsterdam', 'Gerechtshof Amsterdam', and 'naheffingsaanslag parkeerbelasting'. Dutch terms were used in search queries.
[26] Ombudsmanmetropool.nl.

Municipality of Amsterdam, and that of the enforcement agency. Similar to court cases and complaint reports, these websites are anticipated to provide additional information and instructions about obligations, prescribed courses of action, and enforcement activities. In combination with the municipal regulation, these data sources provide data that can be used for the analysis of rules by means of ADICO syntax (y), as well as for the analysis of the integration of IoT in the enforcement (x).

3.6 Validity and reliability

Validity and reliability are quality standards of research. First, I consider how the study reflects on several types of validity that are considered relevant to small-N case study research (Blatter & Haverland, 2012). Thereafter, I discuss how the study reflects on reliability.

First, *internal validity* is understood as the appropriateness of measurement to adequately capture the inferred causality (Bryman, 2012, p. 47). In other words, it concerns the question whether the suggested causal relation in fact comprises causality, instead of a spurious relationship. Controlling for confounding variables increases the internal validity. Two potential confounding variables were identified and controlled for as set out in the previous paragraph. Second, *measurement* or *construct validity* comprises the extent to which a concept is adequately measured (Bryman, 2012, p. 47). Small-N studies score well on this type of validity, considering that the focus on a small number of cases "allows for context-sensitive measurement" (Blatter & Haverland, 2012, p. 67). Be that as it may, a limitation in this regard concerns the novelty of IoT in city contexts. As the concept of IoT develops, the interpretation of this concept is likely to change while it matures over time.

Third, *external validity* refers to the degree of generalizability (Bryman, 2012, p. 47). Compared with large-N research, the generalizability of small-N research should be interpreted more reservedly. Whereas findings from large-N studies can usually be generalized to the large population from which random samples were selected, findings from small-N studies can only be generalized to other cases with similar values on all control variables and the independent variable (Blatter & Haverland, 2012, p. 69). Therefore, the scope of generalization of this study concerns other cases of IoT incorporated in the enforcement. In principle this includes other large municipalities that incorporated IoT in the enforcement of their parking policy. At the end of 2019, the scope of generalization includes: 13 Dutch municipalities that were found to have implemented

IoT enforcement of paid parking.[27] Generalization to other policy domains cannot yet be concluded, provided that an effect might be related to characteristics of the studied policy domain.

Finally, *reliability* concerns the extent to which the same results are obtained when the study is replicated. This is low with small-N research, because a certain degree of subjectivity is inevitable when it comes to interpreting and classifying the context of a case (Blatter & Haverland, 2012, p. 67). To reduce this subjectivity and thereby increase replicability, the established IAD[28] framework is used for the dependent variable, and technical indicators are used for the independent variable. Furthermore, most of the data sources are publicly accessible for researchers that want to replicate or verify this study.

[27] Amsterdam, Rotterdam, Utrecht, The Hague, Leiden, Tilburg, Groningen, Delft, Zwolle, Haarlem, Bergen op Zoom, Rijswijk and Schiedam (Nieuwenhuis, 2019; Rijswijk, 2019; Yellowbrick, 2019; Den Ridder, 2019; Schie, 2019). Dordrecht and Arnhem started pilots with scanning-cars (Verheij, 2017; RTV Dordrecht, 2017; Bruinsma, 2018). Apeldoorn, Maastricht, Den Bosch and Breda intend to implement scanning-cars (Nieuwenhuis, 2019; Brink, 2019).

[28] Institutional Analysis and Development (IAD).

4 CASE I: PAID PARKING 2006–2009

4.1 Introduction

This chapter sets out how the institution of paid parking was shaped and enforced in the Municipality of Amsterdam from 2006–2009. The next paragraph of the chapter outlines the operational rules of the institution as they were set out by the municipality. These rules involve the operational elaboration of the decision-model laid down in the Gemeentewet. The subsequent paragraph explains how the obligations and prescribed courses of actions were enforced.

4.2 Operational rules at the municipal level

Between 2006 and 2009, the Municipality of Amsterdam had two regulations in respect of paid parking. The first regulation concerned the *tax regulation,* which was a formality prescribed by the Gemeentewet. It invoked the power to levy parking taxes.[29] The second regulation was called *Parkeerverordening 2007.* This regulation set out the operational rules and concepts that prescribed how the rules worked on a street-level. It included descriptions of arrangements that were relevant for triggering a tax obligation and what courses of action were available to comply with the obligation. This second regulation is further discussed.

The Parkeerverordening 2007 limited the application of the rules to parking spaces accommodated with parking equipment, referred to as *parking equipment spaces*.[30] Parking equipment was defined as a device with which the parking tax could be paid at the start of parking.[31] When someone 'parked' on a parking equipment space an obligation to make a tax declaration arose, and that person needed to take action. Thereto, the Municipality of Amsterdam prescribed several possible courses of action, involving so-called parking cards. Through these cards the parking tax was levied, which allowed a motor vehicle to be parked on a parking equipment space.[32] The regulation distinguished between three types of parking cards: *time cards*,[33] *scratch cards* and *tourist cards*.[34] All were physical (paper) cards, and all involved a means of fulfillment of the obligation. Time cards and scratch cards are further discussed hereafter.[35]

The first type of parking card concerned time cards. The operational rules stated that time cards were obtained through parking equipment; the devices that were associated with parking equipment spaces. A time card was valid until the date and time of expiration which was stated on

[29] Verordening Parkeerbelastingen 2007. See *Gemeenteblad* 2007, afd. 3A, nr. 23/53.
[30] Ibid., art. 2. See *Gemeenteblad* 2007, afd. 3A, nr. 23/53.
[31] Parkeerverordening 2007, art. 1, x. See *Gemeenteblad* 2006, afd. 3A, nr. 243/655.
[32] Ibid., art. 1. See *Gemeenteblad* 2006, afd. 3A, nr. 243/655.
[33] Time cards are referred to in the regulation as 'minute, part of the day, day, evening, week or month cards'.
[34] See Appendix A: Table 2 for an overview of parking cards.
[35] It was chosen not to discuss tourist cards because of their limited scope.

the card, and it could be used in zones with a corresponding or lower parking tariff.[36] In practice, time cards were obtained through parking machines.[37] These machines displayed an ending time that was increased by throwing coins into the machine's coin slot. When the user reached the desired ending time, the transaction could be confirmed by pressing a green button on the machine. Pressing the button triggered the machine to print the end time on the time card and thereafter eject it. Directions on the cards and machines instructed to place the card clearly legible behind the windshield.[38]

The second type of parking card concerned so-called scratch cards. The rules specified that scratch cards could only be obtained by residents of the municipality, who held a scratch card permit. The permit itself was not a means of paying parking tax, it only entitled the holder to purchase scratch cards. The scratch cards were the actual means of paying parking tax. The cards cost less than regular parking tickets, so that residents with a scratch card permit could receive their guests at lower expense. Scratch cards came with several restrictions. Every three months the holder of the permit was allowed to purchase a maximum of three booklets, each containing twelve scratch cards.[39] One card was valid for two hours.[40] So the total number of parking hours someone could purchase was limited to 72 hours, every three months. In practice the cards were validated by scratching off a date and time.[41] Instructions on the back of the cards stated that they were to be placed clearly on the dashboard. For people who wanted to park for more than two consecutive hours, two cards were allowed to be placed on the dashboard with the same starting time.[42] It was not allowed to use more than two cards consecutively.

Having outlined the operational rules, as they were laid down in regulation, and as they worked in practice, the next paragraph describes how the enforcement was carried out.

4.3 Enforcement of the institution

The enforcement of paid parking was carried out by parking inspectors from Dienst Stadstoezicht. The inspectors usually worked in pairs.[43] Their task was twofold. Inspectors would start by assessing whether a stationary car was in fact *parked*. If the situation concerned parking, a tax obligation existed in respect of that car, and inspectors would subsequently assess whether the obligation was complied with.[44]

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[36] Parkeerverordening 2007, art. 25. See *Gemeenteblad* 2006, afd. 3A, nr. 243/655.
[37] See Appendix B: Fig. 2 for a picture of a parking machine from Amsterdam.
[38] ECLI:NL:RBAMS:2007:BB6673.
[39] Parkeerverordening 2007, art. 20. See *Gemeenteblad* 2006, afd. 3A, nr. 243/655.
[40] Ibid., art. 25. See *Gemeenteblad* 2006, afd. 3A, nr. 243/655.
[41] See Appendix B: Fig. 3 for a picture of a scratch card from Amsterdam.
[42] ECLI:NL:GHAMS:2005:AV2096, see consideration 7.
[43] Ombudsman. (2009). *Tegenstrijdige verklaringen.*
[44] Ombudsman. (2008a). *Ongecontroleerd parkeren.*

Assessing whether a situation concerned *parking* started with examining whether a parking equipment space was involved. These spaces were accommodated with parking equipment, such as parking meters and ticket machines. In practice, parking equipment spaces were divided into parking zones, that were indicated through street signs and ticket machines.[45] To support correct identification of parking zones, inspectors received daily memos with specific information about the neighborhood that they would inspect.[46] They also used maps outlining the borders of the various parking zones. Such maps could also be obtained by citizens, at municipal service points.[47] When an inspector was unsure about the extent of a parking zone, (s)he was instructed to ask for confirmation.[48] After confirming the involvement of a parking equipment space, inspectors proceeded with determining whether the situation concerned parking. Therefore, they had to assess that the situation did not concern the exception for (un)boarding passengers or goods. In practice, the (un)boarding of goods could be difficult to assess, since this often involved the driver leaving the vehicle for several minutes. Inspectors looked at contextual signs like whether the vehicle was located close to a place of interest for which goods might be delivered or picked up, like a restaurant or a store. Not all items were considered goods. Items had to have sufficient magnitude. When a driver returned to the car with something in her/his hands, the inspector would consider the size and weight of the item(s) to determine whether someone is boarding goods.[49]

An inspector who assessed a situation as parking proceeded to the next step. This involved assessing whether tax obligations were complied with. Thereto, inspectors looked for parking cards, which citizens were instructed to place on their dashboard.[50] That way, inspectors were able to see the card through the windshield. A parking card was valid if it had not yet expired and the correct tariff was applied.[51] The check was performed visually, by looking at the information on the card. If an insufficient tariff was applied, or if the observed ending time had expired prior to the time of inspection, the inspector could draw up an additional tax assessment.[52] Before and during the time in which the inspector drew up an additional tax assessment, (s)he looked around to see whether the possible driver of the vehicle was in the process of making a payment at one of the ticket machines. If during that process the inspector did not observe the driver to be making a payment, an additional tax assessment would be imposed.[53] To inform the holder of the vehicle about the additional tax assessment, a notice was placed on the vehicle.[54] In some cases the driver would arrive moments later, with or without a valid parking card. The inspector who drew up the additional tax assessment

[45] ECLI:NL:RBAMS:2008:BN3266.
[46] Ombudsman. (2007a). *Onduidelijke grens van parkeergebied.*
[47] Ombudsman. (2007b). *Bezwaar tegen naheffingsaanslag.*
[48] Ombudsman. (2008b). *Foute parkeerbon, toch betalen.*
[49] ECLI:NL:GHAMS:2007:BB4220; ECLI:NL:RBAMS:2007:BB0002.
[50] ECLI:NL:RBAMS:2006:AX6769.
[51] ECLI:NL:RBAMS:2007:BJ8583; A tariff can be insufficient if it was obtained in a parking zone with a lower tariff.
[52] Ibid.
[53] Ombudsman. (2009). *Tegenstrijdige verklaringen.*
[54] Ombudsman. (2008a). *Ongecontroleerd parkeren.*

could not withdraw it. However, if the driver approached the inspector about the situation, the inspector was instructed to notify a supervisor, who could then decide to withdraw the additional tax assessment.[55]

In sum, this chapter presented the institution of paid parking as it was implemented in Amsterdam from 2006–2009. Based on the discussed regulation, practical instructions and enforcement, three institutional statements can be identified. These statements are presented in Table 4.1.

Table 4.1: Institutional statements

$y_{0\,[i=0]}$	-	People had an obligation [DEONTIC] to pay a parking tax by means of a parking card AND place the card on the car's dashboard [A/M], when they would park on a parking equipment space [CONDITIONS]. Not following the rule results in an additional tax assessment [OR ELSE].
$y_{0\,[i=1]}$	-	Holders of a scratch card permit [ATTRIBUTE] may [DEONTIC] purchase 72 hours of scratch cards every three months [A/M].
$y_{0\,[i=2]}$	-	Holders of a scratch card permit [ATTRIBUTE] must not [DEONTIC] use more than two scratch cards consecutively [A/M]. Not following the rule results in an additional tax assessment [OR ELSE].

[55] Ombudsman. (2009). *Tegenstrijdige verklaringen.*

5 CASE II: PAID PARKING 2016–2019

5.1 Introduction

This chapter sets out the institution of paid parking, as it was implemented and enforced in the Municipality of Amsterdam from 2016–2019. The next paragraph again starts by outlining the operational rules, while the paragraph thereafter describes the enforcement. This chapter concludes with the main points of the chapter.

5.2 Operational rules at the municipal level

In the period 2016–2019, the operational rules were elaborated in a regulation called *Parkeerverordening 2013* (last updated in 2018),[56] and various additional council decisions.[57] The regulation indicated that paid parking applied to parking equipment spaces. However, the term 'parking equipment' was broadened, and included "parking meters, mobile telephones, parking machines, including collective parking meters, websites, central computers, and all that was commonly understood by parking equipment."[58] Parking on a parking equipment space triggered an obligation to make a payment on a tax declaration. Thereto, the license plate number of the vehicle needed to be registered into a digital parking tax file,[59] which kept track of the license plate numbers and periods for which parking tax was paid.[60] Thereto, the Municipality of Amsterdam used a database called the *National Parking Register* (NPR), where registered license plate numbers were stored for three months.[61] Registrations were referred to as parking rights.[62] These were the digital successors of the parking *cards*.[63] Two of these parking rights corresponded with the parking cards from chapter four, namely *time rights* and *scratch rights*.[64] Hereafter, these rights are further discussed.

Time rights corresponded with time cards from chapter four. The regulation specified that time rights were valid from the moment they were registered, up until the end time, and in

[56] Parkeerverordening 2013. *Gemeenteblad* 2017, 234607.
[57] Bevoegdhedenbesluit ambtelijke organisatie Amsterdam, 05-09-2017. 18-07-2017, *Gemeenteblad* 2017, nr. 153029; Uitvoerings- en Aanwijzingsbesluit op grond van de Verordening Parkeerbelastingen 2016 en Parkeerverordening 2013. *Gemeenteblad* 27 juni 2016, afd. 3B, nr. 128.
[58] Parkeerverordening 2013, art. 1. *Gemeenteblad* 2017, 234607.
[59] Ibid.
[60] General comments on Parkeerverordening 2013, *Gemeenteblad* 2017, 234607.
[61] Amsterdam. (2019b).
[62] Parkeerverordening 2013, art. 1. *Gemeenteblad* 2017, 234607; 'Parking rights' are used as an umbrella term, including both durable parking rights by way of parking permits, and 'time-bound parking rights'. To prevent semantic confusion, it was chosen not to specify these as subcategories.
[63] Documentation supplementary to Parkeerverordening 2013. *Gemeenteblad* 2017, 234607; Here the term 'parking rights' is used to refer only to time-bound parking rights.
[64] Time rights are referred to in the regulation as 'minute, part of the day, day, evening, night, week and month parking rights'; Scratch rights are referred to in the regulation as 'parking rights based on scratch card permits'; see Appendix A: Table 3 for an overview of parking rights.

parking zones with a similar or lower tariff.[65] In practice, citizens were offered two ways of obtaining a time right. The first option involves street equipment. Conventional ticket machines were adapted or replaced by new machines.[66] The new machines enabled people to register license plate numbers for a period (minute, day, week, and so forth). The user was subsequently asked to make a corresponding payment with an electronic payment method. Optionally a receipt was printed which was merely meant for accounting purposes. There was no need for placing any physical proof of the transaction on the dashboard.[67] An alternative way of registration concerned *Parkeer en Bel*. This included a registration option by means of a third-party service provider.[68] In order to make use of this option an account had to be set up at a third-party service provider with which the Municipality of Amsterdam had concluded an agreement.[69] Depending on the service provider, several forms of communication could be used (phone call, SMS, smartphone app with internet access). The service provider was contacted for the purpose of notifying that a registration had to be entered into the central computer. Because Parkeer en Bel could be activated from the user's mobile device (e.g. a smartphone) the user had to select the correct tariff, corresponding to the parking zone.[70] Furthermore, because mobile devices reduced the dependence on ticket machines, the Municipality of Amsterdam reduced the total number of ticket machines by 30%.[71] This resulted in an increase in the average distance to the nearest ticket machine.[72] However, when a parking right was obtained through a parking machine a remission time of 10 minutes applied, meaning that no additional tax assessment was imposed within 10 minutes after expiration of the time right. The remission time did not apply to registrations made through Parkeer en Bel.[73]

Scratch rights corresponded with scratch cards from chapter four. The operational rules implied that the same requirements existed for scratch rights, as did for scratch cards.[74] Yet, physical scratch cards were no longer distributed. Instead, the permit entitled the holder to park at a reduced tariff, for a maximum of 72 hours per quarter. Unused hours could be carried forward to the next quarter.[75] In practice, residents registered an account and made payments to increase their balance. Through an online web interface license plate numbers could be registered.[76] By doing so, a parking right was activated for the vehicle, which was then allowed to park on a parking equipment space.

[65] Parkeerverordening 2013, art. 29. *Gemeenteblad* 2017, 234607.
[66] See Appendix B: Fig. 4 for a picture of a new parking machine.
[67] Amsterdam. (2019a). *Betalen bij de parkeerautomaat*.
[68] Amsterdam. (2019b). *Parkeer en Bel.*
[69] Ibid. In 2019 these included: ANWB Parkeren, MyOrder, Park-line, Parkmobile, Parksen, SMSParking, Stadsparkeren, Yellowbrick, MKB Brandstof, MultiTankCard, Easypark.
[70] Ombudsman. (2017a). *Per ongeluk betaald voor duurder tariefgebied*.
[71] From 3.600 to 2.400, between 2010 and 2019 (Parool, 2009; ANS, 2019).
[72] A study found that between 2013 and 2016, the distance percentage of ticket machines within a radius of 100 meter decreased from 80,1% to 68,8% (ANS, 2019).
[73] Uitvoerings- en Aanwijzingsbesluit op grond van de Verordening Parkeerbelastingen 2016 en Parkeerverordening 2013, art. III. *Gemeenteblad* 27 juni 2016, afd. 3B, nr. 128.
[74] Parkeerverordening 2013, art. 23. *Gemeenteblad* 2017, 234607.
[75] Ibid.
[76] See Appendix B: Fig. 5 for a screenshot of the web interface.

As long as the balance had enough prepaid hours, a license plate number could remain registered. Registrations were automatically ended when at a certain hour of the day there was no obligation to pay parking tax.[77] Finally, the system allowed a maximum of five vehicles to be registered concurrently, and vehicles could be registered in the system 24 hours in advance.[78]

5.3 Enforcement

This paragraph describes how the rules were enforced. It is first set out how it was assessed whether the situation of a car concerned *parking*. Thereafter, it is outlined how it was assessed whether the corresponding tax obligation was complied with.

Assessing whether the situation of a car concerned parking was carried out by the engineering company Egis, whose employees were mandated inspectors.[79] The inspectors performed three activities: collecting data from cars in the physical world, image-reviewing at a back office, and incidentally performing on-site follow-ups. Data from cars was collected automatically through scanning-systems, that were mounted on vehicles so that they could collect data while being driven around. The systems were generally mounted onto cars, which were therefore referred to as *scanning-cars*. The enforcement organization had a total of 11 scanning-cars in use.[80] To collect data from the physical world, scanning-cars were equipped with a positioning system,[81] different types of cameras, a processing unit, and a 3G or 4G wireless network connection.[82] The on-board equipment enabled various processes. The positioning system was used to recognize parking equipment spaces, which were numbered and coded into a digital map. For each of the parking spaces the map held attributes such as the coordinates and the status of applicable regulation. That way, the system was not dependent on the interpretation of street signs and parking equipment for the indication of paid parking zones.[83] Through black-and-white cameras, photos were taken from license plate numbers of cars on parking equipment spaces. These were called *scans*. The scanning-system automatically extracted license plate numbers from these photos using ANPR (automatic number plate recognition); an optical character recognition algorithm designed to extract license plate numbers from photos.[84] Four additional *situational photos* were taken in full-color and sent to the back-office using a wireless internet connection. There, an inspector received the four photos on a so-called *Image-Review system*. The situational photos were used to determine whether scanned cars were in

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77 Amsterdam. (2019d)). *Parkeertarieven*.
78 Amsterdam. (2019c). *Handleiding kraskaart- en bezoekersvergunning.*
79 Bevoegdhedenbesluit ambtelijke organisatie Amsterdam, Bijlage 2: Bevoegdheden die rechtstreeks worden ondergemandateerd door de gemeentesecretaris. *Gemeenteblad* 2017, nr. 153029.
80 Amsterdam uses scanning-cars of the type *'ScanGenius'*, produced by ARVOO (Parkeer24, 2017). Earlier, Amsterdam used scanning-systems of the type *'SCANaCAR'*, produced by another company named ACI.
81 GPS or GNSS.
82 cf. Scangenius, 2019; Scanacar, 2019; see Appendix B: Fig. 6 and Fig. 7 for photos of a scanning-car and a scanning-system.
83 Ombudsman. (2019a). *Boetes voor parkeren op eigen terrein*; see Appendix B: Fig. 8 for a screenshot of the digital map.
84 Scangenius, (2019). Note that ANPR is not a new technology. It was developed in 1976. See anpr-international.com/history-of-anpr

fact parked, or whether the situation instead concerned the exception for the (un)boarding of goods or passengers.[85] From a computer screen, inspectors looked for signs including: people inside the car, open doors, people near the car, logos of postal services or police, and whether the hazard lights were on. Inspectors were instructed to impose a fine when a car was empty, the lights were off, and there was no further reason for doubt. Drivers that left their car for the (un)boarding of goods needed to leave visible indicators to prevent a fine. Without the presence of indicators, appeals were not accepted.[86] Situations were assessed by one inspector, but a supervisor performed quality checks on samples.[87] In nearly 20% of the cases the back-office inspector judged the situational photos inconclusive.[88] In those cases the inspector assigned the case to a follow-up inspector, who then used a scooter to visit the involved car for an on-site assessment.[89] Although the assessment of parking was mostly carried out on the basis of image-review and predefined indicators, it remained a human job.

The other type of assessment concerned compliance with the corresponding tax obligation. In contrast to the previous assessment, this one was carried out by an automated system, namely the NPR: the same system that stored parking rights. The database server was set up by the Municipality of Amsterdam, but was later shared with other municipalities. Maintenance of the NPR was commissioned to the *Rijksdienst Wegverkeer* (RDW), an independent government agency responsible for issuing license plate numbers.[90] Within the NPR an automated check took place. This involved comparing the data extracted by the scanning-system to data from registrations of parking rights. The check had a build-in delay to grant people time to register their license plate number into the NPR.[91] This delay was always precisely five minutes. For individuals that used a parking machine to make a registration, it was important to take prompt action and remember their license plate number, as they needed to enter this correctly into the machine.[92] Leaving the parking space within five minutes after being scanned did not cancel the obligation to pay parking tax, because no additional data was collected to notify the NPR that the car had left. [93] If the NPR assessed that a registration was lacking, or that the payment was insufficient, the case was forwarded to the tax department of Amsterdam, which connected the license plate number, via RDW, to the name and address of the license plate holder. That way, the additional tax assessment could be sent to the license plate holder's home address and no more paper notices were left on cars.[94]

[85] See Appendix B: Fig. 9 for a back-office inspector working with Image-Review.
[86] ECLI:NL:RBAMS:2017:2740, consideration 10.5; Ombudsman. (2019b). *Geen laad en losactiviteiten parkeerboete terecht opgelegd*; Ombudsman. (2017b). *Over het hoofd gezien tijdens het laden en lossen*; Ombudsman. (2016a). *Naheffingsaanslag voor mantelzorger ingetrokken*.
[87] ECLI:NL:RBAMS:2017:2740, consideration 10.5.
[88] Kruyswijk. (2017).
[89] EPS. (2019); Gemeente Amsterdam. (2019).
[90] SHPV. (2019).
[91] Ombudsman. (2019c). *Snel parkeergeld betalen anders parkeerbon*.
[92] Ibid.
[93] Ombudsman. (2019d). *Parkeerboete na storing digitaal betalen parkeerbelasting*.
[94] EPS. (2019); Ombudsman. (2016b). *Oneens met parkeerboete*.

In summary, this chapter discussed the institution of paid parking as it was implemented in Amsterdam from 2016–2019. The operational rules indicated that parking on a parking equipment space triggered a tax obligation. The obligation itself was expanded, since the transaction underlying the fulfillment of the obligation required the user to provide data in the form of a license plate number. Registering license plate numbers enabled two changes: (1) it facilitated registrations from multiple access points, like mobile phones and computers; and (2) it made paper parking cards obsolete. The parking cards from chapter four were renamed 'parking rights'. Similar to their paper predecessors, scratch rights had a restriction on their use. However, the restriction was not directed at the consecutive use, but at the concurrent use. As for the enforcement, it worked by collecting data automatically from the physical world through a scanning-system. Thereto, the system used sensors and a digital model that held the status of surfaces throughout the city. The data was processed in two ways: (1) by an inspector at a back-office who assessed parking in accordance with a protocol and predefined indicators; and (2) by a computer system (NPR) that assessed whether parked cars were registered within five minutes. Based on these findings, Table 5.1 presents the institutional statements. Having outlined the institutional statements from both the before- and after-case, the next chapter proceeds with the analysis.

Table 5.1: Institutional statements

$y_{1\,[i=0]}$	-	People have an obligation $_{\text{[DEONTIC]}}$ to pay a parking tax AND register their license plate number AND do this within five minutes $_{\text{[A/M]}}$, when parking on a parking equipment space $_{\text{[CONDITION]}}$. Not following the rule results in an additional tax assessment $_{\text{[OR ELSE]}}$.
$y_{1\,[i=1]}$	-	Holders of a scratch card permit $_{\text{[ATTRIBUTE]}}$ may $_{\text{[DEONTIC]}}$ purchase 72 hours of scratch rights every three months $_{\text{[A/M]}}$.
$y_{1\,[i=2]}$	-	Holders of a scratch card permit $_{\text{[ATTRIBUTE]}}$ cannot $_{\text{[DEONTIC]}}$ register more than five cars concurrently $_{\text{[A/M]}}$.
$y_{1\,[i=3]}$	-	People must $_{\text{[DEONTIC]}}$ leave visible indicators $_{\text{[A/M]}}$, when placing a car on a parking equipment space for the purpose of (un)boarding goods or passengers $_{\text{[CONDITION]}}$. Not following the rule results in an additional tax assessment $_{\text{[OR ELSE]}}$.

6 ANALYSIS

6.1 Introduction

In this chapter the findings are analyzed. The goal is to find out whether covariance exists between independent variable (*x*) and dependent variable (*y*), and subsequently, to explain the result. This goal is achieved in three steps. First, it is analyzed whether covariance between the independent and dependent variable is possible. Thereto, it is examined whether variance occurred for both variables. In the first paragraph hereafter it is determined whether variance occurred in the independent variable (*x*). The subsequent paragraph addresses variance in the dependent variable (*y*). Covariance is only possible if the value of both the independent and dependent variable changed. The final paragraph of this chapter analyzes and explains the result in relation to the propositions that were derived from the existing e-governance literature.

6.2 Integration of IoT in the enforcement

This paragraph assesses for each of the two cases whether it is true or false that IoT was integrated in the enforcement. This concerns independent variable *x*. The value of *x* is measured by assessing whether the constituents of urban IoT are present, which were set out in the operationalization section of chapter three and included: IoT nodes; a control center; interfaces; and an electronic network connecting the sensors, data-storage and interfaces.

Regarding the before-case, no indications were present of IoT nodes, a control center, or an electronic network connecting them. It is arguable whether conventional parking machines qualified as interfaces. Although these devices facilitated transactions, they are not considered interfaces in respect of their function. After all, the function of an interface is to facilitate interaction with the IoT network, of which no indications were found. Considering that none of the constituents of urban IoT were present, it follows that IoT was *not* integrated in the enforcement of the institution (paid parking) in the before-case [x_0 = false].

As for the after-case, all four constituents were present. First, IoT nodes consist of devices that generate data. Observations of devices that met this description were present in the form of scanning-cars, parking machines, and smart devices (e.g. smartphones). Second, a control center involves a backend server that coordinates data in the network, and has a capacity to store and process data. The NPR was observed to fulfill these criteria (storing license plate numbers for 3 months; handling incoming data from nodes; sending data to the municipal tax department; and processing license plate data to assess compliance). Third, interfaces were present in the form of websites and smartphone apps of third-party service providers and a municipal web interface for the registration of scratch rights. Finally, IoT nodes, the NPR, and the interfaces were found to be connected through a network (internet). It is safe to assume that smartphones have wireless internet access. Likewise, scanning-cars used 3G/4G (UMTS/LTE) to transfer data to the back-office and NPR. Web interfaces can be accessed through devices with browsers (TCP/IPv4-6). Seeing that all four indicators were present, it follows that IoT was integrated in the enforcement of the institution (paid parking) in the after case [x_1 = true] (see Table 6.1). With x having different values in the before- and after-case, variance in the independent variable can be concluded [$x_0 \neq x_1$].

Table 6.1: Urban IoT

Constituents [a]	Function [a]	Before-case (x_0)	After-case (x_1)
IoT nodes	Generate data	.	✓
Control center	Electronic data storage and processing in a control	.	✓
Interfaces	Interacting with the system	.	✓
Network	Gateway to interconnect end devices to the control center	.	✓
		x_0 = false	x_1 = true

[a] Adapted from Zanella et al. (2014).

6.3 The institution's operation

This paragraph assesses whether change occurred in the enforced institution's operation (y). That is, change in dependent variable y [$y_0 \neq y_1$]. Variable y consists of an array of institutional statements which were presented at the end of both case chapters (see Table 4.1 and Table 5.1). Each institutional statement had values for its ADICO parameters. As explained in the research design chapter, two types of change could occur with regard to the value of y. On the one hand, implementing new rules or removing old ones changes the configuration of elements of the array. On the other hand, the modification of ADICO parameters could change the composition of an element in the array [$y_{0[i]} \neq y_{1[i]}$]. Both are valid changes of y. Of course, the validity of a change in the composition of an element depends on an adequate selection of *the same element* at different moments in time. The selected empirical materials that were set out in the case descriptions closely revolved around time cards and scratch cards (before-case), as well as time rights and scratch rights (after-case). The Municipality of Amsterdam addressed the latter as the 'digital successors' of the former, thereby underlining the validity of a comparison of these means.

Based on a comparison of the value of the dependent variable from the before- and after-case, two instances of change in the composition of an element were present, namely in the first and third element (i = 0; 2). Furthermore, a change in the configuration was present, as an additional element is identified in the after-case [$y_{1\,[i\,=\,3]}$] (see Table 6.2). Consequently, it follows that between the before- and after-case, there was variance in the value of dependent variable y [$y_0 \neq y_1$]. That is to say that change occurred in the enforced institution's operation.

Table 6.2: Comparison of institutional statements

Before-case (y_0)	After-case (y_1)	Change in:	Observation
$y_{0\,[i=0]}$	$y_{1\,[i=0]}$	Composition	(–) place the card on the car's dashboard; (+) register their license plate number; (+) do this within five minutes [AIM]
$y_{0\,[i=1]}$	$y_{1\,[i=1]}$	.	.
$y_{0\,[i=2]}$	$y_{1\,[i=2]}$	Composition	(–) must not [DEONTIC] use more than two scratch cards consecutively [AIM]; (+) cannot [DEONTIC] register more than five cars concurrently [AIM]
.	$y_{1\,[i=3]}$	Configuration	(+) leave visible indicators [AIM], (+) when placing a car on a parking equipment space for the purpose of (un)boarding goods or passengers [CONDITION]

6.4 Understanding the covariance

In the previous two paragraphs variance was found in both the independent variable [$x_0 \neq x_1$] and dependent variable [$y_0 \neq y_1$]. To limit the risk of erroneously attributing the variance in the dependent variable to variance in the independent variable, confounding factors were controlled for (see chapter three). Table 6.3 presents the overall co-variational table.

Table 6.3: Co-variational table

Variable	Variable description	Case 1	Case 2
Control variable	Gemeentewet	a	a
Control variable	Local administration	b	b
Independent variable x	IoT in enforcement	FALSE	TRUE
Dependent variable y	Operation of institution	y_0	$\neq y_1$

Based on these results covariance is possible between the independent and dependent variable [$x_0 - x_1 \rightarrow y_0 - y_1$]. To explain the effect, the changes in the institutional statements that constituted the variance in the dependent variable are further analyzed in relation to the existing academic literature and the propositions that were derived from it. First, the propositions are briefly restated. Then, for each of the three institutional statements it is analyzed: what changed in the case, how the change(s) relate to the literature, and whether it supports one or more propositions.

The propositions consist of three mechanisms. Each presumes that integration of IoT leads to change in an institution's operation, mediated by changed interpretations of rules and/or the interpretation of behavior. The first proposition presumes that IoT leads to organizational standardization, thereby limiting the room for interpretation of rules by inspectors. The second proposition presumes that using computers to produce decisions requires to interpret rules in advance, thereby restricting facts and circumstances to be accounted for in the interpretation of rules. Finally, the third proposition presumes that the use of IoT sensors requires to interpret behavior in terms of indicators that can be detected by sensors. All three propositions comprise change in an institution's operation, because they entail a new understanding of either the scope of the rules or the scope of the behavior to which the rules apply. Having briefly restated the propositions, the instances of change in institutional statements are hereafter further analyzed.

Identification and fixed interpretation

The first change of an institutional statement consisted of two adjustments in the prescribed courses of action $[y_{0\,[i\,=\,0]} \neq y_{1\,[i\,=\,0]}]$. One adjustment involved registering a license plate number into a database, instead of placing a parking card on the car's dashboard. The other adjustment concerned the introduction of an exact time limit within which registrations had to be made.

In the case, the registration of license plate numbers fulfilled a technical purpose, because it enabled the pairing of data from multiple IoT nodes. License plate numbers served as a point of identification that could be observed by IoT sensors. That way, a payment of parking tax that was registered through one IoT node (e.g. a smartphone or parking machine), could be digitally paired with data generated by another IoT node (e.g. a scanning-system).

As regards the existing literature, possible institutional effects can be identified. Seeing that registered license plate numbers were connected to other personal information of the license plate holder (e.g. a name and home address), and the observation that license plate numbers were stored for three months implies a restriction of privacy. Considering that rational individuals seek to optimize their personal utility (see Shepsle & Bonchek, 1997; Goorden, 2003), the restriction of privacy influences decisions, when individuals perceive the restriction as a cost. Rational deterrence theory suggests that people will not violate rules as long as the benefits do not outweigh the costs (Ritchey & Nicholson-Crotty, 2011; Mendes & McDonald, 2001; Tittle, 1969). As privacy is added to the consideration of costs and benefits, different valuations of privacy would result in more heterogeneous responses to parking costs. As a result, the institutional change could in theory have an unintended effect on how the institution structures social interactions.

The propositions do not provide an explanation for this change. This is because the propositions presume that the effect is mediated through changed interpretations. However, this change *does* result from IoT. Hence, there is still reason to attribute this change to IoT.

As for the other adjustment, the case showed that with the integration of IoT in the enforcement, the time that people were granted to comply was set to exactly five minutes. This time was coded as a delay into the computer system that assessed whether people complied with the obligations (NPR). No indications were found of the existence of such a fixed time frame prior to the integration of IoT. An inspector would take contextual factors into account, for example whether the possible holder of the car was in the process of obtaining a parking card. Naturally, the distance to the closest parking machine varied and now and then people would be seen waiting in line at a parking machine. It follows, from those and similar contextual reasons, as well as the absence of contraindications, that the time that people were granted to comply was variable prior to the integration of IoT.

The literature provides an explanation for the introduction of this context-free time. Computers rely on binary logic, which is supported by schematic rulesets and numerical data (Busch & Hendriksen, 2018). When it comes to computerized decision-making, context cannot be adequately accounted for, because algorithms are written in advance. At that time, it is impossible to oversee the context of each individual case, resulting in a situation in which all citizens receive the same treatment (cf. Bovens & Zouridis, 2002; Cordella, 2007; Kallinikos, 2005; Cordella & Tempini, 2015).

This adjustment suits the second proposition. With the rule being interpreted in advance it ceased to be context dependent. As a consequence, the scope of the rule was no longer the same. What stands out, however, is that there was no written prescript that addressed that people should be granted a certain time to comply. Instead, it appears that the delay that was coded into the assessment, used to be enclosed in the nature of the enforcement by humans. Hence, it seems that although the first proposition provides a plausible explanation, an addition is at place. Namely that implicit properties of an institution can be enclosed in the nature of enforcement by humans, and can require to be emulated in the algorithm that is used to produce decisions. The proposition then applies analogous to the interpretation of the emulated condition. That is, a contextual interpretation of a condition is replaced by a fixed interpretation.

Restrictions by design

A second change in an institutional statement was observed regarding scratch cards $[y_{0\,[i\,=\,2]} \neq y_{1\,[i\,=\,2]}]$. The case showed that with the integration of IoT in the enforcement, the restriction on consecutive use of the property rights was replaced by a restriction on concurrent use.

With regard to the literature, the change limited the number of users for which the property right can be used at any moment, emphasizing the character of a permit system (see Hahn & Hester, 1989). Furthermore, in contrast to what the literature suggested, enforcement of the new restriction was absent (see Roland, 2004; De Boer, 2019; De Bruijn, Ten Heuvelhof & Koopmans, 2007). This lack of enforcement of concurrent use was related to the web interface through which the property right was activated. The system was designed to accept a maximum of five active registrations. As a result of this design, there was no more need for enforcement. Both the control over the number of users for which the property right could be used, as well as the absence of enforcement, imply that the new system increases the public administration's control over the use of the property right, which provides an opportunity for a more efficient allocation of the common-pool resources.

Seeing the propositions, they do not provide explanations for this change. This is again because the propositions presume that the effect is mediated through changed interpretations, whereas this does not concern this change. It does, however, seem to be enabled by IoT. To be more precise, the change seems to be enabled by the connection between license plate numbers and users. After all, limiting the number of concurrent registrations of users, requires to count the number of registrations associated with each user. Having users register license plate numbers through a personal online account (web interface), allows for this enumeration of registrations. Therefore, the change can nonetheless be attributed to IoT.

Distinguishing behavior

Finally, the third change in an institutional statement related to the conditions that separated closely related behavior $[y_{1\,[i\,=\,3]}]$. In the studied cases, this applied to the distinction between *parking* and the exception for *having a car stand still for the (un)boarding of goods or passengers*. The observed change involves that people became responsible for leaving visible indicators, such as leaving the hazard lights on, to signal that their behavior should be interpreted as the exception. Not leaving visible indicators resulted in an interpretation of the behavior as parking, which in turn resulted in an additional tax assessment. Since the municipal administration did not accept appeals if no indicators were visible, the de facto scope of the exception was restricted to the condition that indicators were present during the time in which the exception took place.

In terms of the existing literature, the requirement of leaving visible indicators can be understood as a new 'game rule', that determined whether complying to the obligations of paid parking was appropriate or not (see North, 1991; Streeck & Thelen, 2009; Ostrom, 2005). The new rule can be explained in relation to the integration of IoT in the enforcement, as it changed the role of inspectors considerably. The observed change can be conceptually understood in relation to a transformation from a street-level bureaucracy to a screen-level bureaucracy (Bovens & Zouridis, 2002). Inspectors used to work at the street-level, where they performed on-site inspections and interacted with citizens. The integration of IoT in the enforcement organization enabled remote assessments. In the new situation, screen-level inspectors worked at a back-office, where they assessed behavior based on photos displayed on a computer screen, and in accordance with a protocol of standardized indicators. Under the circumstance of limited information, the protocol drew a clear line. Since the enforcement through IoT allowed to store the data that served as the input for assessments, it also enabled a supervisor to monitor whether or not inspectors adhered to the protocol. These circumstances imply that the discretionary power of inspectors decreased, which supports the conceptual transformation to a screen-level bureaucracy (Bovens & Zouridis, 2002).

The first proposition finds support in this change. Following Bovens and Zouridis (2002), this proposition presumes that the use of IoT for organizational standardization – through predefined forms and indicators – constrains the interpretation of inspectors, and consequently the outcome of what are considered violations. Organizational standardization can also be observed in the division of tasks among inspectors (collecting data, assessing data, and incidental follow-ups). The first proposition appears to be coinciding with the third proposition. The third proposition presumes that enforcement through IoT requires to interpret behavior by way of indicators that can be captured by IoT sensors. Although the assessment of the collected data is assessed by humans, the information remains limited to indicators that can be detected by IoT sensors, resulting in a more restrictive interpretation of behavior. After all, interpretations no longer included exceptions if no indicators were left to be captured by the sensors.

To sum up the main points of this chapter, it was found that covariance between the integration of IoT in the enforcement of paid parking and change in the institution's operation is possible. To explain the possible effect, three institutional statements that had changed were further analyzed. The changes were discussed in relation to the existing literature and the propositions that were derived from it (as set out in chapter two). Each of the propositions was found to have explanatory value. The first proposition found support in the use of IoT for remote assessments. This use of IoT was accompanied by organizational standardization in the form of protocolized assessments with predefined indicators that determined the outcome. The second proposition found support in the interpretation of a condition as a fixed value, whereas it used to be variable. However, whereas the proposition presumed the interpretation of a condition laid down in written rules, this condition was enclosed in the nature of on-site inspection by humans. Nonetheless, the mechanism of the proposition applied analogous to this implicit condition. Coinciding with the first proposition, the third proposition also found support. It was found that the predefined indicators were limited to the information that was collected by IoT sensors.

For each of the three propositions, it follows from their premise that they were limited to explaining changes in the institution's operation, as a result of changing interpretations. In other words, they do not provide explanations for changes that are not mediated by changing interpretations. Two of such instances were found. Although these changes were not explained by the propositions, they are arguably not confounding, since they can also be attributed to the integration of IoT. Both related to a connection between physical objects and the person to which the physical object was attributed to. On the one hand, enforcement through IoT required a point of identification to pair data from various IoT nodes to the same object. On the other hand, based on the discussed institutional theory, the connection implied a greater level of control over the common-pool by the public administration, but at the cost of individual citizens who value privacy.

7 CONCLUSION

This study started with the observation that a specific type of ICT, namely the Internet of Things (IoT), is used for enforcement purposes, taking place in public spaces. Little is known about the effects and ability of IoT to cope with the complexity of the street-level situations. Existing research on the more general use of ICT in the provision of public transaction services, suggests that the application of rules might become more rigid. From that thought, this study addressed the question '(How) does the integration of IoT in the enforcement of an institution lead to change in the institution's operation?' To answer this question, a small-N intertemporal case study was conducted, involving the comparison of an institution before and after IoT was integrated in the enforcement of the institution. The study focused on the institution of paid parking, and the Municipality of Amsterdam was chosen as a case to investigate the institution. The operational level was selected as the level of analysis, and a broad understanding of institutions was followed. Thereto, data was collected about the rules at the operational level. This involved both the rules as laid down in municipal regulation, as well as practical courses of actions that citizens need to take, and how the rules are in practice enforced by inspectors. The integration of IoT in the enforcement of an institution (as independent variable) was measured based on constituents of urban IoT architecture. The Institutional Analysis and Development (IAD) framework was used for the measurement of change in the institution's operation (as dependent variable).

By means of a co-variational analysis, covariance was found between the integration of IoT in the enforcement, and change in the enforced institution's operation. The identified instances of change could be partially attributed to the integration of IoT, based on propositions derived from the e-governance literature. As for the remainder of the identified change, there are also reasons to attribute these to the integration of IoT in the enforcement, but not on the basis of the propositions.

The three propositions presume that change in the institution's operation is mediated by a change in the interpretation of rules and/or behavior. Different interpretations can bring about a change in which behavior is considered appropriate and possible and what is considered a violation (see Streeck & Thelen, 2009). Changed interpretations due to IoT are presumed to follow from: (1) organizational standardization, (2) computer-interpretable prescripts, and (3) sensor detectable indicators. With regard to the first proposition, a link between organizational standardization and the integration of IoT, was observed in a division of tasks among inspectors (data collection, data assessment, and incidental follow-ups). Data collection through IoT enabled remote assessments. Those assessments were based on a protocol with predefined indicators that determined the outcome of assessments. Coinciding with the third proposition, the predefined indicators were limited to indicators that were observable in the collected data. As a result, people became responsible for leaving these indicators, because in the absence of the indicators, their behavior would be interpreted in a way that would result in a sanction.

The second proposition explains the interpretation of a condition as a fixed value. In the case this condition concerned a fixed time that people were granted, before a computerized assessment took place. Prior to the integration of IoT there was no explicit amount of time that people were granted. Instead, this time was enclosed in the nature of on-site inspection by humans, which inherently took time. The amount of time inspectors would grant people was dependent on the context of a situation, thus variable. Although the fixed value concerns the emulation of a condition that did not follow from a written rule, it can still be conceptually explained by the second proposition. Because algorithms are written in advance it is impossible to oversee all context that would result in various interpretations.

Not all changes in the institution's operation could be explained in respect of the propositions. Two other instances of change were identified. These changes, however, can also be attributed to the integration of IoT in the enforcement. The changes concern a link between objects in the physical world and persons with which that object is associated. The link is necessary to pair data from different IoT nodes. From an institutional perspective it brings about a change, as it was found that it could provide a public administration with more control over the common-pool resource, but it also brings about a cost for people who value privacy.

In conclusion, considering that all identified instances of change can be attributed to the integration of IoT, either mediated through changing interpretations, or as a technical necessity, there is reason to believe that integration of IoT in the enforcement of an institution, leads to changes in the institution's operation.

Academic literature

This study used the e-government literature to analyze the effect of integrating IoT in the enforcement. Although the e-government literature is fragmented, the part of the literature that focuses on transactions services proved appropriate (Bekkers & Homburg, 2005; 2007). Scholars that focused on this domain propose that the use of ICT for transaction services can encompass a decrease in discretionary power, which can manifest itself through organizational standardization, as well as through computerized decision-making (Bovens and Zouridis, 2002). A contribution in this regard concerns that this study provides empirical evidence of what Bovens and Zouridis (2002), consider a transformation from street-level bureaucrats to screen-level bureaucrats, in a context of enforcement through IoT. Furthermore, support was also found of a decrease of discretion leading to a more uniform decision-model, which is considered *rigid* by some, and *equal and impartial* to others (cf. Bovens & Zouridis, 2002; Cordella, 2007; Kallinikos, 2005; Cordella & Tempini, 2015).

An addition to the existing literature concerns the finding that inherent properties of 'conventional' enforcement by human inspectors acting on-site, had to be programmed into the algorithm that was used for assessment. Although there was no legal prescript demanding this, not doing so would have resulted in unreasonable outcomes, because people would be sanctioned instantly, not being granted time to comply with obligations. This suggests that using IoT for enforcement purposes requires to think of unwritten properties of the enforcement of an institution. It is imaginable that these properties were implicitly assumed when the institution was devised. This also emphasizes the importance of following a broad understanding of the concept of institutions in relation to enforcement.

Finally, when it comes to the studying of institutional effects of IoT, the operational level proved adequate. The same applies to the ADICO syntax from the IAD framework (see Ostrom, 2005).

Limitations

A limitation of this study is that there was a difference in the data-availability between data from the before- and after-case. Data from case reports (Ombudsman) was found more elaborated in respect of the before-case. An explanation might be that a part of the recent reports still needs to be completed. The chosen time frame of the after-case (2016–2019), also entails that not all court cases from 2019 were yet available. Another limitation that needs addressing involves the reliability of this study with regard to the measurement of change in the dependent variable. Although the IAD framework and ADICO syntax provide an adequate instrument for the measurement of institutional change, it does not measure the impact of these changes. Hence, the relevance of the results should be interpreted reservedly.

Further research

A first point for future research concerns what might be called the discretion of sensors. The studied cases suggest a tradeoff between the amount of data that is available for assessments, and the use of a protocol with predefined indicators. As less data is available, the protocol helps to cope with the uncertainty by drawing a clear line. This raises a normative question: if less information leads to stricter indicators, ergo a more restrictive institution, what then is the responsibility of the public administration when more or better sensors are available? A second point involves the expansion of IoT. More research is needed with regard to the integration of IoT in the enforcement of institutions in other policy domains. I suggest that researchers regard IoT not just as a policy instrument, but as the object of analysis, and study the process of function accumulation.

Policy recommendations

To conclude this study, two policy recommendations are at place. First, it is recommended that policymakers are aware of differences among properties of human inspectors and inspection through IoT. One of the insights of this study is that differences in properties can require to emulate those properties to prevent unreasonable outcomes.

Second, it is recommended that policymakers who are interested in exploring IoT for enforcement purposes, look for physical points of identification that limit constraints on privacy. IoT offers potential benefits for public administrations, as it allows to assert more control over common-pool resources, so that the resources are more efficiently allocated. Another benefit is that it can decrease the need for enforcement. On the other hand, policymakers should be aware of the costs in terms of privacy. The point of identification encountered in the studied case concerned license plate numbers. If IoT enforcement is used directly on humans, face recognition as a point of identification, might become an option. The perception of restricted privacy in terms of costs could induce more heterogeneous responses to rules, in accordance with the value that individuals attribute to their privacy.

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APPENDICES

Appendix A: Tables

Table 1: City Councilors of Amsterdam 2006–2022

Term	Case	Coalition parties (Councilors)
2006–2010	Before-case	PvdA (4), GroenLinks (2)
2010–2014		PvdA (3), VVD (2), GroenLinks (2)
2014–2018	After-case [a]	D66 (4), VVD (2), SP (2)
2018–2022	After-case [a]	GroenLinks (3), D66 (2), PvdA (2), SP (1)

Source. https://www.amsterdam.nl/bestuur-organisatie/college/portefeuilles/ [a] The after-case spans the period from 2016 to 2019.

Table 2: Types of parking cards

Type	Target audience
Time cards [a]	Anyone
Scratch cards	Residents [b]
Tourist cards	Hotel guests

Parkeerverordening 2007, art. 22. See Gemeenteblad 2006, afd. 3A, nr. 243/655. [a] Officially referred to as 'minute, part of the day, day, evening, week or month cards. [b] Conditions apply.'

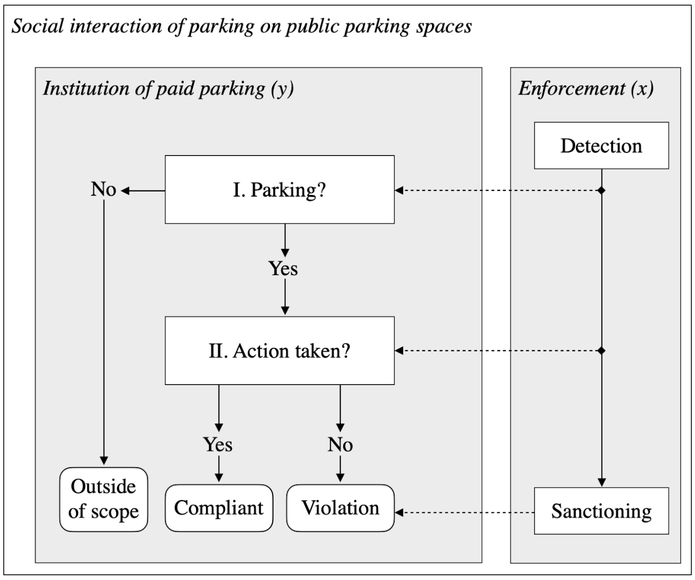
Table 3: Types of parking rights

Type	Target audience
Time rights [a]	Anyone
Parking rights based on a scratch card permit	Residents [b]
Parking rights based on a visitor permit	Residents
Parking rights based on a GA visitor card	Holders of EU-disability cards

Parkeerverordening 2013, art. 26. *Gemeenteblad* 2017, 234607. [a] Minute, part of the day, day, evening, night, week and month parking rights. [b] Conditions apply.

Appendix B: Figures

Figure 1: The game, the rules, and the enforcement



Continuous arrows represent directions of the decision-model. Dotted arrows indicate directions of enforcement actions. Boxes with rounded edges represent outcomes. Roman numbers indicate steps of the decision-model.

Figure 2: Parking machine from Amsterdam 2008

Source. Syselmiru, 2008

Figure 3: Scratch card from Amsterdam

Source. Geersing, 2013, image: Gemeente Amsterdam

Figure 4: Digital parking machine from Amsterdam

Source. Nieuwsuur, 2019

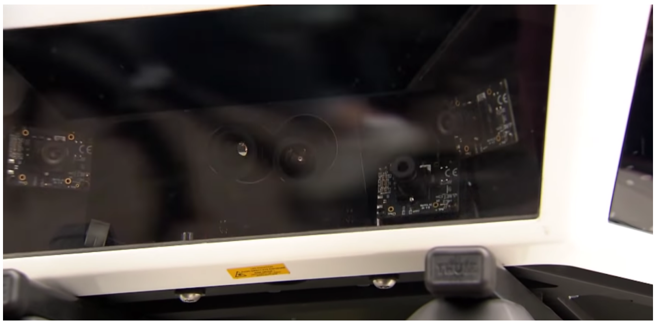
Figure 5: Interface for scratch rights of Amsterdam

Source. https://aanmeldenparkeren.amsterdam.nl/

Figure 6: Scanning-car from Amsterdam

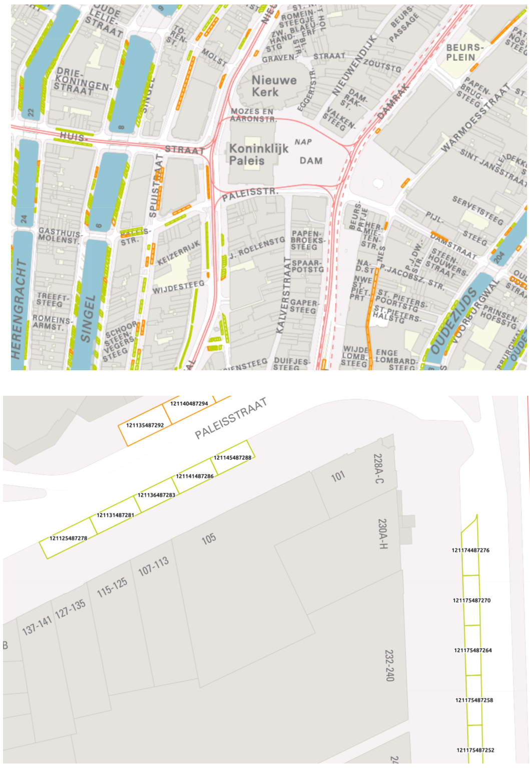
Source. EPS, 2019

Figure 7: Cameras of the scanning-system



Source. NH Nieuws, 2019

Figure 8: Map of fiscal parking spaces in Amsterdam, based on coordinates



Source. https://data.amsterdam.nl/data/?modus=kaart&center=52.3728305%2C4.8910287&lagen=parkvk-pv%3A1&legenda=true&zoom=12

Figure 9: Back-office inspector working with image-review in Amsterdam

Source. NH Nieuws, 2017