UNIVERSITÄT BERN

Infrastructures, Cooperation and Openness in Smart Cities

Inauguraldissertation zur Erlangung der Würde eines

Doctor rerum oeconomicarum

der Wirtschafts- und Sozialwissenschaftlichen Fakultät

der Universität Bern

vorgelegt von

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Bern, September 2019

Acknowledgements

Having finalized my dissertation, of course, I am curious what will happen with our results and findings. Will they be fruitful to others in theory as well as in practice? Will they do any good or will they sink into oblivion? It remains to be seen. However, any favourable outcomes of the present dissertation will be attributed to the creator of all the things worthy to research in the first place, and many dear colleagues, friends and family-members supporting this work as co-authors, supporters and encouragers. In case of doubt, any remaining errors are mine. Thanks to all the taxpayers that made this work possible. May they profit as well from this work eventually.

Thanks to my advisor Prof. Dr. Thomas Myrach for giving me the possibility to work on this dissertation and his valuable feedback on various research attempts, Dr. Matthias Stürmer for his optimism and some great research opportunities, Dr. Oliver Neumann for his encouragement and help with many subtleties of academic research and Oscar Meier for supporting this endeavour through various computer hacks.

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Introduction

"Digitalization is embracing all aspects of our private and professional lives" (Legner et al., 2017). However, digitalization is not something mere virtual happening in distant clouds but requires large infrastructures. They can be in the form of a tangible hardware like computers, sensors and networks or in the form of software like data and applications. Although "many aspects of infrastructure are singularly unexciting" (Star, 1999), infrastructures in general are worth studying because they form "the underlining foundation or basic framework"[1] for our society. The focus of this work lies on Smart City infrastructures and the corresponding cooperation needed to build and/or operate them.

Cities and urban areas are of a worldwide importance by concentrating human social and economic activities there (Mori & Christodoulou, 2012). The idea of Smart Cities engages science and industry (Anthopoulos, Janssen, & Weerakkody, 2016) and is a trend with policy makers worldwide (Caragliu, Bo, & Nijkamp, 2011). Smart Cities are instrumented, interconnected and intelligent cities (Harrison et al., 2010), which means that Smart Cities are cities that collect data from the virtual and physical world and connect this data through communication networks to analytics processes. Such interaction of different sensors and actuators is often referred to as Internet of Things (IoT) communication (Atzori, Iera, & Morabito, 2010). Using various technologies, Smart City initiatives are characterized by the goal to create better environmental, social and economic conditions and increase at the same time the attractiveness and competitiveness of the city (de Jong, Joss, Schraven, Zhan, & Weijnen, 2015). Emphasizing the infrastructure aspect, a Smart City is "connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city" (Harrison et al., 2010, p. 2). Focussing on the exchange of information, "Smart City implies a high-tech intensive and an advanced city that connects people, information and city elements using new technologies" (Bakıcı, Almirall, & Wareham, 2013, p. 139).

A major aspect of Smart Cities is the idea of using open data to achieve the Smart City vision (Bakıcı et al., 2013; Hielkema & Hongisto, 2013; Schaffers et al., 2011). Open data is data that "can be freely used, modified, and shared by anyone for any purpose"[2]. The sharing-aspect of open data and other open undertakings like open networks is closely related to cooperation questions in that the added value of the open idea is the point that open data creators and open network operators are usually not the same as the open data and open network users. Finally, focussing on collaborative innovation within the scope of hard- and software, Smart Cities "are territories with high capacity for learning and innovation, which is built in the creativity of their population, their institutions of knowledge creation, and their digital infrastructure for communication and knowledge management" (Komninos, 2006, p. 1). Integrating the

[1] https://www.merriam-webster.com/dictionary/infrastructure, accessed: 2019-09-17
[2] https://opendefinition.org/, accessed 2019-09-17

subjects of infrastructure, cooperation and the idea of openness, the three individual research papers of this dissertation cover:

a) infrastructure in the form of wireless communication hardware and the cooperation within local communities to build a free, open and worldwide IoT network
b) software in the form of open linked data infrastructure and the beneficial cooperation between government authorities and crowdsourced open knowledge bases to achieve high visibility and usability of this open data
c) collaborative innovation between local governments and utility companies to build Smart City infrastructures combining hard- and software

Whereas the first two papers focus more on the individual constituents of a Smart City in the form of IoT networks and open data, the third paper covers cooperative ways to build innovative Smart City applications based on the former components. Besides the joint subject of openness in the first two papers, they both have a priority on the quality of the open goods, be it the open network or open data respectively. Only a high quality network with good reliability and coverage will be useful and "data is only as useful as its quality" (Zaveri et al., 2016, p. 1).

Summary of Research Papers

a) The first research paper entitled *"Are Communities Key to Performant Crowdsourced Smart City Infrastructures? The Case of The Things Network"* describes *The Things Network*, a global, open and partially community operated IoT network using LoRaWAN technology. It examines the effect of network contributors being organised in local communities and shows that such community engagement results in a higher operational performance of the network infrastructure.

b) The second research paper entitled *"Balancing control, usability and visibility of linked open government data to create public value"* discusses linked open data and open knowledge infrastructures and the cooperation between governments, as primary provider of open data, and open knowledge bases operated in a crowdsourced manner. It shows that the full potential of open data and open knowledge is only enabled by governments working together with the public to link data of various sources to create the maximum impact.

c) The third research paper entitled *"Joining Forces for Public Value Creation? Exploring Collaborative Innovation in Smart City Initiatives"* examines the possibility of local governments working together with the cities' utility companies to create more public value within Smart City projects through a collaborative innovation setting fuelled by information and communication technology. It presents a framework of different collaboration settings and its respective effects on innovation outcomes. It shows that successful collaborative innovations for creating public value in the form of

Smart City infrastructure need a stewardship like relationship between local government and utility company that is characterized by mutual interests and the collective working towards a larger purpose.

As fundamentally changing the current digital transformation may be, this dissertation indicates that some old-world experiences are still valid. It supports the conclusion that although the digital era will significantly change the infrastructure landscape within Smart Cities, it will not change the fact, that well planned and executed cooperation and collaboration usually leads to better and more desirable results. Furthermore, it hints at openness being a fruitful *modus operandi* in tackling the various challenges within Smart Cities.

Paper	**Research Question**	**Research Method**	**Publication**
a)	How does community membership of TTN gateway owners influence the operational performance of their gateways?	Quantitative study based on longitudinal data (>20 months) on gateway reliability and community membership automatically gathered via API.	Will be submitted to *Business & Information Systems Engineering* (BISE)
b)	What options do public organizations have to publish their Linked Open Government Data in such a way that data control, data visibility and data usability are balanced according to the organizations' requirements?	Conceptual paper enriched with case studies.	Published in the *International Journal of Public Sector Management* (IJPSM) 2019, https://doi.org/10.1108/IJPSM-02-2018-0062
c)	How do different types of collaborative innovation between local government and utility companies influence the innovation-related outcomes?	Qualitative research based on interview case studies leading to a model for collaborative innovation.	Conditional accept for publication in *Government Information Quarterly* (GIQ) 2019

Table 1. Research question, research method and place of publication of the research papers.

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Are Communities Key to Performant Crowdsourced Smart City Infrastructures?

The Case of The Things Network

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Abstract. Smart Cities need a modern communication infrastructure to connect the physical to the virtual world to fulfil their promises of an intelligent, attractive and sustainable place to live and work. This research covers the global and open LoRaWAN network *The Things Network*, which provides such connectivity. It is built by an organisation operating a central backend infrastructure and by volunteer contributors around the world deploying their own wireless gateways, which forward data received from various wireless devices to the central backend. The gateway owners are encouraged to join local communities of other contributors. As community identification and community membership is an important subject in crowdsourced initiatives, this study investigates the effect of a community membership of gateway owners. This research demonstrates that such a membership leads to a significantly better operational performance of the corresponding gateways. Furthermore, it delivers insights into the robust network coverage within different cities. The results of this study encourage crowdsourced project owners to create community mechanisms for continued and reliable service provision. Furthermore, it provides a decision basis for public administration workers commissioned to build Internet of Things connectivity for Smart City applications.

Keywords: Smart City, Internet of Things, LoRaWAN, Crowdsourcing, Motivation, Community, Performance.

1 Introduction

Over the last decades, urban areas around the world are engaged in various Smart City initiatives to create better environmental, social and economic conditions and increase at the same time the attractiveness and competitiveness of the city (de Jong, Joss, Schraven, Zhan, & Weijnen, 2015). This idea of Smart Cities is capturing the attention of science and industry (Anthopoulos, Janssen, & Weerakkody, 2016) as well as being a current trend with policy makers (Caragliu, Bo, & Nijkamp, 2011). But the multitude of Smart City definitions results in some ambiguity of the concept (Albino, Berardi, & Dangelico, 2015). Caragliu et al. (2011) try to present an encompassing definition in stating that a city can be considered as smart "when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance." Others have stressed the importance of network connectivity in Smart Cities as well (Hollands, 2008; Kitchin, 2014; Nam & Pardo, 2011). Such connectivity is needed to link the physical to the virtual world (Harrison et al., 2010). The linkage between the material world recorded through various peripheral sensors and the virtual world represented by centralized analytical processes is characteristical for Smart City services (Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014).

The interaction of different devices (e.g. sensors or actuators) over a network is referred to as Internet of Things (IoT) (Atzori, Iera, & Morabito, 2010). More generally, it is called a machine to machine (M2M) interaction (Madakam, Ramaswamy, & Tripathi, 2015). The concept of IoT is "designed to support the Smart City vision" (Zanella et al., 2014, p. 22). IoT achieves its widespread connectivity through the use of network infrastructures (Wortmann & Flüchter, 2015). For such infrastructures, multiple wired and wireless network technologies with different characteristics are available (Montori, Bedogni, Di Felice, & Bononi, 2018). They mainly differ in transmission range, transmission capacity, energy consumption and cost. One group of networks playing a major role in IoT connectivity are so called Low Power Wide Area Networks (LPWANs) which have the characteristics of low power consumption, long range transmission and low-cost (Mekki, Bajic, Chaxel, & Meyer, 2019). Table 1 shows an overview comparison of some common wireless technologies with LPWAN.

Technology	Transmission Range	Transmission Capacity	Energy Consumption
Bluetooth	Low	Medium	Low
WLAN	Medium	High	Medium
Cellular	High	High	High
LPWAN	High	Low	Low

Table 1. Comparison of different wireless technologies.

LPWAN technologies exist in licensed and license-free frequency ranges (Mekki et al., 2019). The ability to operate in a license-free environment allows the operation of crowdsourced LPWAN infrastructure whereas in licensed regimes, only third party service providers and telecom operators are allowed to set up the necessary infrastructure (Habibzadeh, Soyata, Kantarci, Boukerche, & Kaptan, 2018). One interesting implementation of a LPWAN is the LoRaWAN technology which is regarded as "one of the most promising technologies" for IoT (Vangelista, Zanella, & Zorzi, 2015, p. 1). It operates in a license-free frequency range with a star-of-stars topology (Montori et al., 2018).

An initiative called *The Things Network* (TTN) is using the advantages of such a license-free technology to build a global, open and crowdsourced LoRaWAN network. The necessary gateways acting as transceivers to provide wireless coverage across the globe are provided by volunteer gateway owners (Blenn & Kuipers, 2017). The organisation behind TTN offers the possibility for these gateway owners to organise themselves in local communities. However, such a community membership is voluntary. By allowing everyone to use its network, TTN is a direct competitor to telecommunication operators around the world starting to offer their own IoT networks. To sum up the embedding of TTN in a Smart City landscape: TTN uses the LoRaWAN network technology, which has LPWAN characteristics that is used for IoT connectivity, which in turn connects the physical to the virtual world in Smart City applications.

With its crowdsourced, open and free characteristic, TTN adds to a tradition of "wireless communities" (Baig, Roca, Freitag, & Navarro, 2015) and providing of free connectivity to the general public resembles the concept of "wireless commons" (Damsgaard, Parikh, & Rao, 2006). However, crowdsourced networks may only be considered a serious alternative to professional network providers if widespread coverage is available and the connectivity provided is reliable. Given its crowdsourced nature, the reliability and coverage of TTN depends crucially on the individual performance of contributors building the network by deploying their own gateways. This individual performance may be affected by the optional community membership of gateway owners as communities play an important role in other crowdsourced activities like open source software (OSS) (O'Mahony & Ferraro, 2007). Furthermore and more generally, communities are known to be crucial in achieving goals that could not have been accomplished by individuals only (Hargadon & Bechky, 2006). Finally, a participatory culture is one basic condition of sustainable digital infrastructures (Stuermer, Abu-Tayeh, & Myrach, 2017). Therefore, this studies research question is as follows: *How does community membership of TTN gateway owners influence the operational performance of their gateways?*

2 Theory

If people are going to invest their own resources like knowledge, time and finance into crowdsourced projects that benefit a broader public, the question arises about the motivation of such contributors to do so. In the domain of OSS, this contributors' motivation has been thoroughly analysed. Lerner and Tirole (2002) state that potential contributors to a crowdsourced project only participate in a project if they derive a (broadly defined) net benefit from engaging in the project. The different motivational factors are usually classified into internal/intrinsic factors and external/extrinsic rewards (e.g. Hars & Ou, 2002; Lakhani & Wolf, 2005; Wu, Gerlach, & Young, 2007). Von Krogh et al. (2012) finally developed a fine-grained theoretical framework around the individual motivation of the OSS contributors consolidating the knowledge of more than a decade of motivation research in OSS. They classify motivation into three categories: Intrinsic (ideology, altruism, kinship amity, enjoyment and fun), internalized intrinsic (reputation, gift economy/reciprocity, learning, own-use value) and extrinsic (career, pay) motivation.

Besides OSS, another relevant domain for motivation in crowdsourced projects is the research about so-called wireless communities. Such communities have been built to share WLAN hotspots with others (Damsgaard et al., 2006). Bina & Giaglis (2006, p. 1) notice that "motivation plays a critical role in the formation and sustained existence of wireless communities." Camponovo et al. (2013a) find utilitarian motivation (getting free connectivity) and idealistic motivation to be the main reason for participation in such wireless communities. According to Von Krogh et al. (2012) the former would correspond to an internalized intrinsic motivation and the latter to an intrinsic one. The idealistic motivation also includes the idea to fight against a digital divide (Baig et al., 2015).

This study focusses on the aspect of community membership. Such a membership is an important differentiation between TTN gateway owners and a strong signal of a community identification that is a part of an intrinsic motivation (Hars & Ou, 2002). "Community identification instills a feeling of belonging to a certain group, and urges people to help others in that group" (Von Krogh et al., 2012, p. A4). Community identification may be understood as an expression of pro-social motivation or public service motivation in a setting of mutual reciprocity within a group, which is different from a purely enjoyment-based intrinsic motivation (Neumann, 2019; Osterloh & Rota, 2007). Furthermore, community membership as expression of a participatory culture is one of the basic conditions for sustainable digital infrastructures (Stuermer et al., 2017) and as such important for an initiative like TTN competing with professional network providers.

In OSS research, the performance and success is often considered at the level of the whole project (Crowston, Howison, & Annabi, 2006; Midha & Palvia, 2012; Subramaniam, Sen, & Nelson, 2009). On the level of the individual contributor, Lakhani and Wolf (2005) show that community-related intrinsic motivation is a significant driver for the effort of contributors. However, the question remains whether such increased effort also translates into better performance.

Addressing this gap, the current study examines the relation between community identification and the operational performance of individual contributors in crowdsourced projects. The proposed model points out that community identification as an attitude and part of an individual intrinsic motivation can lead to the behaviour of joining a community, which may influence the individual operational performance. The community membership in turn reinforces the community identification. This model is shown in Figure 1.

Whereas in other settings, behaviour often can only be measured in terms of certain intentions to do something, the case of TTN presents the advantage, that the resulting behaviour can be measured objectively in the form of community membership and the robust and comprehensive variable of operational performance that will be introduced below.

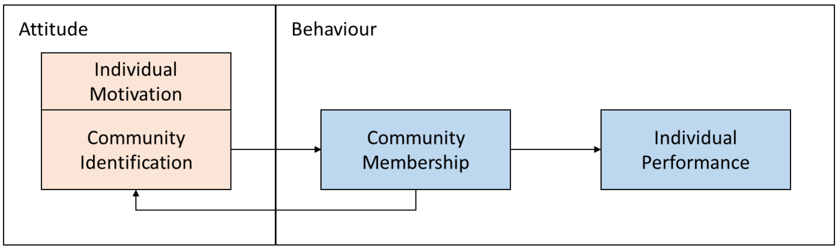

Figure 1. Model of individual motivation and performance.

Of course, community identification and community membership itself does not directly influence the operational performance of the gateway. But Smith & McKeen (2004, p. 393) find communities to be "the mechanism through which knowledge get both created and turned into action." And "the community produces open knowledge about practices and experience" (Baig et al., 2015). An additional effect of the community is to lower the transaction costs (Taylor & Singleton, 1993) of activities like choosing a suitable gateway or installing gateway supervision techniques. Moreover, community membership is a source for technical support and continuous mutual assistance, which in turn can have a positive effect on the operational performance of the gateway. We thus hypothesize: *Community membership of TTN gateway owners is associated with a higher operational performance of their gateways.*

3 The Things Network

TTN consists on the one hand of an organisation that operates the necessary backend infrastructure and on the other hand of individual contributors operating local gateways all over the world. These gateways are connected to the TTN backend via internet and forward data received wirelessly from LoRaWAN nodes to the backend (see Figure 2) where the owners of the nodes are able to further process this data. Nodes are typically sensors that transmit various measurement values or actuators that receive a signal to trigger certain actions. TTN allows creating so-called integrations in the backend to process the received data and transmit data back to the nodes. This can be done by the help of web services like IFTTT[1] that allow reacting on the reception of certain sensor information by sending out notifications or triggering actuators.

As a global, open and crowdsourced LoRaWAN network, TTN is able to transmit data with low energy consumption over large distances at low cost, which makes it particularly applicable for IoT purposes. By using unlicensed frequencies, LoRaWAN is especially well suited for crowdsourced applications allowing everyone to operate gateways and nodes to transmit data without the need for permission by public authorities. However, using unlicensed frequencies does not imply that there are no regulations in place. Amongst other, maximum transmission power, frequencies to use and transmission time limitations (duty cycles) are restricted (ETSI, 2017).

[1] https://ifttt.com/

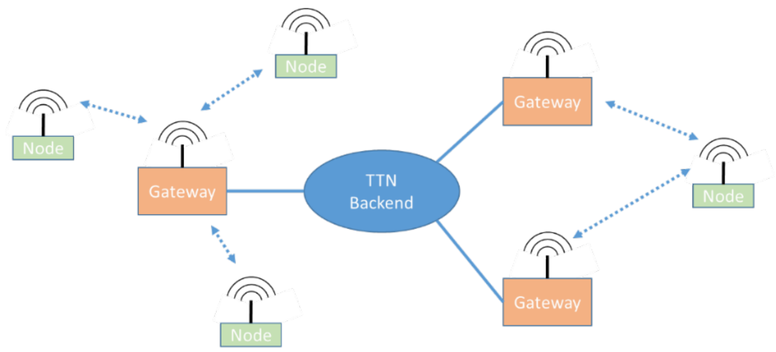

Figure 2. TTN backend, gateways (wired) and nodes (wireless).

The technical characteristics of LoRaWAN and therefore of TTN allow gateways for mutual assistance in that every gateway in reach of a node forwards the data to the central backend. Multiple received packages are sorted out only in the backend. This failure tolerant mechanism allows continued connectivity as long as at least one gateway is in reach of a transmitting node.

There are many different makes and models of gateways present. They range from home built devices based on cheap single-board computers and prebuilt LoRaWAN modules to professional grade, ready to use gateways for long endurance also in harsh outdoor conditions. TTN itself is offering their own gateway solution as well, specifically tailored for use with TTN.

TTN gateway owners can be organised in local communities that are part of a city or region. However, it is not mandatory to do so and it is up to the gateway owner whether he or she joins a community. Communities consist of at least two gateways and eight members, connected by a channel for internal communication. Currently, TTN consists of 185 official communities worldwide with many more in the process of being established. Large communities exist for example in Amsterdam, Zurich, Sidney, Berlin and Bern. Local communities organise different events, like meetings, hackathons and workshops. The structure of TTN with a centrally administered and owned backend infrastructure and community organised voluntarily contributing gateway owners makes it a form of a "hybrid community" in comparison to "pure" communities that are organized by the members itself (Camponovo, Picco-Schwendener, & Cantoni, 2013b).

The voluntarily community structure makes TTN especially interesting for this research by providing objectively assessable data for community identification in the form of community membership of gateway owners. Instead on survey data from amongst gateway owners about their motivation of contributing to TTN, this research is based on the independent variable whether a gateway owner is part of a local community. This data can be collected in an automated way independently from any gateway owner input as long as the gateway owner chooses to share this information publicly.

4 Sample, Measures and Methods

TTN provides an API[2] that allows assessing the last successful contact between each gateway (37’222) and the central backend. As gateways are configured to contact the backend on a regular basis, these contacts can be used to determine the online status of all the individual gateways. To obtain longitudinal data, the TTN API was queried on an hourly basis and the results for all gateways were stored in a database. The interval of one hour was chosen for practicability reasons. Gateways do contact the backend once a minute but data collection, storage and analysis in such an interval would be too costly. The investigation period between 2017-09-11 and 2019-07-18 resulted in a longitudinal time frame of around 22 months. Within this period, the number of registered gateways grew from 3140 to 37’222. Currently, this growth is accelerating and has reached around 100 gateways being added to the network each day (see Figure 3).

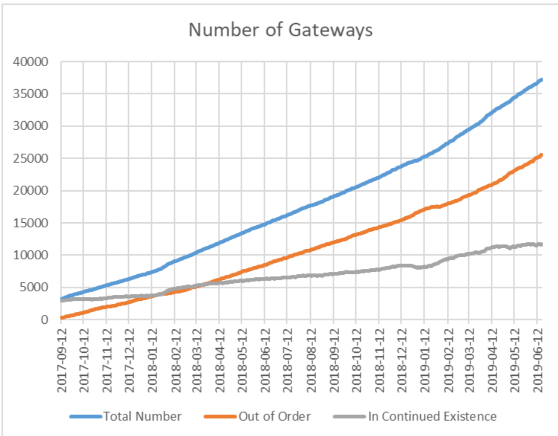

Figure 3. Number of gateways during measurement campaign.

To determine the independent variable whether a gateway is operated within a local community, a twostep process was applied to the API data. First, by means of an additional command line tool[3], the individual gateways from the API data represented by unique identifiers could be linked to individual users (represented by an anonymous user name). Second, these users’ automatically created webpage at TTN[4] were web scraped for the community membership indication of a particular user. As these web pages have computer generated identical structures, this process could be fully automated with no user input required. It was possible to determine the community membership of around 60% of the 37’222 gateways measured (n=22’322). Attempts to

[2] http://noc.thethingsnetwork.org:8085/api/v2/gateways

[3] https://www.thethingsnetwork.org/docs/network/cli/quick-start.html

[4] Every TTN user has got a public webpage according the following address scheme: https://www.thethingsnetwork.org/u/<user-name>

measure motivation in more dimensions than only community membership as result of a community identification in form of surveying among gateway owners failed because of a too low response rate.

The dependent variable operational performance was operationalized using three different measures: The probability of a continued existence of a gateway, the mean reliability of a gateway and the probability of a gateway achieving a high reliability greater than 99%.

The continued existence of a single gateway was measured as a binary stating whether a gateway is still at least from time to time online. This measurement is important taking into account the fact that a majority of all gateways are not existent anymore. A gateway was considered in continued existence if there was at least one successful contact with the TTN backend during the past 30 days. This period proved to be sensible as the experience showed that gateways seldom get back online after such an extended period of time. If a gateway was in continued existence, the reliability of the gateway was measured as fraction of the time that the gateway was actually online. This measurement was based on the hourly API data. A gateway was considered online, if the last contact to the TTN backend was no longer than one hour ago. Again, this proved to be a reasonable period because online status changes did not happen regularly on a minute basis. The mean reliability was calculated by averaging all the gateways in continued existence. Achieving a high reliability greater than 99% again was a binary calculated from the reliability measurements of gateways in continued existence. The reason for measuring this value is the comparatively low mean reliability which would not enable the operation of a useful and reliable network if there were no gateways with values greater than 99% reliability.

All three dependent variable were checked for statistical relevance. For the probability of a continued existence and the probability of a high reliability, a Pearson's chi-square test with Yates' continuity correction was applied to determine the p-value. The independence of data assumption and the expected frequencies of the contingency tables assumption (Field, Miles, & Field, 2012) are met. To determine the statistical relevance of the mean reliability, a Wilcoxon rank sum test with continuity correction was applied to determine the p-value because of non-normality of the mean reliability.

The above mentioned command line tool also provides information concerning geolocation and gateway make and model of a specific gateway if the corresponding gateway owner does not decide to hide this information from the public. All the data combined also allowed the examination of the reliable coverage of certain locations within cities. This was achieved by combining the reliability data of various gateways within a specific radius around these locations to determine the minimal number of gateways that were online at any time.

5 Results

The hypothesis states that community membership of gateway owners is associated with a higher operational performance. Table 2 shows the operational performance values of the TTN gateways depending on the community membership of the gateway owner. The mean reliability and the probability of high reliability are calculated considering the gateways in continued existence only.

n=22’322		no	yes	p-value
Independent variable	Community membership	69.4%	30.6%	
Operational performance (dependent variables)	Probability of continued existence	32.2%	47.0%	< 2.2e-16***
	Mean reliability	64.2% SD=34.3%	74.4% SD=27.7%	< 2.2e-16***
	Probability of high reliability > 99%	14.2%	15.2%	0.21

Table 2. Main result table with operational performance values of TTN gateways depending on community membership.

Table 2 shows significant effects for the probability of continued existence and the mean reliability. Gateways operated in a community context have a higher probability to be in continued existence and if so, they show a higher mean reliability compared to gateways operated outside a community. The effect of a higher probability of continued existence is even more noticeable when only gateways are considered, that were registered a longer time ago. For gateways with data available for more than 18 months, the probability of a continued existence of gateways operated within a community is nearly double compared to such outside of a community context. The generally low percentage of gateways in continued existence (see also Figure 3) hints at a characteristic of TTN as field of experimentation for people generally interested in LoRaWAN and IoT technologies. The effect of the community is less strong for the mean reliability. Regarding the mean reliability measures, it has to be taken into account, that the distribution of reliability is highly non-normal. There is no significant community effect observable concerning the probability of high reliability as the p-value of 0.21 does not allow to reject the null hypothesis with confidence.

To exclude the possibility that the observed community effects are only due to differences in make an model of the gateways used and the geographic location of the gateways and their owners, the operational performance parameters haven been calculated for all the different combinations of gateway make and model and geographical locations. The data available suggested a clustering of gateway makes and models into four categories:

- Pro: Professional grade ready to use gateways built for long endurance and outdoor use
- TTG: The TTN distributed *The Things Gateway* tailored specifically for use with TTN
- RPi: Gateways based on a raspberry pi with an added LoRaWAN module
- other: Various more or less home built and other uncommon devices

The location on the other hand has been clustered into the different continents. TTN gateways are not evenly distributed across the globe. High concentrations of gateways can be observed especially within cities in Europe (for example see Figure 3). Table 3 shows categorical and geographical distribution of TTN gateways. The large number of unknown values is due to the fact that gateway owners can decide on their own, whether they want to share the information about gateway make and model and the geographic location with the public.

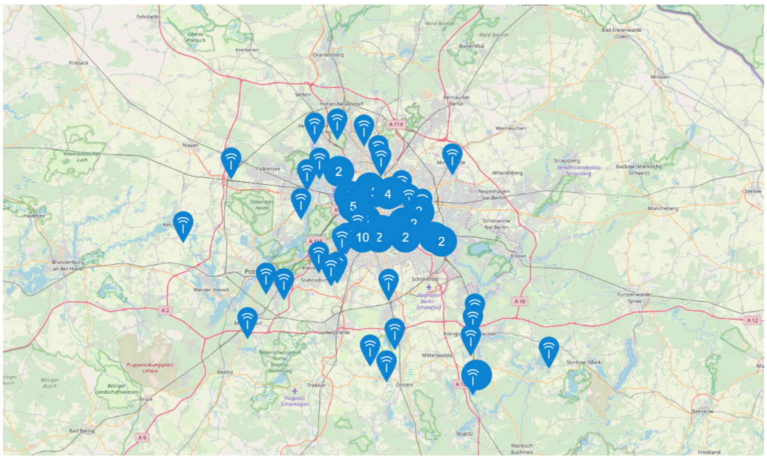

Figure 4. Placement of gateways in Berlin and the surrounding area[5].

	all	Pro	TTG	RPi	other	unknown
all	37’222	3546	2964	5725	12’712	12’275
North America	1507	211	187	177	544	388
South America	868	80	25	124	433	206
Europe	11’518	1334	1353	2691	4178	1962
Africa	264	28	7	59	112	58
Asia	1700	88	26	338	775	473
Australia	743	179	58	97	297	112
unknown	20’622	1626	1308	2239	6373	9076

Table 3. Categorical and geographical distribution of TTN gateways.

The higher operational performance in regard to the probability of a continued existence for gateways operated within a community holds true for most of the combinations of gateway categories and geographical regions (see Appendix). This allows excluding

[5] Source: https://www.thethingsnetwork.org, retrieved on 6th of August 2019

the possibility that the effect is only due to differences in various gateway categories and locations.

The data collected for the operational performance allowed further analysis regarding coverage and reliability of the whole network. Besides reliability of single gateways, extensive coverage and reliability of the whole network is a requirement for trustworthy and performant wireless network infrastructures. Drawing on the exact geolocation data of the gateways it was possible to determine network coverage and network reliability for selected locations in different cities. Table 4 shows the minimal number of gateways that were online at all times in the first half of 2019 within a radius of three kilometres around specific locations in various cities.

City	Location	Latitude [°]	Longitude [°]	Minimum number of gateways online at all times
Amsterdam	Main_Station	52.37875	4.900677	11
Berlin	Alexanderplatz	52.52217	13.412539	7
Bern	Main_Station	46.94932	7.43916	10
London	Kings_Cross	51.53155	-0.124335	4
Paris	Chatelet	48.86180	2.347195	1
Vienna	Main_Station	48.18511	16.376474	3
Zurich	Main_Station	47.37785	8.54033	16

Table 4. Network coverage in selected cities for the first half of 2019 within a radius of 3 kilometres around the specified location.

6 Conclusions

This research shows that *The Things Network* is a dynamically growing alternative in the LPWAN and IoT market. The number of registered gateways increased more than tenfold within the investigated 22-month period. Whereas a large portion of these gateways do not show a robust performance, the sheer number of gateways available and the fact that a transmitting node just has to be in reach from at least one working gateway makes up for this point. Furthermore, the fact that there are locations with permanent coverage over an extended period of time allow TTN to be considered for not only proof of concepts and experimenting but also for serious applications that depend on coverage and reliable connections.

This research uses objectively assessable data for gateway performance and community identification as opposed to research that depends on the self-declaration of such behavioural variables by the individual contributors. It highlights the positive effect of community identification as part of an intrinsic motivation on the performance of contributors and their gateways. The data shows that being a member of a local community results in a higher operational performance of the gateway. This effect is most pronounced for the continued existence of gateways leading to the conclusion that the effect of the community may lead to a higher endurance of the gateway operators.

Using the community to get technical assistance seems to be less relevant as the percentage of high performance gateways does not vary significantly with community membership. This makes sense since technical assistance to achieve a high reliability is easily available through other, mostly online, sources and materials.

Previous research already showed that community identification is related to a higher effort (David & Shapiro, 2008; Hars & Ou, 2002; Lakhani & Wolf, 2005) of contributors to crowdsourced projects. The scientific contribution of this study is the fact that community identification not only leads to a higher effort, but also to a better actual performance of the contributors' work as shown in Figure 1.

The results of this study are also relevant for practitioners and in serving as a recommendation for project managers of crowdsourced projects to build community mechanisms right into their project to leverage positive community effects. For public authority representatives commissioned with creating Smart City solutions and IoT connectivity, this research presents some indications that TTN may be considered as a serious alternative to professional network operators. This is also supported by the enormous growth of installed gateways during the sample period. The more than tenfold increase in gateway numbers is an expression of attracting a critical mass of contributing gateway users, which is seen as a very important factor in community built network infrastructure success (Camponovo, 2011).

The main limitation of this research is the fact that the community identification was only measured through a binary variable representing the community membership. It would be of great interest to be able to measure the identification more precisely and in different dimensions like the manner of the community engagement and the time spent in favour of the community. Furthermore, the data regarding gateway category and geographic location was only known through self-declaration of the gateway owner. Another limitation is the fact that the reliability could only be measured on the level of the gateways. This does not include an end-to-end consideration with the TTN backend included. There were times where no data was received from the API but these outages could either only be caused by the API being down or the complete TTN backend. Finally, as in every research of such kind, there is only evidence of a correlation between community membership and higher operational performance. This study gives reasonable explanation of this correlation but cannot make a causation statement. Furthermore, it could be argued, that community membership is a consequence of a pre-existing higher commitment. The method applied does not allow excluding such a possibility but if this would be case, the expected result would show that the community membership does not improve operational performance in every gateway category because one would expect people with higher commitment preferably selecting certain makes and models of gateways. Based on the data, this is not the case. Finally, this research can not ruling out the observation of the enormous growth of the network being only a hype effect in contrast to a sustainable development.

Further research should address these limitations. A better understanding of the community engagement and involvement should be the goal to explain the impact of a community on the performance of individuals.

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Appendix

	all	Pro	TTG	RPi	other	unknown
all	1.46	1.18	1.08	1.32	1.53	1.25
North America	1.37	1.18	1.18	1.05	1.65	0.87
South America	1.37	0.92	0.40	2.23	1.48	0.58
Europe	1.35	1.18	1.07	1.21	1.43	1.30
Africa	1.46	1.87	NA	1.18	1.75	2.57
Asia	1.94	1.42	2.17	3.01	1.73	1.46
Australia	1.58	1.49	0.92	1.27	1.60	1.30
unknown	1.24	1.03	0.80	1.05	1.18	1.20

Table 5. Ratio of probability of continued existence of gateways operated in community vs. out of community.

Citation information for the published version: Hitz-Gamper, B.S., Neumann, O. and Stürmer, M. (2019), "Balancing control, usability and visibility of linked open government data to create public value", **International Journal of Public Sector Management**, Vol. 32 No. 5, pp. 451-466. https://doi.org/10.1108/IJPSM-02-2018-0062

Balancing Control, Usability and Visibility of Linked Open Government Data to Create Public Value

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Abstract. Linked data is a technical standard to structure complex information and relate independent sets of data. Recently, governments have started to use this technology for bridging separated data 'silos' by launching linked open government data (LOGD) portals. The purpose of this conceptual paper is to explore the role of LOGD as a smart technology and strategy to create public value. This is achieved by enhancing the usability and visibility of open data provided by public organizations. In this study, three different LOGD governance modes are deduced: public agencies could release linked data via a dedicated triple store, via a shared triple store or via an open knowledge base. Each of these modes has different effects on usability and visibility of open data. Selected case studies illustrate the actual use of these three governance modes. According to this study, LOGD governance modes present a trade-off between retaining control over governmental data and potentially gaining public value by the increased use of open data by citizens. This study provides recommendations for public sector organizations for the development of their data publishing strategy to balance control, usability and visibility considering also the growing popularity of open knowledge bases such as Wikidata.

Keywords: linked data, open data, linked open government data, data governance, public value, Wikidata.

1 Open Data and Public Value

In recent years, a growing adoption of open government data (OGD) policies can be observed (H.-J. Wang & Lo, 2016), and many governments including those of the U.S., EU and UK have launched their own OGD portals online. OGD is part of the larger open data movement, which promotes the idea that non-personal and not security related data should be made available to everyone free of charge and restrictions[1]. Partly, this movement is the result of increasing pressure on governments to become more transparent (Welch & Wong, 2001). As government is one of the principal producers and collectors of data in a vast array of domains, government data is often viewed as a valuable resource offering great opportunities to stakeholders if it is openly available. Most notably, several scholars have argued that the creation of public value is one of these opportunities, if not the most important one (Attard, Orlandi, & Auer, 2016; Hui

[1] Open Data Handbook: http://opendatahandbook.org/guide/en/what-is-open-data

& Hayllar, 2010; Lee & Kwak, 2012; Zuiderwijk & Janssen, 2014) and many practitioners mention the creation of public value as one of the key goals of open data initiatives (Janssen, Charalabidis, & Zuiderwijk, 2012).

Generally, the promise of OGD is that it has a positive impact on society in four pivotal areas: 1) government transparency and accountability, 2) citizen inclusion and empowerment, 3) government efficiency and effectiveness, and 4) economic growth (Davies, 2013). Although, these effects of OGD have not been tested systematically and empirically (Safarov, Meijer, & Grimmelikhuijsen, 2017), there is evidence of OGD impact on the public sphere (de Kool & Bekkers, 2016; Lourenço, 2016). As such, the promises of OGD agree with many definitions of public value. Bryson et al. (2014), for instance, define public value as "producing what is either valued by the public, is good for the public [...], or both, as assessed against various public value criteria". Benington and Moore (2010) emphasize that public value means, "first, what the public values", focusing on "individual interests [...] of current users" and, "second, what adds value to the public sphere", focusing "on the longer term public good, including the needs of generations to come". Note that both of these definitions ascribe considerable interpretative power to the public when it comes to determining the public value of a phenomenon, meaning that how the public perceives the impact of government activities is key to whether they create public value or not. Additionally, to allow OGD to create public value, the data needs to be reliable and valid and it should enable citizens to create something they deem valuable (Harrison et al., 2012).

Importantly, the impact of OGD in the four pivotal areas named above is not an immediate result of making government data public, because OGD does not have any value in itself (Janssen et al., 2012). Instead, making an impact requires external actors to invest time and resources into working with OGD, for instance by data interlinking, visualization, analysis, or interpretation (Attard et al., 2016) and by eventually producing innovation (Lakomaa & Kallberg, 2013) and other forms of impact (M. Stuermer & Dapp, 2016). Jetzek (2016) mentions sharing and market mechanisms as the two principal ways of generating value by means of open data. To this end, OGD platforms and data formats need to be designed in a way enabling external actors to easily access, combine and use the data provided, even if it originates from multiple different public (and private) organizations.

In addition, concerns about privacy and 'big brother' surveillance threats are relevant in the context of OGD. Janssen and van den Hoven (2015) point out that both transparency and privacy are important values of governments. In their terminology big and open linked data (abbreviated as BOLD) presents new challenges to administrative organizations providing transparency within governmental activities while ensuring the privacy of its citizens.

Multiple analyses of existing OGD portals have illustrated that the use of OGD is often hampered by the multitude of different data formats and the lack of machine readability of the data (Neumaier, Umbrich, & Polleres, 2016; Smith & Sandberg, 2018; Umbrich, Neumaier, & Polleres, 2015). Additionally, Zuiderwijk, Janssen et al. (2012) have identified ten key impediments of public value generation, focusing on the perspective of the user. According to these authors, availability and access, findability, usability, understandability, quality, linking and combining data, comparability and compatibility, metadata, interaction with the data provider, and opening and uploading are key issues hampering public value generation by users. So, merely opening to the public the data 'silos', which many public organizations maintain is, in many cases, insufficient to foster the creation of public value. While opening data to the public certainly enhances visibility of the data and thereby government transparency, the data within individual open data 'silos' are often difficult to browse, query and connect (Shadbolt et al., 2012) due to a lack of common unique identifiers of data records and commonly used vocabularies and ontologies. Thus, the use of such open data remains limited, hampering the possibilities of external actors to interact with the data and leverage their public value potential (Heath, 2008). In our view, this last aspect and particularly its connection to linked data, has thus far been widely overlooked in the literature on OGD, constituting a substantial gap in research.

In this study, alternatives are explored regarding how public organizations can improve the way they provide open data to the public, enhancing both visibility and usability and thereby maximizing their potential to create public value. To this end, a user's perspective is adopted, heeding the call by Janssen et al. (2012). The focus lies on how OGD 'silos' can be bridged by the use of linked open government data (LOGD) (Shadbolt et al., 2012) as an overlap of government data, open data and linked data (see Figure 1).

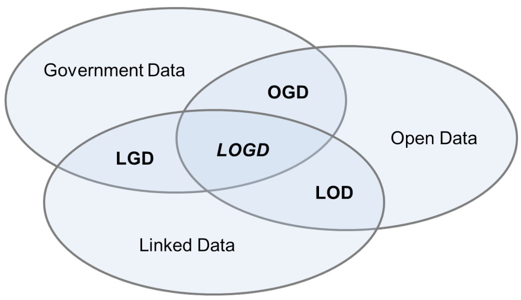

Figure 1. Linked open government data (LOGD) as overlap of government data, open data and linked data.

LOGD is already in use for several years in the public sector around the world (Ding, Peristeras, & Hausenblas, 2012). Starting in the UK the government has integrated LOGD into its OGD portal Data.gov.uk (Kalampokis, Tambouris, & Tarabanis, 2011). The US government is using linked data with their open government platform Data.gov (Bizer, 2009). Within the EU several research projects have resulted in recommendations for ontological frameworks and implementation models (Höchtl & Reichstädter, 2011). Villazón-Terrazas et al. (2011) have developed and validated methodical guidelines for publishing LOGD. Zuiderwijk, Jeffery et al. (2012) emphasize the potential of metadata in a linked data context and its value for users and publishers alike.

Consequently, the research question of this study is: *what options do public organizations have to publish their LOGD in such a way that data control, data visibility and data usability are balanced according to the organizations' requirements?*

We attempt to answer this question by deducing three different LOGD governance modes and their respective impact on control, visibility and usability, and we illustrate their use in selected case studies as suggested by Siggelkow (2007). As such, this study supports public sector organizations in assessing the existing potential, opportunities as well as risks derived from the implementation of LOGD and corresponding strategies as a smart technology to generate public value. Furthermore, this study intends to advise public organizations in handling the challenge of citizen participation in the form of data publishing via open knowledge bases like Wikidata.

This study follows an interdisciplinary approach, drawing on theory and literature from two disciplines: public management and information systems. In section 2, linked data will be introduced and its role as a solution to enhance the usability and visibility of OGD is explored. In section 3, three LOGD governance modes will be derived following a deductive approach along different levels of control, which public organizations are able to exert on their data during the publishing process. These LOGD governance modes will then be substantiated by case studies featuring these modes in section 4. Section 5 concludes the findings of this study.

2 Linked Data

Linked data is a collection of best practices to publish and connect structured data on the Web (Bizer, Heath, & Berners-Lee, 2009). On a technical level, linked data means using Web technologies to create links between data from different sources in a way that the data is machine-readable and has an explicitly defined meaning (Bizer, Heath, et al., 2009). The necessary mechanisms are specified in the Resource Description Framework (RDF),[2] which defines a language for representing information as linked data. Such linked data consists of nodes and directed arcs linking pairs of nodes. A subject node, predicate and object node form a so-called RDF triple. A unique identifier called Uniform Resource Identifier (URI) represents the individual nodes. Triples can be interlinked by using an object as a subject for another triple or by using new objects for existing subjects (see Figure 2). The aggregate of many interlinked triples then constitutes a so-called graph. A database suitable for storing linked data triples is called a triple store. (Bizer, Heath, et al., 2009).

[2] RDF Syntax: https://www.w3.org/TR/REC-rdf-syntax/

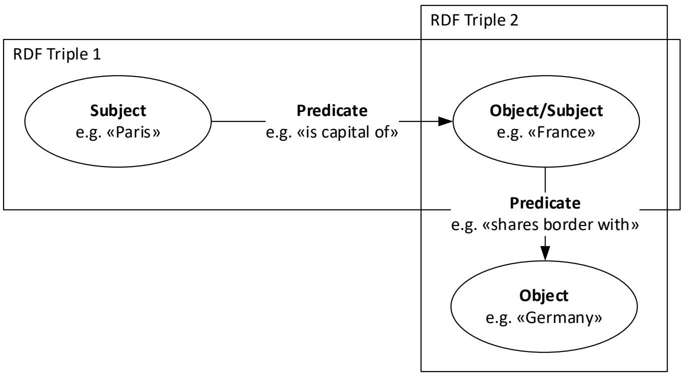

Figure 1. Two interlinked RDF triples.

Adherence to linked data principles can foster the use of OGD because it makes the aggregation and integration of heterogeneous data from different sources much easier (Heath, 2008; Neumaier et al., 2016). In this vein, Berners-Lee (2006) has presented a five star rating scheme for data encouraging government data owners in particular to use linked data as a possibility to bridge data 'silos'. The criteria for such five star data are: 1) availability on the web, 2) availability as machine-readable structured data, 3) availability in a non-proprietary data format, 4) availability by the use of RDF to identify things and finally 5) based on the technical possibilities resulting from 1) to 4): the inclusion of links to other related data (see Figure 3).

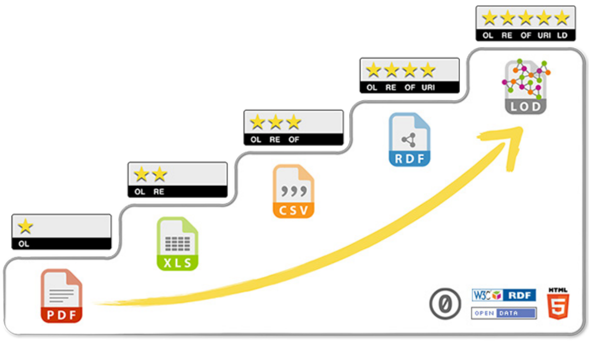

Figure 2. Five star open data rating scheme.[3]

Linked data allows for a complete separation of the data and any specific view upon it thus enabling forms of use that the creators may not have anticipated in advance (Heath, 2008). Moreover, using the established linked data principles, there is no need for the data consumer to learn a multitude of different data access techniques for different data sources (Bizer, Heath, et al., 2009; Hausenblas, 2009). Ultimately, the use of linked

[3] Source: http://5stardata.info

data is envisioned to enable everyone to use the Web like a single global database (Bizer, Heath, et al., 2009), called the linked open data cloud (LOD cloud). Figure 4 depicts the current state of this LOD cloud representing more than a thousand datasets from all over the Web.

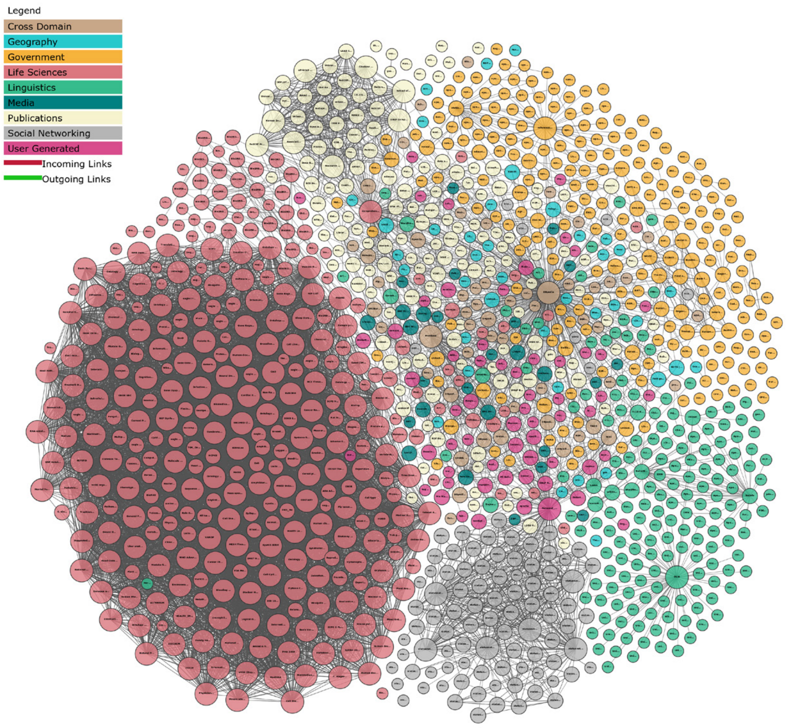

Figure 3: Current state of the LOD cloud (Abele, McCrae, Jentzsch, & Cyganiak, 2017) representing linked datasets.

Besides the mentioned advantages geared mainly towards data users, publishing LOGD also has some advantages for the data publishers: 1) the integration of additional data is cost effective (Bizer, Heath, et al., 2009), 2) there is no need to adhere to a particular scheme (Neumaier et al., 2016), and 3) releasing information as LOGD is cheaper than producing reports (Hendler, Holm, Musialek, & Thomas, 2012).

2.1 Data Interlinking for Enhanced Usability and Visibility

The data interlinking functionality of linked data is essential to achieve the goal of five star data (Berners-Lee, 2006). Linking the data is done by the RDF mechanism with the option to choose from two linking directions: outgoing and incoming links. Figure 5 shows the effects of these two types of linking. Outgoing links enhance the *usability* by connecting the data to other sources of information within in the LOD cloud. Incoming links improve the *visibility* by making the data easier to find for users browsing the LOD cloud.

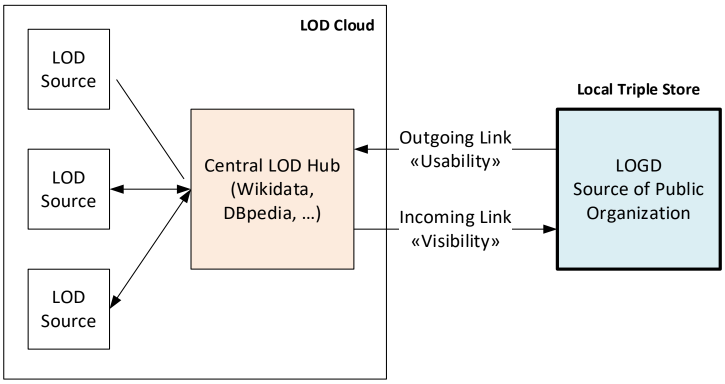

Figure 4. Outgoing and incoming links from the perspective of a local triple store.

Since an outgoing link is set up within the local triple store, creating such links requires no additional write access outside the local triple store. Incoming links however, need to be created in the LOD cloud and accordingly require write access to a triple store in the LOD cloud (see Figure 6). This emphasizes the importance of open knowledge bases acting as central LOD hubs (see Figure 5) in the LOD cloud where incoming links to a local triple store can be set up. These LOD hubs are a central element of the web of data (Bizer, Lehmann, et al., 2009).

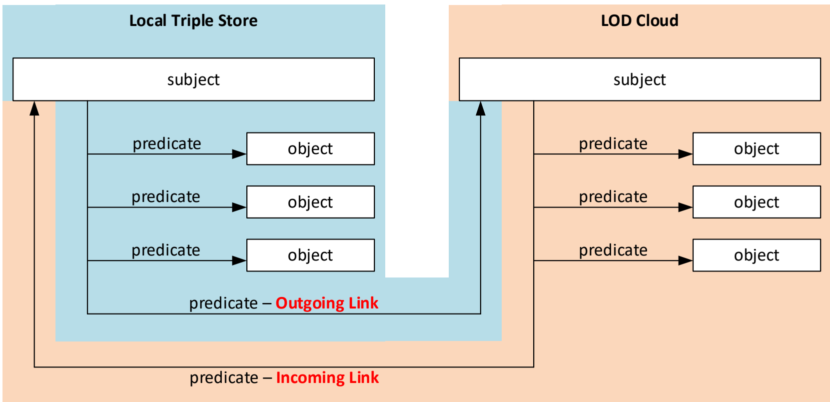

Figure 5. Outgoing and incoming links and their required write access.

3 Three LOGD Governance Modes Based on their Level of Control

Public organizations may face severe consequences if their data turns out to be inaccurate, outdated or incomplete, because they are accountable both legally and politically for the actions they take (Gilmour & Jensen, 1998). Correspondingly, they often prefer to be in full control over what and how the data they release is published (Janssen et al., 2012). As West (2003) shows, keeping control can, however, diminish some of the advantages of open knowledge. Keeping full control can even form some serious barriers to usability and visibility of the published data. Therefore, we believe public organizations should carefully choose the best option to publish their LOGD in view of the trade-off between data visibility, usability and control. In line with Stuermer et al. (2009), Boudreau (2010) and West and Bogers (2014), we consider the level of control to be an important discriminator. Hence, three main options are deduced regarding the degree of keeping control of the LOGD publishing process: a public organization can 1) keep full control over the entire publication process by using a *dedicated triple store*, 2) share it with some other public organizations in the form of a *shared triple store* or 3) share the control completely with the public by using an *open knowledge base* to publish their LOGD. We call these three options LOGD governance modes (see Table 1). Whereas option one and three present the poles of a keeping control scale, option two is a compromise. Different implementations of option two have in common the use of a single collective triple store shared by different public organizations.

Sharing the control with other public organizations has consequences by sharing information between the participating organizations, which is seen as a key strategic activity for public organizations (Yang & Maxwell, 2011). Sharing infrastructure can also lead to improved collaboration (Zuiderwijk & Janssen, 2014). However, public organizations often act independently without considering activities by other public organizations (Gil-García & Pardo, 2005). Nugroho et al. (2015) recommend assigning a designated organization for implementing open data policies and providing a shared infrastructure.

As will be shown, these modes have direct and indirect consequences on the usability and visibility of the data. In our view, these consequences should be viewed as inherent potentials as well as risks of the individual LOGD governance modes. In a particular implementation of a mode, such potentials may be realised or missed, while risks could be mitigated by the application of appropriate strategies.

3.1 Direct Consequences of the LOGD Governance Modes

The higher the level of control the higher are usually the design freedoms for the LOGD publishing process. Such design freedoms include the technical implementation, the representation of the data and the applied open data license.

Freedom to choose the technical implementation of the triple store and the query interface can be of importance for special purpose data, which profits from certain non-standard functionalities, such as sophisticated geospatial data operations. Freedom to choose the data representation eliminates restrictions concerning the vocabulary used for predicates to describe the data. In such a case, using a self-defined as well as an established standard vocabulary is possible without additional expenditure. In a shared environment or with an open knowledge base, there are usually requirements concerning the vocabulary and accordingly, changes like establishing new predicates are complex or even impossible. Freedom to choose the open data license allows the use of a tailored licence contrary to open knowledge bases, which may define certain restrictions concerning the allowed open data licenses.

The visibility of the LOGD depends crucially on the number of users and the incoming links to the data (see Figure 5). Open knowledge bases acting as data hubs in the LOD cloud have an advantage in this area due to the large contributor and user base as well as the high amount of data and its pre-existing links. Consequently, dedicated triple stores of small and specialised public organizations will probably face difficulties in creating enough attention of users for their data.

Open knowledge bases are geared towards attracting as much data as possible. Therefore they provide tools, instructions and examples for transforming the data into linked data triples and for the associated ontological process (Vrandečić & Krötzsch, 2014). This is not the case for a dedicated or shared triple store. Operating a dedicated triple store comes with a lower cost-effectiveness because of the missing possibility to share the cost among different data providers. In contrast, open knowledge bases usually offer their services at no cost for the data provider. Open knowledge bases are built around the idea of a community supporting the project and taking responsibility for the data published (Vrandečić & Krötzsch, 2014). This is not the case for a dedicated or shared triple store operated by a public organization. Furthermore, Lee and Kwak (2012) show that choosing an open knowledge base for publishing LOGD demonstrates a higher level of engagement with the public, leading to the realization of greater public value.

LOGD governance mode	**Dedicated triple store**	**Shared triple store**	**Open knowledge base**
Control			
Level of control	high	medium	low
Sharing of control	low	medium	high
Design choices			
Freedom to choose technical implementation	high	medium	low
Freedom to choose data representation	high	medium	low
Freedom to choose licence	high	medium	low
Visibility			
Visibility of triple store	low	medium	high
Further characteristics			
Support for data publishing	low	medium	high
Cost effectiveness	low	medium	high
Development of community	low	low	high
Engagement with the public	low	low	high

Table 1. The three different LOGD governance modes and their potential direct consequences.

3.2 LOGD Governance Modes and Data Quality

Because of their influence on data quality, the different LOGD governance modes have some more indirect consequences on data usability and somewhat on data visibility. Wang and Strong (1996) define data quality as data that is "fit for use" by the data consumer thereby establishing a link between data quality and usability. Only if the data is fit for use, it will actually be used creating the precondition for generating public value. Wang and Strong (1996) present different data quality categories and dimensions to evaluate the various aspects of quality. Strong et al. (1997) further emphasize the close relationship between data quality and usability. Although Zaveri et al. (2016) adapt and extend the abovementioned categories and dimensions explicitly to a linked data context, we have adopted the original classification from Wang and Strong (1996) as a more general concept of data quality for our research. We will cover only the dimensions influenced by the different LOGD governance modes. Wang and Strong (1996) have introduced four data quality categories and their associated dimensions: 1) intrinsic data quality, which is the quality of the data itself including accuracy, objectivity and believability, 2) contextual data quality representing dimensions such as added-value, timeliness and completeness, 3) representational data quality including interpretability, ease of understanding and consistency and finally, 4) accessibility data quality. The influence of the different governance modes on data quality are discussed in the following paragraph and summarized in Table 2.

1) At first sight, intrinsic data quality does not depend directly on the LOGD governance mode. As the name suggests, it seems to be an exclusively intrinsic feature of the data itself. However, if the published LOGD is mixed with data from other sources, either in a shared environment or in an open knowledge base, the collective intrinsic data quality may suffer from bad quality data from other sources, which may not be distinguishable from the original source without additional effort.

2) Regarding contextual data quality, the added value of using open knowledge bases may be their sophisticated tools to analyse and visualize the data. The data timeliness in a dedicated triple store operated by a public organization may be lower than in an open knowledge base with its many contributors, which are furthermore not tied to strict publishing procedures. The completeness of the data, however, is a challenge for open knowledge bases because an individual contributor may possess only incomplete information. As such, completeness in open knowledge bases is a subject of in-depth considerations (Ballatore, Wilson, & Bertolotto, 2013; Färber, Bartscherer, Menne, & Rettinger, 2017). For a dedicated triple store operated by a public organization, completeness of the available data is more easily ensured based on the systematic method of operation of such organizations.

3) Representational data quality includes interpretability and ease of understanding. Due to the restrictions of the vocabulary that may be used in a shared or open environment, these governance modes have an advantage in this regard. Representational consistency however, is positively influenced by a smaller number of contributors, favouring a dedicated solution. Furthermore, this simplifies the creation of a very concise representation of the data because of the possibility to create well-tailored, new predicates instead of having to choose from a limited vocabulary.

4) Accessibility data quality is influenced by the technical realization of the triple store. Open knowledge bases can have an advantage in this regard because they offer their service to a wide variety of users, and, therefore are strongly interested in being as accessible as possible.

LOGD governance mode	**Dedicated triple store**	**Shared triple store**	**Open knowledge base**
Intrinsic data quality			
Accuracy, objectivity, believability	high	high	low
Contextual data quality			
Value-added	low	low	high
Timeliness	low	low	high
Completeness	high	medium	low
Representational data quality			
Interpretability	low	low	high
Ease of understanding	low	low	high
Representational consistency	high	high	low
Concise representation	high	medium	low
Accessibility data quality			
Accessibility	low	low	high

Table 2. The three different LOGD governance modes and their potential effects on data quality and subsequent data usability.

4 Case Studies

The following section provides case studies observed in Switzerland for each of the different LOGD governance modes.

4.1 Method and Case Selection

In accordance with Siggelkow (2007), the following case studies are used to illustrate and make plausible the conceptual considerations leading to the LOGD governance modes described above. Furthermore, the case studies contribute to additional insights to the LOGD phenomenon (Walsham, 1995). The case selection was done not by random selection to achieve representativeness but by choosing important cases illustrating the LOGD governance modes following King et al. (1994). As such, the selected cases represent good practice examples. Regarding the selection of the case of an open knowledge base, Wikidata was chosen as an archetype of such open knowledge bases. This Wikidata case is further supplemented by considerations on how public organizations could react to such open knowledge bases.

4.2 Case Study Dedicated Triple Store

The Swiss Federal Office of Topography operates a federal spatial data infrastructure including a dedicated triple store, which provides datasets as linked data.[4] The available datasets contain mainly spatial information about the country, its cantons, districts and municipalities. This information is version-controlled to enable the reconstruction of the temporal evolution. Furthermore, the data is enriched with some current statistical data such as population numbers. The municipalities in the triple store have additional outgoing links to Wikidata.

Furthermore, Wikidata also links back to the municipalities stored in the dedicated triple store thus creating incoming links in the triple store of the office of topography. This is possible easily because of the open nature of Wikidata where the general public is allowed to create new links. This linking between Wikidata and the dedicated triple store enables the creation of mashups combining data from both sources without effort. Figure 7 demonstrates such a mashup combining geographical boundary data for a Swiss municipality with additional information about the mayor of the municipality and its political party. The latter information originates from Wikidata. This combination of data was achieved by a single SPARQL query[5] to the dedicated triple store and did not involve any data transformation, which would be necessary if the data were not linked.

[4] www.ld.geo.admin.ch

[5] http://yasgui.org/short/rJAIpzpw7

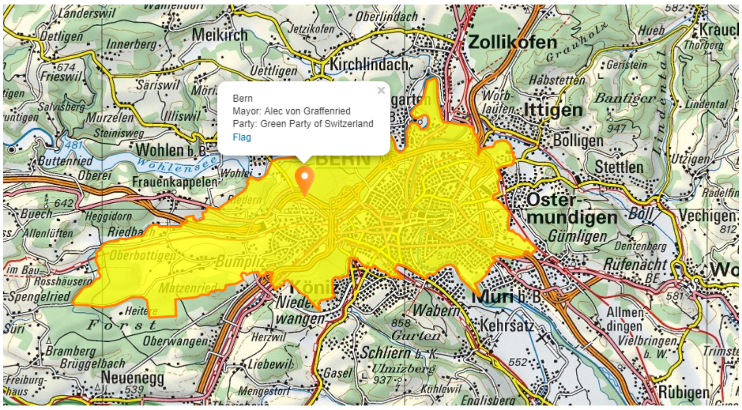

Figure 6. Data mashup by using geographical boundary data from a dedicated triple store and additional information from an open knowledge base (Wikidata) by execution of a single query.

4.3 Case Study Shared Triple Store

The Linked Data Service (LINDAS)[6] operated by the Swiss Federal Archives is an example of a shared triple store. It can be used by Swiss public organizations to make their data available as LOGD. So far, it is a prototype to examine the potential of LOGD. The setting up of LINDAS included the creation of a nation-wide consistent URI naming scheme. Today, the data available on LINDAS consists of twenty-one different data sets. Many of them are often only fragments of larger data sets to enable specific use cases to demonstrate the possibilities of LOGD. The total count of LOGD triples in LINDAS is about forty million. An excerpt from the available datasets and its providers is shown in Table 3.

Dataset description	Dataset provider
Air quality in Switzerland	Federal Office for the Environment
Heavy metal legacies in Switzerland	Federal Office for the Environment
Historicised municipality inventory	Swiss Federal Statistical Office
Public transport stops	Federal Office of Transport
Animal transports data	Federal Food Safety and Veterinary Office
Governmental agency directory	State Secretariat for Economic Affairs
Meteorological weather data	Federal Office of Meteorology and Climatology

Table 3: Excerpt of available datasets and their providers in the shared triple store LINDAS.

[6] https://lindas-data.ch

Implemented application scenarios include an animal disease outbreak analysis, an energy management algorithm for railway coaches, a historicised official municipality register, and historical federal budgets.[7] Today, LINDAS does not include any links between the different LINDAS datasets and no outgoing links to Wikidata or other open knowledge bases.

4.4 Case Study Open Knowledge Base

Wikidata[8] is a crowdsourced open knowledge base. It is part of the Wikimedia Foundation and as such a member of a well-established culture of contributions by the general public. It contains more than 41 million items and currently has nearly 7900 active users with more than five edits over a one-month period.[9] Wikidata explicitly does not store facts but so-called statements since sometimes there is no global agreement on the "true" data (Vrandečić & Krötzsch, 2014). These statements are represented as linked data. Since Wikidata is not a primary source of information, these statements are supposed to contain a reference to the corresponding source. Wikidata can also deal with contradictory statements (Vrandecic, 2013). The content of Wikidata can be accessed through the Wikidata website, via the linked data query language SPARQL or by using an Application Programming Interface (API). Wikidata is designed to be used by both humans and machines.

Public organizations are affected by open knowledge bases like Wikidata for two reasons. First, Wikidata challenges such organizations by allowing everyone to publish LOGD from the manifold of available sources of government data. Even if public organizations choose not to publish any linked data at all, there would be LOGD available to the public affecting their sphere of interest. This would result in the public organizations losing the data publishing sovereignty in their own realm. Second, public organizations may use Wikidata for their own benefit and profit from the elaborated and free platform and visibility that it offers to improve the impact of LOGD thus generating potential to create public value.

Publishing data on Wikidata requires the use of a certain licence that guarantees a public domain dedication. Due to the openness of Wikidata, there is no guarantee that data put on Wikidata by public organizations will not be edited in a fraudulent or faulty way by third parties. However, Wikidata as a socio-technical system is prepared for such scenarios and provides tools enabling its community to roll back fraudulent or faulty edits. The large number of users and editors also increases the probability of detecting such edits promptly and reliably.

In Wikidata, there are no rules excluding information from certain sources nor are there any restrictions in regard to data published by public organizations. Wikidata requires published data to be in accordance with Wikidata's notability criteria.[10] These criteria include referring to a conceptual or material entity, which can be described using publicly available resources.

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[7] https://www.egovernment.ch/en/umsetzung/e-government-schweiz-2008-2015/lindas/
[8] https://www.wikidata.org
[9] Source: http://wikidata.wikiscan.org (accessed: 18th of February 2018)
[10] https://www.wikidata.org/wiki/Wikidata:Notability

Our case study example of LOGD on Wikidata are the more than 2000 Swiss municipalities that have an entry on Wikidata. The range of available data for these municipalities varies from only a few basic statements including for example the number of inhabitants to very detailed information such as on the heads of government of the particular municipality during the 16th century.

Open knowledge bases will be of increasing importance because more and more applications are using the publicly available data stored there. An example case for such an application could include information concerning the tax rate (which in Switzerland differs from municipality to municipality) and the available building area reserve within a certain municipality. This information could be used in a housing search engine as decision guidance for someone contemplating to move to a certain place or not.

5 Conclusions

The main contribution of this study is the distinction of three different LOGD governance modes for data publishing and their resulting characteristics regarding the degree of control, data usability and data visibility. Furthermore, different possibilities for linking LOGD from different sources and the resulting effects on data usability, data visibility, and, finally the creation of public value are illustrated. These effects should be seen as inherent chances and risks, not definite outcomes. On the one hand, valuable chances to support public value creation could be missed. On the other hand, risks inherent to a certain LOGD mode may be mitigated by responding appropriately. Using the presented LOGD governance modes and linking the data will help not only to open up the data 'silos' but also effectively tear down any 'silo' boundaries. Furthermore, using open data in more effective ways by drawing on help from the outside may also help public organizations to cope with what has been described as the "big data revolution" in public affairs (Mergel, Rethemeyer, & Isett, 2016).

As Table 1 and Table 2 show, there is no single LOGD governance mode combining all the advantages thus, we conclude that public organizations should be aware of the different forms of data governance and their strengths and weaknesses. Depending on the scenario, governments may choose to select a dedicated triple store, a shared triple store or an open knowledge base such as Wikidata. In this process, public sector IT departments should use their knowledge about open standards to play a key role (Fishenden & Thompson, 2013).

If a public organization needs to retain full control over the data during its whole life cycle, they may choose to operate a dedicated triple store. In this case, the organization should consider creating outgoing links to the LOD cloud to enhance usability and setting incoming links to the local store in open knowledge bases like Wikidata to enhance visibility. If, on the other hand, saving resources is of prime importance and some loss of freedom and flexibility is considered acceptable, a public organization may choose to publish via a shared triple store. This will enable the organization to share some of the expenditures. Finally, regarding data sets containing information usable in a wide variety of ways and possibly of interest to the general public like public transport, geography, climate and weather, a public organization should consider publication of this data in an open knowledge base like Wikidata. Citizens using such data to create valuable applications could compensate the loss of control of the public organization. Such a use of LOGD would be promising for the creation of public value (Attard et al., 2016; Hui & Hayllar, 2010; Lee & Kwak, 2012; Zuiderwijk & Janssen, 2014).

Our case studies show, that the three LOGD governance modes are indeed used for publishing LOGD. The first case demonstrates a dedicated triple store showing the possibility of a technical realisation supporting specific data (in this case geospatial data) and the possibility to visualize such data right from the query interface. Examples and instructions how to use the data show the intention of the data publisher to help potential users benefit from the LOGD in order to create public value. The second case study involves a shared triple store (LINDAS) showing the cooperation of different public organizations to publish their data. Unfortunately, the datasets on this shared triple store are not interlinked to each other and there are no outgoing links to open knowledge bases. This shared triple store has some characteristics of a showcase targeted more at publishing organizations than at data users. Correspondingly, there is less support for potential data users like instructions and examples. However, recent actions of the Swiss Federal Archives point to a future of LINDAS as a more productive shared triple store environment. About 26 million Swiss Francs[11] are being invested for this purpose. The third study looks at the open knowledge base Wikidata. It shows one of the strengths of such an open knowledge base, taking as an example the vast amount of very detailed and specific information about individual municipalities. However, such very profound information is available only for a small subset of the entirety of Swiss municipalities demonstrating a lack of data completeness.

Using the dedicated triple store of the office of topography as an example, we have briefly illustrated some of the potential of the use of LOGD. Thanks to the linking of the underlying data, no more than the execution of a single query was necessary to combine data from the dedicated triple store and from Wikidata.

Concluding, we believe that the general concept of LOGD may help to lower the impediments to the use of open data mentioned by Zuiderwijk, Janssen et al. (2012). Linked data allows for easier understandability of OGD, linking and combining different OGD sources, and the addition of metadata to OGD. Additionally, the choice of an appropriate LOGD governance mode may help to decrease further, specific impediments. Using an open knowledge base for example, allows for easier access to OGD and stimulates the interaction with the data provider.

The main limitation of our approach is its conceptual nature. Future research should include a more in-depth, empirical analysis with the goal of formulating best practices for LOGD publishing involving open knowledge bases. Furthermore, some mixed approaches should be considered, like publishing only parts of the data to an open knowledge base while reserving the complete data for a dedicated or shared triple store. Such approaches would presumably be able to combine the advantages of both modes.

[11] https://www.inside-it.ch/articles/51757

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Citation information for the published version: Oliver Neumann, Christian Matt, Benedikt Simon Hitz-Gamper, Lisa Schmidthuber, Matthias Stürmer, Joining forces for public value creation? Exploring collaborative innovation in smart city initiatives, **Government Information Quarterly**, Volume 36, Issue 4, 2019, https://doi.org/10.1016/j.giq.2019.101411

Joining Forces for Public Value Creation? Exploring Collaborative Innovation in Smart City Initiatives

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Abstract. Creating public value is a key goal of public administrations, both in their daily business and in the growing field of smart government and smart cities, which focuses on IT-enabled innovations in the public sphere. However, many public administrations still struggle with such innovations due to complex technologies, high investments, and the numerous stakeholders involved. To address this issue, some local governments in continental Europe have turned to collaborative innovation approaches, partnering with (semi-)public utility companies in the hope that their additional innovation assets will boost innovativeness. Nevertheless, it remains unclear how exactly such collaborations should be governed to ensure that the focus remains on creating public value, as utility companies may have their own agendas. To explore this question, we conducted a comparative case study in the context of smart city initiatives with four cases in Swiss local governments. Drawing on agency and stewardship theory, we then propose a model of public-value-focused collaborative innovation, enabling us to explore various collaboration characteristics and their effects on public value creation. Our findings suggest that both agency- and stewardship-based collaborations increase innovativeness. However, while agency collaborations tend to produce smart city innovations that mainly serve the utility companies' business interests, stewardship relationships lead to innovations that are focused more on public value creation. As such, our study extends the literature on the effects of collaborative innovation on public value, and it provides practical recommendations on how such collaborative innovation should be designed.

Keywords: public value, collaborative innovation, local government, utility company, stewardship theory, agency theory, Switzerland

1 Introduction

The pursuit of public value creation is increasingly viewed as a core paradigm in public administration, guiding public action and laying the foundations for government legitimacy at all levels, federal, regional and local (Bryson, Crosby, & Bloomberg, 2014; Cordella & Bonina, 2012; Talbot, 2009). The concept of public value has been defined in many different ways, for instance as "what impacts on values about the 'public'" (Meynhardt, 2009, p. 205), where values about the public can refer to different dimensions such as service quality, integrity, equal opportunities and citizen involvement (Jørgensen & Bozeman, 2007; Meynhardt, 2009). Acknowledging the relative "fuzziness" of the concept and the many other definitions around (Bryson, Sancino, Benington, & Sørensen, 2017; Talbot, 2009), for the sake of clarity and simplicity, this study uses the public value definition as laid out above.

In recent years, a new avenue for public value creation has been identified in the growing field of IT-enabled innovations in the context of digital government (Cordella & Bonina, 2012; Pang, Lee, & DeLone, 2014; Soe & Drechsler, 2018). This development is particularly prevalent in the literature on smart cities and smart government, as these concepts encompass at their core dimensions such as citizen centricity, innovation and technology savviness (Gil-Garcia, Zhang, & Puron-Cid, 2016). It is especially the dimension of citizen centricity that is closely related to the concept of public value: "Citizen centricity is a key dimension characterizing smartness in government. It implies that governments know what citizens want and use ICTs to fulfil citizens' needs and provide personalized information and services" (Gil-Garcia et al., 2016, p. 527). At the same time, achieving smartness in government depends on IT-enabled innovations which, in turn, require profound knowledge of certain key technologies such as mobile phone services, artificial intelligence, wireless technologies, power grids, a multitude of different (IoT-)sensors, broadband, wide-area networks, data management and analytics and RFID tags (Kankanhalli, Charalabidis, & Mellouli, 2019; Naphade, Banavar, Harrison, Paraszczak, & Morris, 2011). For instance, smart city initiatives, smart parking solutions, in which the interaction of sensors, apps and corresponding user interfaces ensures that citizens are better informed about free parking spaces, may allow local governments to improve public value aspects such as service quality and reliability (Meynhardt, 2009). Other examples of possible smart city services include air pollution control, citizen issue reporting, home crime prevention, and missing children prevention (for an encompassing list of services, see Lee & Lee, 2014).

However, since the necessary knowledge of technologies is often not sufficiently available in governments, driving IT-enabled innovation internally is in many cases not a viable option. Additionally, to make such public-value-focused innovations work, different IT-devices and applications across several stakeholders need to work together, requiring not just profound technological skills, but also concerted efforts from local governments and other players, such as sensor manufacturers, parking providers, and app developers (Bryson et al., 2014; Sørensen & Torfing, 2011). It further has to be noted that, failures in such complex, IT-enabled innovation projects may not only lead to high costs, but also to public administrations wasting resources that could have been used to leverage public value creation potential elsewhere. Considering this is important as the public sector faces particular challenges to succeed in complex innovations due to constraints from political decision-making (Koppenjan & Klijn, 2004), long-time horizons of investments, comparatively small innovation budgets (Borins, 2001), and a culture of risk aversion and resistance to change (De Vries, Bekkers, & Tummers, 2016; Feiock, Lee, Park, & Lee, 2010; Mulgan & Albury, 2003).

To address these challenges and to drive IT-enabled innovation in smart government initiatives, public administrations increasingly collaborate with public, non-profit and private actors. Such joint innovation programs have been termed "collaborative innovation" (Hartley, Sørensen, & Torfing, 2013; Sørensen & Torfing, 2011; Torfing, 2019), defined as "multi-actor collaboration that [...] may foster innovation by bringing together public and private actors with relevant innovation assets, facilitating knowledge sharing and transformative learning, and building joint ownership to new innovative visions and practices" (Sørensen & Torfing, 2012, p. 1). The innovation assets held by partnering actors may include experience, knowledge about new technologies, creativity, or budget (Crosby, 't Hart, & Torfing, 2017), so that the problem-solving capacities and innovativeness of the involved public administration are enhanced through the collaboration. Collaborative innovation is thus, at least in the context of the public sector, often seen as a "superior innovation driver" (Torfing, 2019, p. 1).

However, it should not be overlooked that cooperation partners may have interests of their own and the administrations' goal to create public value through IT-enabled innovation may not necessarily be coherent with them (Klievink, Bharosa, & Tan, 2016). Public and semi-public utility companies, which will be at the fore in this study, like any other company tend to primarily strive to create private business value in the form of revenue and profits (Moore, 1995, p. 35), which illustrates the potential for a conflict of interest in such collaborative innovation. Therefore, it is essential to investigate the results of collaborative innovation with regard to the creation of public value in more detail.

Previous research has stressed that the relationship between IT resources and public value creation is mediated by capabilities such as public service delivery, public engagement, co-production, resource-building, and public-sector innovation capability, and that these capabilities are important levers for public managers to stimulate public value creation (Pang et al., 2014). However, empirical evidence on the aspects of innovation and co-production/collaboration from a public value-perspective is still scarce. Hence, a first important gap in the literature that we address is *whether* collaborative innovation can contribute to the creation of public value as one of the principal aims of public administration (Meynhardt, 2009; Moore, 1995) or rather leads to increasing business value. A second important gap that we seek to close is *how s*uch collaborative innovation should be designed and governed for increasing innovativeness while ensuring that the focus is on public value creation.

To address the aforementioned research gaps, we conduct a case-based analysis in the context of smart city initiatives in local governments. Many local governments have started turning to public and semi-public utility companies, which are primarily responsible for providing natural monopoly services such as water, gas, electricity and telecommunications services, as partners in collaborative innovation in their smart city programs. This development is particularly evident in continental Europe, where utility companies are often at least partially owned by the municipalities, meaning that utilities in these countries are state-owned enterprises (SOEs) and usually have strong relationships with the respective local governments (OECD, 2017) compared to their often privatised counterparts in the UK or the US. And although such utility companies are often still quite closely integrated with the local governments, more flexible regulation has led them to resembling private sector organisations regarding their organisational structures and processes, improving both their innovativeness and competitiveness (Vogelsang, 2002).

Not only owing to their extensive presence in many central European markets, we hold that analysing collaborative innovation between public and semi-public utility companies and local governments is of high interest for practice and research alike. It is also the particular nature of utility companies as often SOEs that makes such an analysis particularly appealing in the context of public value creation. We focus intentionally on the local level of government where the interaction between public administration and its users is the most direct (Benington, 2009) and public value creation is more tangible than at higher administrative levels. Based on our theoretical model, which draws on agency theory (Jensen & Meckling, 1976; Ross, 1973) and stewardship theory (Davis, Schoorman, & Donaldson, 1997), we conducted a comparative case study involving four cases where local governments in Switzerland use different approaches to collaborative innovation with a utility company in the context of smart city initiatives.

In all, by analysing the effects of different types of collaborative innovation in the public sector, this study contributes to the literature on public value creation when multiple stakeholders are involved (Bryson et al., 2017; Hartley, Alford, Knies, & Douglas, 2017; Page, Stone, Bryson, & Crosby, 2015). Cordella and Bonina (2012) underline the importance of analysing the effects of the public sector's IT adoption on social and political dimensions rather than applying private sector frameworks with a focus on achieving only better financial outcomes. The public value paradigm serves as an ideal theoretical framework for investigating the outcomes of collaborative innovation, as the framework takes both the complexity of implementing IT-enabled innovation (Cordella & Bonina, 2012) and public sector-specific goals in the smart city context into account. By illustrating how such collaborative innovation setups are designed in practice, we also contribute to the literature on collaborative innovation in the public sector (Hartley et al., 2013; Sørensen & Torfing, 2011; Torfing, 2019), adding to recent research that links collaborative innovation to public value governance (Crosby et al., 2017). Additionally, we provide actionable recommendations for practitioners in local public administration on how to optimise their collaborative innovation approaches in order to enhance public value creation. Our contribution is timely as many local governments are currently engaging in IT-enabled innovation endeavours in the context of smart city programs (e.g. Gil-Garcia, Helbig, & Ojo, 2014; Meijer & Bolívar, 2016).

2 Theoretical Foundations

2.1 Public Value Creation through Collaborative Innovation

One of the key goals of public sector organisations is the creation of public value, which means that public managers are "explorers commissioned by society to search for public value" (Moore, 1995, p. 299). Bryson et al. (2014, p. 448) understand public value as "producing what is either valued by the public, is good for the public [...], or both, as assessed against various public value criteria". Benington and Moore (2010) point out that public value means "first, what the public values", focusing on "individual interests [...] of current users" and, "second, what adds value to the public sphere", focusing "on the longer term public good, including the needs of generations to come" in a collectively shared view of a good and just society (Geuijen, Moore, Cederquist, Ronning, & Twist, 2017). In this study, we draw on Meynhardt (2009, p. 205) who offers a more tangible definition and conceptualisation of public value: "Public value is what impacts on values about the 'public'". The said values, in turn, may refer to one or more of the four commonly used public value dimensions: moral-ethical (e.g. integrity, human dignity), hedonistic-esthetical (e.g. service quality, reliability), political-social (e.g. citizen involvement, compromise), or utilitarian-instrumental (e.g. openness, sustainability). Public value is, of course, not static or inherent but arises through activities such as public service delivery (see e.g. Hartley et al., 2017; Moore, 1995). As such, a particularly promising avenue for public value creation is innovation in regard to the products and services which public administrations offer to citizens (Bommert, 2010; Cordella, 2007; Hartley, 2005; Pang et al., 2014). Hartley (2005, p. 30) even argues that "in public services [...] innovation is justifiable only where it increases public value in the quality, efficiency or fitness for purpose of governance or services." This notion of public sector innovation is also inherent in the concept of smart cities, "which deals with innovation (not necessarily but mainly ICT-based) in the urban space that aims to enhance the 6 city dimensions (people, economy, government, mobility, living and environment)" (Anthopoulos, Janssen, & Weerakkody, 2016, p. 89). All of the six mentioned dimensions may be understood as contributions to public value creation.

However, especially in the context of IT-enabled innovations which are often the basis for smart city initiatives, the innovativeness of public administrations is impeded by at least four important factors (Borins, 2001; Sørensen & Torfing, 2011). First, adherence to legal and bureaucratic rules is a key principle in government organisations, which often means that the consequences of failed innovations are grave. This in turn leads to high-risk aversion among politicians and public employees, which is detrimental to innovation. Second, there is a lack of competition, economic incentives and venture capital in the public sector confining innovativeness. Third, the complexity of public services tends to be high due to political and legal obligations and the multitude of stakeholders, which governments have to take into account, making change and innovation difficult. Innovation in the public sector often follows complex multi-step processes requiring stringent management efforts to succeed (Wonglimpiyarat & Yuberk, 2005). Fourth, and of particular relevance in IT-enabled innovation, local governments frequently lack personnel with sufficient knowledge of the latest technological developments and innovations. This last issue is further aggravated by the not-so-innovative image of most public organisations, leading innovative individuals to self-select into the private sector. It is important to note, however, that some of the described features of governments hindering innovation are in place for a reason, and some of them even directly create public value, for instance in the dimensions of equal opportunities (Cordella, 2007; Cordella & Willcocks, 2010). Nevertheless, a certain amount of innovativeness is still desired. Borins (2001, p. 311) describes this dilemma as follows: "In all likelihood, we as a society do not want the public sector to be as innovative as the private sector, nor to display the volatility of Internet start-ups. Yet it is equally likely that we want the public sector to be more innovative than it traditionally has been".

Collaborative innovation has been suggested as one possible approach to overcome the dilemma described above, helping public organisations to create public value through innovation by combining resources, sharing knowledge, and making use of innovation assets of partners (Soe & Drechsler, 2018; Sørensen & Torfing, 2011; Torfing, 2019). This is also reflected in the following definition, where collaborative innovation is understood as "multi-actor collaboration that [...] may foster innovation by bringing together public and private actors with relevant innovation assets, facilitating knowledge sharing and transformative learning, and building joint ownership to new innovative visions and practices" (Sørensen & Torfing, 2012, p. 1). As such, public value need not be created by a single public organisation independently but can be created in an orchestrated collaboration with other public or private organisations (Crosby et al., 2017), which is a shift from pure in-house production to a joined-up production mode (Cordella & Paletti, 2018).

However, it has to be noted that despite the various benefits associated with collaborative efforts, collaborations in the context of local public administration may also fail to deliver public value (Barringer & Harrison, 2000). Reasons for failure of interorganisational collaboration include, for example, the challenge of combining different organisational cultures and divergent expectations concerning value creation (Bryson et al., 2017). If multiple stakeholders are involved in public value creation through collaborative innovation, one has to consider that "different individuals and groups in society hold different views about which conditions in their societies should be viewed as public problems to be solved by government action, and what particular actions should be taken by the government to address the problems" (Geuijen et al., 2017, p. 629). It is especially the configuration of the collaboration between governments and their partners in IT-enabled innovation that we hold to be important for the innovation outcome and whether public value is created or not. However, to date, empirical research investigating how collaborative innovation needs to be designed in the context of IT-enabled innovations from a public value perspective is still scarce (see also Cordella & Bonina, 2012), although the research interest on the public value of IT-enabled projects in the smart city and e-government context is growing (Twizeyimana & Andersson, 2019). Specifically, there is a lack of both comparative case studies on public value in this context, and empirical research on questions related to the creation of public value (Klievink et al., 2016; Twizeyimana & Andersson, 2019). In the following, we address these gaps in research, drawing upon agency and stewardship theory to develop a model that describes different forms of collaborative and IT-enabled innovation and their impact on public value creation. Moreover, we empirically illustrate the model based on a comparative case study involving four cases in Swiss local governments.

2.2 Agency Theory and Stewardship Theory

Agency and stewardship theories are particularly suited for analysing collaborative innovation setups since they allow us to scrutinise the interplay between frequently less innovative actors, such as local governments, and potentially more innovative actors, such as utility companies. Agency and stewardship theories have in common that both refer to the relationship between two parties: principals, who seek partners to support them in certain activities which promote their mission or interest (such as driving innovation), and agents, respectively stewards to perform the desired activities on their behalf or cooperate with them (Davis et al., 1997). However, there are also some notable differences between agency theory and stewardship theory, which we will discuss next:

Agency theory (Jensen & Meckling, 1976; Ross, 1973) assumes that actors are rational, self-serving economic beings seeking to maximise their individual utility. This holds for both agents and principals, whose relationship is usually based on a contract where the agent carries out certain duties on the principal's behalf and receives a reward in return. Financial incentives and monitoring instruments are used to ensure that the agent will act in the principal's interest. This is because the agent's and the principal's interests usually diverge and there is a lack of trust (Van Slyke, 2006). However, such incentives and monitoring measures may often not be very effective, for instance if agents have an informational advantage over the principal regarding the tasks they perform on their behalf and their respective outcomes (Davis et al., 1997), when the agent's contributions are difficult to measure, which is often a problem in the public sector, or if agents are already committed to the goals of the principal (Cordella & Cordella, 2017). Notwithstanding the theoretical complexities and conjectures surrounding agency theory (Davis et al., 1997; Eisenhardt, 1989), for the purpose of our discussion, we rely on this basic understanding of agency theory.

Stewardship theory responds to the shortcomings of agency theory and agency-based collaborations by studying "situations in which executives as stewards are motivated to act in the best interests of their principals" (Donaldson & Davis, 1991). In contrast to agency collaborations, the interests and actions of stewards are aligned with the interests of their principals (Davis et al., 1997). Stewards are assumed to act for the benefit of the principal because they value the utility drawn from such behaviour and working towards a larger purpose as higher than the utility gained from self-serving behaviour (Davis et al., 1997). As Block (2013, p. 16) puts it, "stewardship begins with the willingness to be accountable for some larger body than ourselves". In contrast to agency theory, governance mechanisms and extrinsic incentives are not necessary to align the steward's behaviour with the principal's interests. Instead, "stewards are motivated to behave in ways that are consistent with organisational objectives" (Davis et al., 1997, p. 25) and control mechanisms may even diminish the motivation of stewards (Argyris, 1972; Frey & Jegen, 2001). As such, stewardship theory promotes organisational structures that facilitate and empower the work of individual actors, whereas agency theory favours monitoring and control (Davis et al., 1997). Across several disciplines and contexts, the stewardship perspective has been used to complement agency theory, e.g. to explore the relationship between venture capitalists' and entrepreneurs (Arthurs & Busenitz, 2003), between public administrators and non-profit organisations (Van Slyke, 2006), or among family members in family businesses (Corbetta & Salvato, 2004; Eddleston & Kellermanns, 2007). In addition, Van Slyke (2006) found that principal-agent relationships usually evolve into principal-steward relationships over time as trust between the actors increases, suggesting that the two theories are closely intertwined and should be used in conjunction.

Stewardship attitudes are assumed to be especially prevalent in public organisations, where the promotion of the public interest and the creation of public value are key organisational goals (Bryson et al., 2014). For instance, public employees are often interested in serving the public interest, hold high levels of organisational commitment, and identify themselves with organisational activities and missions (Pandey & Stazyk, 2008; Ritz, Brewer, & Neumann, 2016), as opposed to purely pursuing self-interest. As such, public employees may be regarded as stewards of a rather vaguely defined principal: the public at large, represented by government organisations and institutions. However, government workers are not the only possible stewards in this context, as other non-public or semi-public organisations may also contribute to the pursuit of the goals of governments, be it as stewards or agents (Van Slyke, 2006) - for instance in collaborative innovation.

2.3 A Conceptual Model of Collaborative Innovation and Public Value Creation

While collaborative innovation between (local) governments and innovation partners that hold additional innovation-related resources seems like a promising way to increase the general innovativeness of public administration, the need to identify and develop adequate collaboration and governance procedures for such innovations to succeed has been stressed repeatedly (Kankanhalli, Zuiderwijk, & Tayi, 2017; Scupola & Zanfei, 2016; Sørensen & Torfing, 2017). As the creation of public value is key in public sector innovation and smart city initiatives, it is of paramount importance that attention is paid to the goals that are to be achieved through innovation. In the case of collaborative innovation between governments and innovation partners, it thus has to be considered that innovation partners often strive to create business value such as revenue and profits for their own business, as opposed to public value. Against this backdrop, more knowledge is needed about how collaborative innovation between governments and innovation partners should be designed and governed to ensure that the focus is on creating *public value* instead of just *business value* (also referred to as private value).

This distinction of those two types of *value creation* is in line with Cordella and Bonina (2012, p. 516), who point out "that public sector strategies differ from private sector strategies because the former are driven by the overriding goal of creating public value, while the latter are aimed at creating private value". In addition, even though in continental Europe, many utility companies, which are the focus of this study, are only semi-private or even still public, they still operate in a market environment, resembling private sector companies. Therefore, while, the interests of the government and the innovation partner should ideally be the same, this will often not be the case, highlighting the need to design cooperation in a way that ensures the interests of the government remain at the fore. In light of the above discussion on agency and stewardship theory, we assume that the mode of the relationship between governments and innovation partners is crucial to achieve public value creation in collaborative innovation, as it allows for a trustful and voluntary alignment of interests between the principal (the government) and the steward (the innovation partner).

For our conceptual model, we apply agency theory and stewardship theory as the key modes to describe the relationship between governments and innovation partners. We expect that, while both modes generally lead to higher innovativeness because of the combination of innovation assets, each of the two relationship modes will lead to different types of value creation. More specifically, as illustrated in Figure 1, if the relationship between a government (principal) and an innovation partner (agent) is a relationship in which the principal gives an innovation mandate to and controls the actions of the agent, we expect the agent to still mostly pursue its self-interest. At the same time, the agent will likely use its informational advantage to render monitoring difficult to impossible. Consequently, an agency-type relationship will tend to produce innovation-related outcomes geared mostly towards creating business value for the innovation partner rather than public value. In contrast, if the relationship is of the stewardship type based on mutual trust and empowerment, we assume that the government (principal) as well as the innovation partner (steward) will be stimulated by motives beyond self-interest. As a result, they will jointly aim at contributing to the principal's key mission, which is promoting the public interest and creating public value. However, this should not necessarily prevent the innovation partner from also pursuing other goals such as creating business value as a result of the collaborative innovation. As such, we assume that only a stewardship mode of collaborative innovation will be compatible with the definition of public sector innovation by Daglio, Gerson, and Kitchen (2015, p. 4), who stress that "public sector innovation is about new ideas that work at creating public value". According to these authors, besides novelty and implementation, which are features of any type of innovation, public sector innovation additionally requires an impact on public results, efficiency and effectiveness of public service delivery, and an orientation towards citizen satisfaction, which we predict will be enabled through a stewardship-type collaborative innovation.

To summarise, we expect stewardship relationships in collaborative innovation between public administrations and innovation partners to create innovation-related outcomes geared towards both public value and business value, which in the context of IT-enabled innovations in smart city initiatives is more desirable than innovation-related outcomes aligned with business value creation only. In the following, we will analyse four case studies of local governments in Switzerland pursuing collaborative innovation approaches with utility companies as innovation partners to illustrate our model. Besides determining the types of value creation, we will also analyse the effects of the approaches chosen on the level of overall innovativeness.

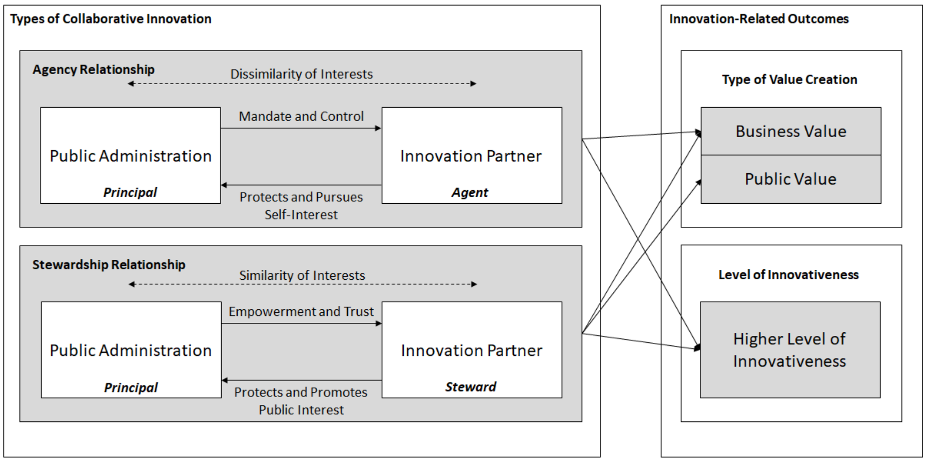

Figure 1. Types of collaborative innovation and innovation-related outcomes.

3 Methods

3.1 Case Selection and Data Collection

As outlined in the introduction, the specific context in which we explored our research question is collaborative innovation between local governments and public and semi-public utility companies in smart city initiatives in Switzerland. Much like other organisations such as living labs (Gascó, 2017), utility companies can serve as innovation intermediaries between governments and citizens. Since in continental Europe, many utility companies are (partially) SOEs, they usually have close ties with local governments and better knowledge of technological developments, given the rather technical nature of their business. This oftentimes makes them suitable partners in collaborative innovation for local governments, especially in the smart city context. Additionally, utility companies are usually less constrained by innovation-inhibiting factors than a public administration. For instance, utility companies are exposed to a certain degree of market pressure, which helps to improve the joint innovativeness in collaborative innovation with the public sector (Hartley et al., 2013).

We used an exploratory multiple case study research approach and investigated innovation activities in the context of smart city initiatives of four utility companies in three major cities in Switzerland. These cases were not randomly sampled but purposefully selected because we identified them as most suitable to help us understand the problem and analyse the research questions (Creswell & Creswell, 2018; King, Keohane, & Verba, 1994). The suitability of the chosen cases grounds in a publicly known track record of innovation projects allowing us to study innovation undertakings with various outcomes. Such theoretical sampling allows illuminating and extending relationships among constructs (Eisenhardt & Graebner, 2007), increasing robustness and methodological rigor when choosing a multiple-case study approach (Eisenhardt, 1991).

Based on the central elements of the different types of collaboration and innovation-related outcomes, we developed a semi-structured interview guideline to obtain explorative insights into the collaborative innovation between local governments and utility companies. This approach allows in-depth descriptions of social phenomena thus helping us to understand the underlying causal relationships (Yin, 2018). In total, we conducted 15 in-depth interviews with key key senior decision makers from the local governments and managers of the utility companies (Appendix 1). All of them are knowledgeable experts who are able to provide diverse perspectives on the focal phenomena (Eisenhardt & Graebner, 2007). In the governments, we interviewed the politician or the secretary general involved in the strategic steering committee of the utility company (e.g. board of directors). In addition, we interviewed the government official in charge of the smart city strategy and the activities of the city (town clerk, head of economic development, Chief Digital Officer). Within the utility companies, we interviewed the Chief Executive Officer (CEO) of the organisation as well as the managers responsible for innovation and the smart city projects. By choosing senior professionals from higher hierarchy levels, we ensured that our interviewees were able to represent not only a particular and personal point of view, but also a comprehensive view of the matter.

The interviews took one hour on average and were conducted between October and December 2017 at the workplace of the interviewees. We followed a semi-structured interview guideline consisting of four sections. The main section was derived from our theoretical model (see Figure 1). It focused on the particular relation between local government, the utility company and the type of innovation value creation asking questions like “in which domains do the interests of the different actors overlap and in which do they diverge?” or “to what extent does the utility company pursue its own commercial activities?” The other sections addressed questions like “is there an innovation assignment by the local government to the utility company?” and “how is the success of innovation measured, which instruments exist?” In addition, more open and explorative questions were included, giving our interview partners the possibility to bring further topics to our awareness. Each interview was conducted by two members of the research team. For consistency, we ensured that one of the authors participated in each of the 15 interviews. We used the possibility of having more than one interviewee per utility company and local government to cross-check the answers given by interviewees of the same utility company or local government.

3.2 Case Descriptions

The selected Swiss cities are of representative size (75,000 to 390,000 inhabitants) for many European municipalities (Table 1). All three cities have one or two utility companies that innovate through various initiatives such as smart city projects, Internet of Things pilot programs and other IT-enabled activities. Such innovation activities are typical for many of today’s utility companies owning large water, sewage, electricity and gas supply infrastructures for many decades and having started to invest in fiber optics in the past 10 years (Shumate, 2008). Needing to develop innovative services and products to help exploit their expensive communication infrastructure, utility companies often start new smart city-related projects within their municipality. Nevertheless, the utility companies remain at least partially under public control, limiting their strategic and operative flexibility.

Among the four analysed cases presented in Table 1, Utility Companies B and D are fully public since they are organised as departments of the local public administration and operate under public law. Utility Companies A and C, in contrast, are only semi-public, being partially or fully owned by the local governments but legally and organisationally independent from them. A and D operate a broad range of networks offering services based on electricity, water, gas, heating and fiber optics. B only operates an electricity and fiber optic network whereas C offers services based on gas supply. The information gathered about the individual cases, as displayed in Table 1, originates from both publicly available sources such as annual reports, company and government websites as well as from public news coverage.

	Case A	**Case B**	**Case C**	**Case D**
Utility Company	A	B	C	D
City	I	II	II	III
Networks operated	Electricity, water, gas, heating, fiber optics	Electricity, fibre optics	Gas	Electricity, water, gas, heating, fiber optics
Annual revenue	+420m USD	+900m USD	+450m USD	+210m USD
Employees	+600 employees	+1100 employees	+210 employees	+280 employees
Organisational independence of utility company	Independent, owned by the city	Part of public administration	Independent, majority owned by the city	Part of public administration

Example of smart city innovations/technologies	Citizen information and feedback application	Public low-power wide-area network; smart parking application	No projects with explicit public value focus	Citizen information and exchange platform; smart power management solution

Table 1. Characteristics of the four utility companies (derived from their annual reports).

In the following, for each of the four cases, representative examples of the specific types of IT-enabled innovations that have resulted from the respective collaborative innovation activities in the local smart city context are given. Case A includes a smart city web and mobile application that provides data to the public, which is collected by the utility company anyway, like webcam pictures of various city locations and temperature and flow data of the local rivers. Another example is the development of a web and mobile application that allows citizens to report defects of various infrastructures within the city in a central place. Case B includes the deployment of a low-power wide-area network (LPWAN) within the city by the utility company. Using this LPWAN, another collaborative innovation is the development of a smart parking solution. A further project includes the preparation for future electric mobility applications. Case C is notable in that the innovation collaboration with regards to IT-enabled innovation from side of the utility company is mostly focused on other privately owned businesses related to the utility companies present and envisaged core business and not so much on creating public value. Finally, case D includes a smart city mobile application that intends to promote communication between different districts. In addition, in a newly built model neighbourhood, the innovation collaboration led to an intelligent energy control reducing the environmental impact and improving comfort. Furthermore, the utility company is building a "Smartnet" to connect various sensors and actuators within the city. Another example of innovation collaboration is a project for future electric mobility.

3.3 Data Coding and Analytical Method

All interviews were recorded and transcribed verbatim. We developed the coding schema following the deductive category assignment method (Mayring, 2014). We thus operationalised the constructs of our theoretical model into specific perspectives and attributes and applied them to the interview transcripts using the qualitative data analysis software MAXQDA (Kuckartz, 2014). The relevant perspectives for our theoretical model comprised the role of the utility company, its relationship with the government, and the innovation-related outcomes. The coding schema of the perspectives and attributes was refined during the coding process by merging sub-attributes into main attributes (Mayring, 2014). In total, we ended up with 16 codes and 287 codings related to our theoretical model. In accordance with recommendations by Ospina, Esteve, and

Lee (2018) on transparency of qualitative data analysis and interpretation, we illustrate the perspectives and their related attributes in Table 2.

Perspective	**Attributes**	**Source**	**Example Coding**
Role of utility company	Identification with city	Code "Identification"	CEO of Utility Company A: "We translated our new company website into the local dialect."
	Trust by citizens	Code "Trust"	CEO of Utility Company D: "The utility company belongs to the citizens. Therefore, they trust the company."
	Pressure to innovate	Code "Innovation Incentive"	CEO of Utility Company B: "We see tremendous change; […] we could lose our traditional role."
	Innovation department	Code "Innovation Competence"	Head of the office for economic development of City II: "The utility company has a department with employees hired for innovation."
	Key actors of innovation	Code "Key Player"	CEO of Utility Company D: "The government has commissioned the utility company to bundle these topics with the innovation delegate XY":
	Business agility	Code "Agility"	Head of marketing and sales of Utility Company A: "More prototypes, more pilot-customers and if it works out, roll it out on a larger scale."
	Error management culture	Code "Error Culture"	CEO of Utility Company A: "It has to be possible to try things out and let them die if they don't work out well."

Relationship with local government	Smart city strategy of local government	Code "Smart City"	CEO of Utility Company B: "There is a political assignment to develop a smart city strategy."
	Type of assignment mandate	Code "Assignment Mandate"	CEO of Utility Company B: "The assignment to contribute to smart city solutions must come from the parliament or the citizens."
	Innovation mandate	Code "Innovation Mandate"	Head of marketing and sales of Utility Company A: "We've wanted to get such a mandate for quite a long time."
	Dependence of utility company on political processes	Code "Political Dependence"	CEO of Utility Company B: "Whenever we have to involve the parliament, the project will be delayed by at least half a year."
	Key local government actor for relation with utility company	Code "Key Player"	Member of the city executive government of City I: "We need someone to pull all the strings and we have provided resources for such a position."
	Communication between local government and utility company	Code "Communication"	Head of telecom unit of Utility Company B: "Our company gives lectures within the local government [about the technological possibilities]."
	Common understanding of innovation	Code "Common Understanding"	CEO of Utility Company A: "The problem is: we would have to develop a common self-understanding in the city."

	Alignment of strategies and structures	Code Alignment"	CEO of Utility Company A: "The politicians want exactly the opposite [...] but we really do not want that!"
Innovation-related outcome	Type of value creation	Code "Value Creation"	Head of marketing and sales of Utility Company A: "The benefit for the citizens is still limited at the moment."
	Level of Innovativeness	Code "Innovative-ness"	Head of corporate development of Utility Company C: "Our team can quickly react to [changing] customer needs."

Table 2. Coding schema for the data analysis.

4 Results

4.1 Role of the Utility Companies

Upon exploring the specific role of the individual utility companies, we wanted to know if they identify themselves with their cities, thus feeling a special obligation towards them. Such an identification would set the utility companies apart from other external actors in the market. An identification with the city was found in the cases of A, B and D. Utility Companies B and D, which are part of the local government, have a special connection owing to their organisational placement. We also found that the employees of these companies are proud to be a part of their cities. Company A, which is characterised by a higher organisational independence, nevertheless identifies itself with the city. It even translated its webpage into the quite distinct local dialect to show its commitment. This identification was also confirmed by the town clerk of City I, stating: "In working together with our utility company, we realise that it feels a special responsibility towards the city." The case of Utility Company C is different, since the geographical focus of its activities goes beyond the city limits. Consequently, it does not identify itself particularly with the city. This was pointed out by the head of corporate development at Utility Company C: "We see ourselves as a country-wide energy supplier and not as a city utility company." Notably, Utility Company C is the only one that does not include the name of the corresponding city in its company name.

Whether utility companies feel particularly obliged to their host cities also relates to whether citizens put specific trust in those companies. We clearly see this in the cases of A, B and D. The CEO of Utility Company D stated: "The utility company belongs to the local citizens and therefore they trust us more. Furthermore, the citizens are aware of our loyalty to the city." This could distinguish utility companies further from other external actors. The situation is different for Utility Company C. Having no direct customer relationship to the local citizens, it does not enjoy a special form of trust from them.

In addition, our findings indicate that all four companies feel pressure to innovate. Innovation, however, is not only a pressure but also something they are interested in. This can be ascribed to the fact that the traditional business model of all the utility companies is changing very fast. The CEO of Utility Company B said: "I have the strong conviction that the next five to ten years will change our traditional business dramatically. We see a tremendous transformation." Even more pressing is the situation of Utility Company C because its business model was primarily based on the distribution of gas and its host city has ambitious environmental goals clashing with a business based on non-renewable resources. The situations of the utility companies in regard to innovation pressure are remarkably different from the local governments. The town clerk as a member of the local government of City I explained: "The city will certainly still exist in twenty years, it won't go bankrupt." We found that local governments see no fundamental changes to their range of public services in the near future.

We were interested in whether higher innovation pressure for the utility companies results in the establishment of innovation units within these companies. This is only the case for Utility Companies C and D, both of which have designated innovation departments. In the case of Utility Company C, this department even has an innovation fund available to support promising start-ups.

Finally, local governments and utility companies greatly differ in terms of business agility and error management culture (see also Soe & Drechsler, 2018). As expected, from the local governments' points of view, government institutions are stable and reliable. The operations of local governments typically have a time horizon of decades and they have a strong emphasis on avoiding errors. The secretary general responsible for Utility Companies B and C explained: "Public administrations have an aversion to high risk and the ruling zero-error-culture leads to a pressure for projects to be successful which prevents an innovation-friendly atmosphere." Despite their long-time investment horizons, utility companies have started to become increasingly agile in adapting to the rapidly changing conditions.

4.2 Relationships between Local Governments and Utility Companies

Concerning smart city strategies, we found that only City III has already established such a strategy. In the other two cities, such a strategy either is under development or has been declared the goal of the current legislative period. The assignment mandate for Utility Companies A and D is a general one whereas for Utility Company B, the local government has issued performance contracts for several tasks such as operating a fiber optic network. In the case of Utility Company C, the local government is represented in the supervisory board of the company. A specific innovation mandate has only been given to Utility Company D. Utility Company A has only a very general assignment to take innovative actions. However, the company wants a specific mandate as the head of the unit responsible for innovation told us: "There is no innovation mandate at the moment. We have wanted such a mandate for some time but without success.

There must first be a common understanding of the initial positions and the goal to pursue. But this is absent today." Utility Companies B and C have no mandate specifically targeted at innovation. In general, we found that the more integrated into local governments the utility companies are, the more are they restricted by a dependence on political processes. The results in this perspective reflect the degree of organisational independence of the individual utility companies. This is expressed by the following statement of the CEO of Utility Company B: "As soon as we have to involve the parliament, it will delay our project by at least half a year and all that is discussed will be known to the public [and to competitors]."

In local governments, various players are responsible for the relation to the utility companies concerning IT-enabled product and service innovations for citizens. These actors play an important role as representatives of the principal. In the case of City I, this is the town clerk who is part of the city's chancellery. This person has a broad range of duties and responsibilities and consequently stated: "This sometimes makes me concerned that we do not have enough resources to deal with all the incoming innovative ideas." For Utility Companies B and C, the key player in the local government is the head of the office for economic development. For Utility Company D, the local government has established the position of a Chief Digital Officer, who sees as one of the position's main tasks ensuring that innovation remains citizen-orientated. This person highlighted the considerable efforts necessary to achieve this goal, telling us: "My role as Chief Digital Officer is to connect all the different departments [of the city government]."

An important aspect in a stewardship-like relation is the communication between principal and steward, a common understanding of the corresponding matter and the alignment of strategies and structures on both sides. Our findings show that for Utility Company A, the communication with the local government is difficult and, consequently, there is a lack of common understanding with the main actors using key terms on innovation and smart city quite differently. We also saw that the strategies and structures on both sides are not well aligned. This clearly contrasts with Utility Company D, which profits from efficient and regular communication, particularly between the Chief Digital Officer and the head of innovation of the utility company, which has led to a solid alignment between strategies and structures on both sides. In Utility Company C, communication and a common understanding with the local government appears to be less relevant because it operates more independently. Consequently, the alignment in this case is of lower importance for innovation-related outcomes.

The different attributes of the relationship between utility companies and local governments correspond to different levels of agency and stewardship relationship characteristics. An assessment of these levels based on the different attributes is given in Figure 2.

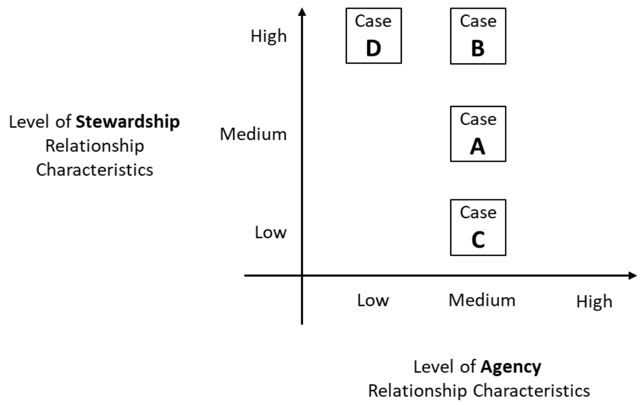

Figure 2. Level of agency- and stewardship relationship characteristics of the four cases analysed.

4.3 Innovation-Related Outcomes

Our theoretical model ascribes innovation-related outcomes, subdivided into the type of value creation and the level of innovativeness, to the attributes of the role of the utility companies and their relation to the local governments resulting in different levels of agency- and stewardship relationship characteristics. Our exploratory findings suggest that innovativeness is not only driven by an existing goal to innovate and planned and accomplished innovation projects, but is highly dependent on the role of the individual utility company and its relationship with the local government.

With regard to the *type of innovation value creation*, we found that all utility companies seek to innovate to achieve business value to secure and strengthen their own business. This is even true for Utility Company D that shows the lowest level of agency relationship characteristics. However, Utility Companies A, B and D also have the goal of striving for public value, which is a result of their increased values of stewardship relationship characteristics. This is most prominent and explicit in the case of Utility Company D. The goals specified in its assignment mandate include increasing the attractiveness of the city location and being part of the social environment of the city. These could both be attributed, according to Meynhardt (2009), to the political-social dimension of public value. For example, Case D aims at improving communication between districts, contributing to environmental protection, and utilizing sensors to make city life smart.

As for the dimension of utilitarian-instrumental public value, Utility Company D has the obligation to support the "2000-watt society" as part of a sustainable development of the city. The assignment mandate for Utility Company A states that the company should not only be committed to its customers but to every citizen of City I. Case A has developed smart city web and mobile applications, offering citizens public information and services. For example, an online reporting platform aims at facilitating the communication between citizens and public administration in terms of infrastructural defects. This resembles more of a public value view compared to business value. However, aiming at public value does not necessarily imply giving away services for free but the utility companies are glad to provide them at a cost-neutral level to allow others to create additional value for the local citizens. The CEO of Company B told us: "We contribute to the smart city by supplying the fiber optic network. We could even collect a multitude of data and provide it afterwards [to the citizens]." That Utility Company A does not only focus on business value is also noticed by the member of the executive government of City I, stating: "Utility Company A has even launched an energy-saving program which potentially threatens their core business model." This reflects a public value orientation beyond self-interest.

Apart from general sustainability and ecological goals that are driven by their inherent business interests, we were unable to find clear indications that Utility Company C aims for public value in any of the four dimensions. In contrast, it focuses on privately owned businesses, thereby concentrating on achieving business value. This is a result of the lowest level of stewardship relationship characteristics found in the four cases. The head of corporate development of Utility Company C even stated that while the company is mostly owned by the city, their strategic objectives are influenced so marginally by the local government that ownership by private investors would not change their strategic goals at all. Summarising, we see that stewardship relationship characteristics promote IT-enabled collaborative innovation geared towards both public value and business value creation, whereas agency relationship characteristics lead to innovations mostly geared towards business value. Not only the relationship characteristics, but also the types of collaborative innovations implemented give some indications of the type of value creation.

Regarding the *level of innovativeness*, the role and relationship between utility company and local government is most beneficial in the case of Utility Company D, resulting in a high degree of innovativeness. This finding is supported by the following quote of the Chief Digital Officer of City III: "The chairs [of the innovation board] will be the head of innovation of the utility company and myself so that we can come out of a 'silo-mindset' and produce strong collaboration, and that we can also distribute what we learn to other departments." The high innovativeness of Utility Company C is largely owing to its strong innovation department. The head of corporate development of Utility Company C stated: "Our [innovation] team can quickly react to [changing] customer needs." The low innovativeness of Utility Company A can be attributed to its difficult relationship with the local government. This conclusion is backed by a statement given by the CEO of Utility Company A: "We asked the local government to give us an innovation mandate but the councillors did not want to [...]. The way they would like us to act would cause us problems." The medium level of innovativeness of Utility Company B is a result of strategies and structures, which are established but not well rehearsed. To sum up, regarding the level of innovativeness in collaborative innovation, both stewardship and agency relationship characteristics tend to increase the overall innovativeness in IT-enabled innovation. Although all cases analysed have implemented collaborative innovations already, they differ with regard to the level of innovativeness due to variations in role and relationship characteristics.

A structured summary of our results with regard to the role of the individual utility companies, their relation to the local governments, the resulting level of agency- and stewardship characteristics and the subsequent innovation-related outcomes is presented in the following Table 3. The assignment of the categories low, medium and high to the attributes of the perspectives is based on the number and significance of the statements of the interviewees. They represent a relative positioning of the cases examined.

Perspective	**Attributes**	**Case A**	**Case B**	**Case C**	**Case D**
Role of utility company	Identification with city	High	High	Low	High
	Trust by citizens	High	High	Low	High
	Pressure to innovate	High	High	High	High
	Innovation department	None	None	Yes	Yes
	Key actors for innovation	Head of marketing and sales	Head of telecom unit	Head of corporate development	Head of innovation
	Business agility	Medium	Medium	High	Medium
	Error management culture	Medium	Medium	High	Medium
Relationship with local government	Smart City strategy of local government	Intention to develop	Under development	Under development	Established

	Type of assignment mandate	General strategy	Performance contract	Participation in supervisory board	General strategy
	Innovation mandate	General	None	None	Specific
	Dependence of utility company on political processes	Medium	High	Low	High
	Key local government actor for relation with utility company	Town clerk	Head of economic development	Head of economic development	Chief Digital Officer
	Communication between local government and utility company	Difficult	Established but not well-rehearsed	Low relevance	Well-rehearsed
	Common understanding of innovation	Low	Medium	Low relevance	High
	Alignment of strategies and structures	Low	Medium	Low relevance	High
	Level of agency relationship characteristics	Medium	Medium	Medium	Low
	Level of stewardship relationship characteristics	Medium	High	Low	High

Innovation-related outcome	Type of value creation	Business and Public value	Business and Public value	Business value	Business and Public value
	Level of innovativeness	Low	Medium	High	High

Table 3. Summary of interview findings.

5 Propositions and Implications

5.1 Propositions

Our research aimed at identifying whether collaborative innovation between local governments and utility companies in smart city initiatives can fulfil the intended goal of creating public value and how such relationships need to be designed for this purpose. In this section, we summarise our key findings and derive three propositions.

First, our results illustrate that, although local governments strive to advance IT-enabled innovation, they indeed face various constraints in technological expertise and financial resources, which seem to be particularly prevalent in smart city projects owing to the complexity of the technological design and the number of parties involved. However, upon collaborating with utility companies, local governments benefit from the companies' innovation assets such as pressure to innovate, higher levels of agility, and an established failure management culture. So, based on our exploratory findings we assert that collaborative innovation appears to be a viable approach to increase innovativeness in smart city initiatives. This result is consistent across public and semi-public utility companies and relatively independent of how closely the utility company is organisationally integrated into the local government. So, regardless of whether a stewardship-like relationship or an agency-like relationship between a local government and a utility company is used, the innovativeness of the local government will increase through the collaborative innovation with the utility company. Importantly, this does not say anything about the type of value (public or business) that is created by the resulting innovations yet. Accordingly, we conclude:

Proposition 1: Regarding the level of innovativeness in collaborative innovation, both stewardship and agency relationships between a local government and a utility company will increase the overall innovativeness in IT-enabled innovation.

Second, our findings suggest that the type of collaborative innovation relationship between the local government and the utility company has an impact on the type of value that is created through the collaborative innovation. More specifically, a stewardship relationship between local governments and utility companies tends to lead to innovations geared towards both public value and business value, whereas principal-agent relationships tend to purely foster business value creation. While all utility companies in our sample primarily innovate based on expected financial returns, the utility companies characterised as stewards do not exclusively aim for business value but also feel more responsible for pursuing the overall goal of generating public value. This is emphasised by expressions of internalised goals geared towards public value creation by interview partners from utility companies whose relationship with the local government tends to be based on stewardship, particularly in the political-social (e.g. citizen involvement, compromise) and utilitarian-instrumental (e.g. openness, sustainability) public value dimensions (Meynhardt, 2009). Based on this finding we conclude:

Proposition 2: Regarding the type of value creation in collaborative innovation, a stewardship relationship between a local government and a utility company promotes IT-enabled collaborative innovation geared towards both public value and business value creation, whereas agency relationships will lead to innovations mostly geared towards business value.

Third, our findings indicate that if a collaboration between a local government and a utility company can neither be characterised as a stewardship relationship nor an agency relationship with clearly defined mandate and control mechanisms, or if the collaboration is simply not close enough, there will be a lack of common understanding of the aims of the collaborative innovation. This might be even more explicit in IT-enabled smart city initiatives since these often provide some leeway for the process as well as the final outcome of the project owing to their complexity. However, as a result of the lacking common understanding, the cities' innovativeness will not profit from the collaboration. According to agency theory, an explicit mandate and control mechanisms are a precondition for a common understanding. If set up appropriately and if the context is considered carefully (Cordella & Cordella, 2017), they can help develop an agency relationship into a stewardship relationship over time (Van Slyke, 2006). Beyond these two pure forms, hybrids of agency and stewardship relationships can also lead to successful partnerships (Huang, Baptista, & Newell, 2015; Sundaramurthy & Lewis, 2003). Importantly, the lack of an increased innovativeness of a local government in such cases also implies that potential for both public value and business value creation through IT-enabled innovations will not be levered. Therefore, we conclude:

Proposition 3: If there is neither a stewardship nor an agency relationship (nor a hybrid of the two) between a local government and a utility company, a lack of common understanding of the collaborative innovation will hamper the improvement of the cities' innovativeness, which in turn means that certain potential for public value creation through IT-enabled innovations will not be exploited.

5.2 Implications for Research

Foremost, this study has implications for research on public value creation when multiple stakeholders are involved (Bryson et al., 2017; Hartley et al., 2017; Page et al., 2015). We contribute by examining how local governments collaborate with utility companies to introduce complex, IT-enabled initiatives and thereby produce "value-creating public innovation" (Crosby et al., 2017, p. 659; Geuijen et al., 2017). The findings of the comparative case study analysis give empirical evidence that creating public value from collaborative innovation is a complex process (see also Cordella & Bonina, 2012). In particular, the collaboration between local governments and utility companies that might be characterised by conflicts of interest in terms of the objectives of IT-enabled initiatives involves a priori challenges that have to be overcome during the innovation process to pursue public value. In order to understand how negative outcomes of IT collaboration to the detriment of public value can be reduced (Cordella & Willcocks, 2010), we have empirically analysed which conditions are best suited to create public value in such collaborative innovation by combining the insights from public managers, local politicians, and collaboration partners (Hartley et al., 2017). We thus not only analyse the performance of collaborative innovation, but also look more closely which type of relationships between innovation partners results in which type of outcome. This analysis of how public value can be created contributes to previous literature in reasoning by established theories and providing empirical examples why public value creation is characterised by high complexity. Applying both agency and stewardship theory makes it possible to get a more refined picture on the potential of generating public value with collaborative innovation, in addition to seeking for managerial outcomes and business goals (Cordella & Bonina, 2012). We thus contribute to public value literature by investigating value creation in the context of collaborative innovation and measuring the value created for both governments and non-governmental partners (Klievink et al., 2016; Twizeyimana & Andersson, 2019). More specifically, we describe how collaborations that are entered due to efficacy and innovation reasons can lead to seeking public value, a topic of high relevance when considering the importance of collaboration for public sector organisations.

Our study has implications for research on collaborative innovation by investigating how local governments work together with utility companies to enhance innovativeness (Page et al., 2015). More specifically, we examine which role utility companies play in smart city innovation projects and how their relationship is characterised. We show that the type of relationship influences the local government's innovativeness, and thus take a first step towards assessing the outcomes of collaborative innovation (Torfing, 2019).

While organisational innovation efforts have been studied extensively in business research (Devece, Palacios-Marqués, Galindo-Martín, & Llopis-Albert, 2017; Roberts, Campbell, & Vijayasarathy, 2016) and public administration research (Grimmelikhuijsen & Feeney, 2017; Hansen, 2011), this study combines the rationales of both the semi-public and public sectors investigating the inter-organisational collaborations in IT-enabled innovations. While researchers have already adopted institutional theory to study institutional forces driving innovation adoption (Bunduchi, Smart, Charles, McKee, & Azuara-Blanco, 2015; El-Haddadeh, Weerakkody, & Al-Shafi, 2013), our approach to collaborative innovation linking public management literature with other literature streams from public sector innovation research and information systems, proposes an actor-centric perspective to better understand the emergence of innovations focused on creating public value. To explain these relationships, we develop a model contrasting agency theory with stewardship theory. In line with Hirsch et al. (1987) and Davis et al. (1997), we suggest that the limits of agency theory have to be acknowledged when analysing relationships between government institutions and (semi-)private business actors. Stewardship theory can lend a helping hand to agency theory due to its focus on goal congruence. We therefore also contribute to theoretical discussions concerning relationships between two actors collaborating in innovation projects that go beyond the smart city context investigated here.

5.3 Implications for Practice

In addition to the implications for research, this study offers recommendations for practitioners in local public administration, public and semi-public utility companies, and possibly also for other types of SOEs or other forms of collaborative innovation between public and private sector partners in the context of IT-enabled innovations and smart city programs.

First and foremost, when the goal is to create public value through collaborative innovation, which usually is the goal in smart city initiatives, it is important to understand that the design of the collaboration matters. More specifically, public managers should strive to establish a stewardship-type relationship with their innovation partners. To that end, public managers are advised to generally create a very close relationship with the innovation partner, e.g. a utility company, that is characterised by mutual trust and empowerment instead of monitoring and control. A close organisational integration of the innovation partner, such as a utility company, can facilitate this, as can regular communication and a high identification with the city by the innovation partner. It should, where possible, be avoided to contract out innovation, giving mandates to innovation partners and expecting them to independently create and deliver innovations in return for remuneration. Instead, collaboration should be understood literally as *working together* to create public value. Particular attention should also be paid to creating a common vision of the goals of the collaboration, focusing on creating public value. In this, public managers should emphasise and explain transparently that the collaborative innovation is about creating public value (or creating value in certain public value dimensions; (Meynhardt, 2009)) and serving the citizens of the city, as "stewardship begins with the willingness to be accountable for some larger body than ourselves" (Block, 2013, p. 16). Arguably, this is easier to achieve with public and semi-public organisations, such as the utility companies studied here, than with private sector organisations.

Second, our findings indicate that many utility companies, at least in Switzerland, are generally willing to contribute their innovation resources such as technical knowhow and process experience to a trustful relationship with local governments. However, an optimal collaboration relationship requires close ties between relevant exponents from the utility company with a department in the local government that has an affinity to innovation processes and supports the utility company with information and involvement on the political level. Therefore, we suggest positioning the management of innovation programs, such as smart city or digitalisation strategies for governmental units, close to influential political actors such as a mayor's department or an office for economic development, that will then coordinate the collaboration with the innovation partner(s) and ensure that the focus remains on creating public value. As such, in an ideal setting, the local government acts as a partner enabling the utility company to innovate successfully for the citizens in close collaboration. Thus, local governments, although typically characterised by lower innovativeness due to bureaucracy and legal constraints, can yet foster innovation and thereby increase public value driven by utility companies as trusted partners.

Third, utility companies are usually attractive employers for innovative, technically experienced employees motivated to use their skills for their own city. Moreover, due to their market-orientation, utility companies strive to signal their innovativeness and competitiveness publicly. At the same time, public and semi-public utility companies often have very close ties to and existing personal networks within local governments. Therefore, it is advised to specifically involve public and semi-public utility companies in collaborative innovation to make use of their additional innovation resources. This may also hold for other public sector innovation initiatives and contests such as hackathons (Johnson & Robinson, 2014) and it may even be worth considering to let the utility company take on a leadership role in such processes. For the Anglo-Saxon context, it is advised to work towards a more joined-up mode of collaboration with utility companies and other collaboration partners that have previously been privatised, in an effort to return to a more horizontally coordinated setup that will allow for stewardship-type relationships in collaborative innovation (see also Cordella & Bonina, 2012).

6 Conclusion, Limitations, and Future Work

While it is known that IT-enabled innovations have large potential to improve public value creation (Cordella & Bonina, 2012; Pang et al., 2014), particularly in smart city initiatives (Gil-Garcia et al., 2016), we also know that such projects frequently fail and their outcomes are not always for the better or in very public interest (Bannister & Connolly, 2014). To improve their innovativeness regarding IT-enabled innovations in smart city programs, many local governments in continental Europe have started using collaborative innovation approaches with public and semi-public utility companies. However, thus far it was unclear how such collaborations may lead to public value creation and how exactly they need to be designed. Thus, we have to improve our understanding of whether and how utility companies - or other innovation partners - can contribute to public value creation by actively engaging in local governments' innovation projects and thereby make cities smarter (Gil-Garcia et al., 2016). In this study, we draw on both agency and stewardship theory to explore the cases of four public utility companies in Switzerland and their relations with three different cities in smart city initiatives.

Our key findings are that the collaborative innovation approaches and the resulting innovation-related outcomes differ substantially in their form and scope. To summarise, both types of relationship (agency and stewardship) between a local government and a utility company, if designed adequately, have been found to contribute to higher innovativeness of the local government or city in general, because the utility companies under study indeed tend to have specific innovation assets that local governments lack and that are essential in such more complex smart city initiatives. In addition, utility companies have certain advantages over completely private companies, such as closer ties and mutual trust with the local governments, which help promoting innovation in the public sphere.

However, the resulting innovation-related outcomes differ substantially in terms of whether business value or public value are created, depending on whether an agency or stewardship model of collaboration is used. Utility companies acting as stewards tend to feel more committed to help create public value, which does not mean that they would stop entirely to pursue their own business interests. On the other hand, utility companies acting as agents remain focused rather strongly on creating business value for themselves in collaborative innovation. Therefore, local governments need to choose adequate governance mechanisms according to the predisposition of the characteristics and their relationship with utility companies in order to exploit the public value creation potential of their partners in innovation projects (see also Bryson et al., 2014). Of course, although innovation partners such as utility companies may place their focus on business value, it should also be noted that certain innovations resulting from an agency-type collaborative innovation may - even if not intended - as a by-product of business value also create a certain public value. This could be the case, for instance, if an innovation that increases the cost-efficiency of the innovation partner also happens to save environmental resources and thereby create public value in the dimension of sustainability.

Our study has several limitations, some of which provide promising areas for future research. In this study, we have focused on investigating the role of public utility companies as one specific case of SOEs and their relations with local governments in smart city programs in Switzerland. Although we assume that these relationships are somewhat representative for other continental European countries as well, we acknowledge that results might differ across countries. This may be the case especially for countries featuring different political systems or higher degrees of privatisation of public infrastructure, such as the Anglo-Saxon ones. Thus, as the generalisability of our findings is unclear, we recommend conducting more research on the topic in other countries and in contexts other than smart city programs to compare the findings.

Moreover, in other contexts, other types of SOEs such as less technology-oriented ones, or even citizens (see e.g. Meijer, 2015) may also be acting as innovation partners of governments at all levels. In this light, it might be worthwhile to search for possible differences and similarities to the IT-enabled collaborative innovation initiatives between local governments and utility companies studied here. While we have in this study focused on public value creation and the citizen centricity-dimension of the smartness concept (Gil-Garcia et al., 2016), future research could also adopt a different perspective, for instance by drawing on the citizen engagement or sustainability dimension of smartness.

More investigation is also required to gain insight into how the collaboration between public administrations and innovation partners such as utility companies affects public sector innovation in the long-term. While we have adopted a cross-sectional view that allowed capturing innovation activities around public-value focused product and service innovation, we were not able to monitor innovation success in the long run.

In addition, owing to the qualitative nature of our study, it was not possible to empirically validate the success of such innovation projects and associate them with specific key performance indicators. This was also partly due to the "complexity and ambiguity of public value" (Hartley et al., 2017, p. 671) which makes objective measurement difficult. For future research, we suggest using our exploratory insights as a first step to develop a quantitative survey in order to record the views of a larger number of local governments (or other levels of government) and to assess the effect of different forms of collaboration at a larger and more international scale. In this sense, also the role of the public utility company might be different. While we analysed cases in which the public utility company served as the main innovation agent for the local government, there might also be large innovation networks, in which the public utility company could have a much smaller share, and which should be analysed as well.

Lastly, by focusing on IT-enabled innovations in smart city initiatives, we have confined ourselves to a particular type of innovation in the local public sector. However, circumstances and innovation-related outcomes might be different for strategic or process innovation (Hartley, 2005) which could affect public administrations as well as innovation partners. We therefore recommend that future research expand the scope and focus towards other types of innovation.

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Appendix

#	Case	City	Organisation	Role of the interviewee	Duration
1	A	I	Utility company	Head of marketing and sales	65 min
2	A	I	Local government	Member of the city executive government and member of the board of directors of the utility company	67 min
3	A	I	Utility company	CEO	60 min
4	A	I	Local government	Town clerk	76 min
5	B	II	Utility company	CEO	70 min
6	B	II	Utility company	Head of telecom unit	67 min
7	B+C	II	Local government	Secretary general of the department responsible for the utility company	61 min
8	C	II	Utility company	Person 1: Head of corporate development Person 2: Digital innovation manager	64 min
9	B+C	II	Local government	Head of the office for economic development	60 min
10	D	III	Local government	Chief Digital Officer	53 min
11	D	III	Utility company	Head of innovation	37 min
12	D	III	Local government	Member of the city executive government (responsible for the utility company)	59 min
13	D	III	Utility company	CEO	55 min
14	D	III	Utility company	Head of telecom unit	51 min
15	D	III	Local government	Head of financial department	53 min

Appendix 1. Overview of cases and interview partners.

Statement of Authorship

„Ich erkläre hiermit, dass ich diese Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen benutzt habe. Alle Koautorenschaften sowie alle Stellen, die wörtlich oder sinngemäss aus Quellen entnommen wurden, habe ich als solche gekennzeichnet. Mir ist bekannt, dass andernfalls der Senat gemäss Artikel 36 Absatz 1 Buchstabe o des Gesetzes vom 5. September 1996 über die Universität zum Entzug des aufgrund dieser Arbeit verliehenen Titels berechtigt ist.“

Bern, 19.09.2019 Benedikt S. Hitz-Gamper