New kind of IoT platform for Smart City by innovative procurement procedure

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M Vehviläinen[1] and T Vainio[2]

[1]ICT Infrastucture, City of Tampere, Frenckellinaukio, FI-33101 Tampere
[2] Smart Energy and Built Environment, VTT Technical Research Centre of Finland, Visiokatu FI-33101 Tampere

maarit.vehvilainen[at]tampere.fi

Abstract. The City of Tampere, like many other cities, has opened databases available to citizens and businesses. The information has been opened using existing information channels. Since the city typically works in silos, there is also open data made available in silos. The process by which information is first collected and then made openly available does not serve the needs of a digitalized society. Since the problem is common, measures to remedy it had been set as an objective under the EU Smart City theme, from which the City of Tampere received funding. The aim was to design and acquire an information system capable of both collecting and distributing information to both internal and external users. The specific objectives were to make information flow between the actions of the city and to facilitate the participation of the residents in the decision, rather than simply being the recipients of the information. Innovative procurement was applied to acquire a completely new type of information system. Hackathons were used to refine the characteristics of the acquisition with the participation of multi-disciplinary consortia. The project resulted in an IoT platform for the City of Tampere, which streamlines information processing and helps cooperation within the city's departments. The model of public procurement because of the project is generally valid and useful in other cities as well.

1. Introduction

The interpretations and definitions for Smart City used by different interest groups, stakeholders or regions vary. Often the impression is that a smart city is the same as a digital city, and sometimes its meaning is close to that of a sustainable city. [1] Today we do see these definitions as two sides of the same coin. In Smart City, digitalization is tying together all parts of built environment, like services, housing, mobility, infrastructure, and energy [2]. Many cities worldwide join the Smart City concept that relies on using information and communication technologies (ICT) and internet of things (IoT) solutions in citizens' everyday lives to improve their quality of life and assist local governments in overcoming challenges in the urban resource' usage, reallocation, and delivery of services [3]. These represent a Smart City trend that emphasizes the role of technology. The creativity of population has also been elevated to an essential feature of Smart City [4].

Digital technologies enable residents to improve their quality of life and well-being, create business-friendly business environments and ensure the smoothness, efficiency, and accessibility of the production of services provided by the city. The Smart City leverages modern digital technologies such as the Internet of Things (IoT). A IoT Platform refers to systems based on the automatic transmission of data by technical devices and the remote monitoring and control of devices via the internet. For the

snapshot of the urban environment sensing, several sensors, controls, and data sources are added to IoT Platform.

The diverse utilization of information allows the city to obtain a better understanding about the current state and future needs, and thus improve services for citizens as well as keep costs under control. The systematic utilization of data also offers high-quality analytics to support decision-making. In smart lighting related projects, the starting point has been the Internet of Things (IoT) -based platform, into which information produced by various sensors and systems has been imported. The SenCity project [5] showed that intelligent street lighting solutions can achieve energy savings of up to 50 percent. But the energy saving isn't the only benefit achieved. An IoT based system helps with lighting maintenance. It indicates, for example, technical faults and condition of light poles. With different pilots and projects Tampere has proven the potential of the intelligent street lighting for innovative solutions and the need for an IoT platform. IoT Platform collects different data into a "data lake", which will be used as a source for analysis, and shared to third parties through open interfaces and marketplace.

The technical challenges of IoT, like different standards and data models, have been identified. The Open & Agile Smart Cities network (OASC) does valuable work to obtain common data models and standards with urban data. Problems, associated with standards and models, can be bypassed by using City Platform as unifying a middle layer [6][7]. The first platforms have been warehouses for data and have contained only past information. The data was the first gathered and then distributed via Platform for those who were interested it. Such a process no longer responds to demand. Today's City IoT Platforms have to act as Data Market Places what can gather and distribute real time data [8][9][10][11]. Besides the third parties, also the city itself can benefit from the active utilization of data flows [11][12][13]. This new city mission has been a common development theme in the EU Smart City project Stardust. This article presents the case of Finland, which took advantage of an innovative procedure for the acquisition of a new type of City IoT platform. In many ways, the objective of the acquisition was to rationalize the management of the city's data assets and enhance their exploitation.

2. Current situation and development requirements

Entities of the city do not negotiate the possibility of making a joint purchase (**Figure 1**). This leads to customized systems. In procurement, data is often left under the management and ownership of the service provider. The correct owner of the data - the city - receives only monthly reports in a portable document format (pdf), and even a small change to the required report is onerous.

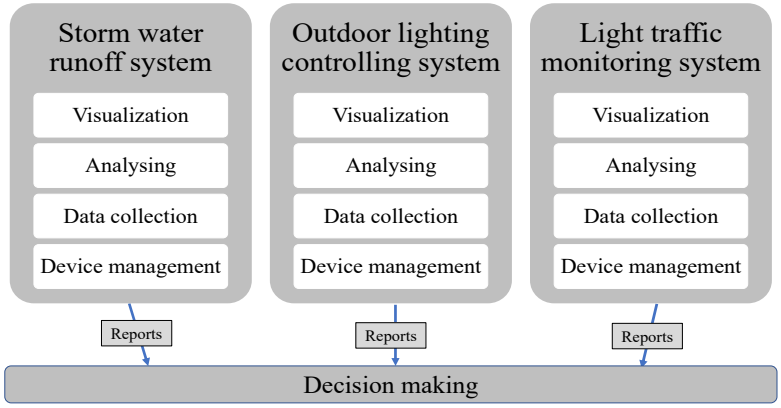

Figure 1. Traditional way of working in silo organizations

In the case of Tampere, there is a need for comprehensive data process renewal. The current city open data portal [14] bases on CKAN architecture which is intended for powering data hubs and data portals. It is easy tool for publishing, share and use data. The parallel product Wordpress supports news, guides, and blogposts about open data activities. The city has opened and published data they own but do not

know users and use cases. However, one ways systems like this, are no longer enough. They cannot process real-time data and act as Data Market Place. Also, the qualitative shortcoming is that CKAN does not support the implementation of the city's strategy.

The preliminary technical requirements for the new IoT Platform are derived from the experiences of current open data portal and content goals from the city's strategy. One of the four priorities of the strategy is Creative and Innovative City. It outlines that the city wants to be an intelligent data user and enabler of data-based innovations. The need for improvement concerns the collection of information on the urban environment and utilization in the maintenance of systems (Figure 2). A very important role of the new IoT Platform is to support the city in achieving its sustainable development goals [15].

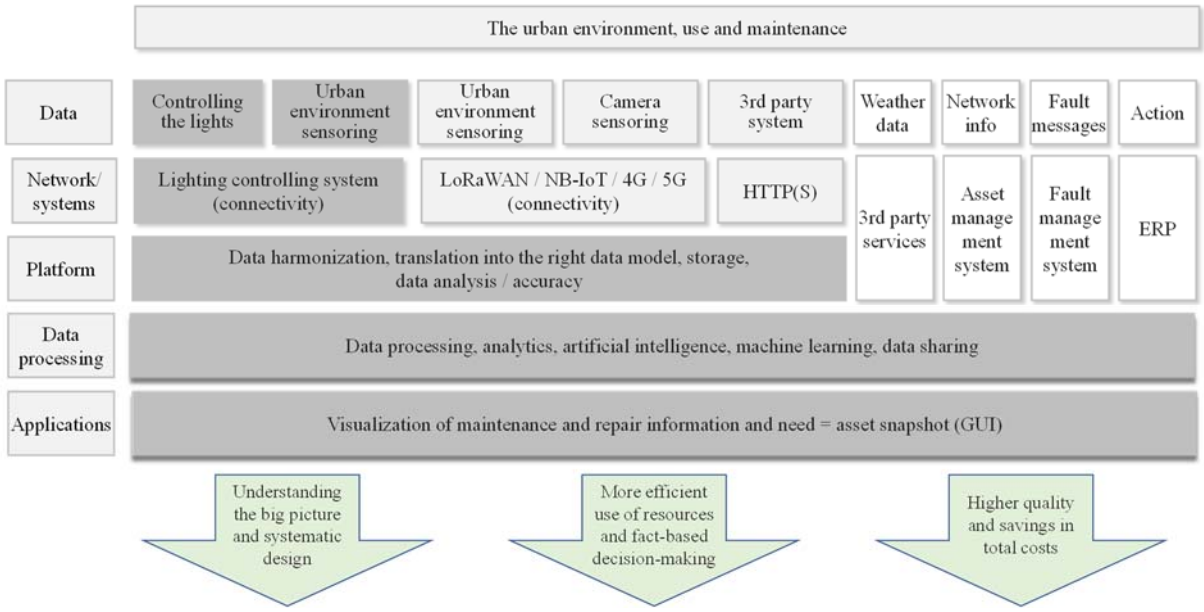

Figure *2*. Goals related to maintenance of urban environment to IoT platform

3. Innovative procurement process

The goal of public procurement has traditionally been efficiency: obtaining desired goods or services at the lowest price. Traditional public procurement typically targets ready-made products and services. In contrast, when public organizations engage in public procurement of the innovation, they place orders to fulfil specific needs and expect companies to address them by offering innovative solutions. The European Commission is supporting pre-commercial procurement to help public procurers and suppliers develop innovative solutions to societal challenges. In 2007 the EC enacted a Communication to introduce a legal framework for Pre-Commercial Procurement of innovative solutions in the public sector. Smart cities have been identified as an area where innovation contests have particularly significant potential. Smaller contests often take the form of hackathons, what that bring together participants to work intensively over a short time to solve a problem [16].

These are the main reasons, why the city rejected the traditional method of procurement. In the Tampere case, the innovative procurement was formed in two parts: the definition of the service to be acquired by hackathons and the actual procurement by using competitive dialogue. Peer support for procurement planning, like requirements, was received from Stockholm, where a similar acquisition was underway at the same time [17].

IoT platform acquired in this procurement is the basis for the implementation of future IoT solutions. To anticipate future needs, several hackathons and workshops were held. Table 1 shows some gathered information on IoT Platforms of organized events and figure 2 shows the progression. It was clear from the beginning that the diversity of IoT platform to be acquired will require the competence of more than

one company. Companies had to form clusters before enrolling in the hackathon and agree with the mutual rules of play. A working partnership is important for hackathon as well as in the future, as the objective was a 10-year contract during which IoT Platform will be further developed.

Table 1. Summary of two different type hackathons [16]

	Enlighten Tampere	Junction
Goals	Project goals; city-level strategic goals (including innovation policy-related goals); P&R, visibility, and communication goals; capability building.	
Structure	Introductory event and two-day camp. National innovation partnership procedure adapted to EU procurement rules. Self-organized event (with a facilitator) by three smart city development projects. Six companies (out of 24) were invited to participate because of bidding competition.	Competitive negotiation procedure. A big annual two-day event with thousands of participants, organized by a third party. The city participated with two challenges that were announced in the event. The third party selected the initial participants, and city project officers chose the best solutions.
Problem statement	Technology-driven challenge. Co-designed with three EU-funded development projects, the Smart City development programme, public procurement experts of the city, and the hackathon facilitator. One openly defined challenge. Problem statement did not derive from a clearly defined problem but a mixture of goals and actors.	Problem-driven challenge. Co-designed with three EU-funded development projects, the Smart City development programme, the city's public procurement experts, and other city representatives. Two openly defined challenges. Problem statements did not derive from a clearly defined problem but a mixture of goals and actors.
Outcomes	All six participants submitted proposals. The city selected three winners to continue the development and form a joint solution in three separate pilots. One of the solutions generated subsequent innovation.	Three winners were selected. The process stopped after the hackathon because none of the solutions originated from an established company.

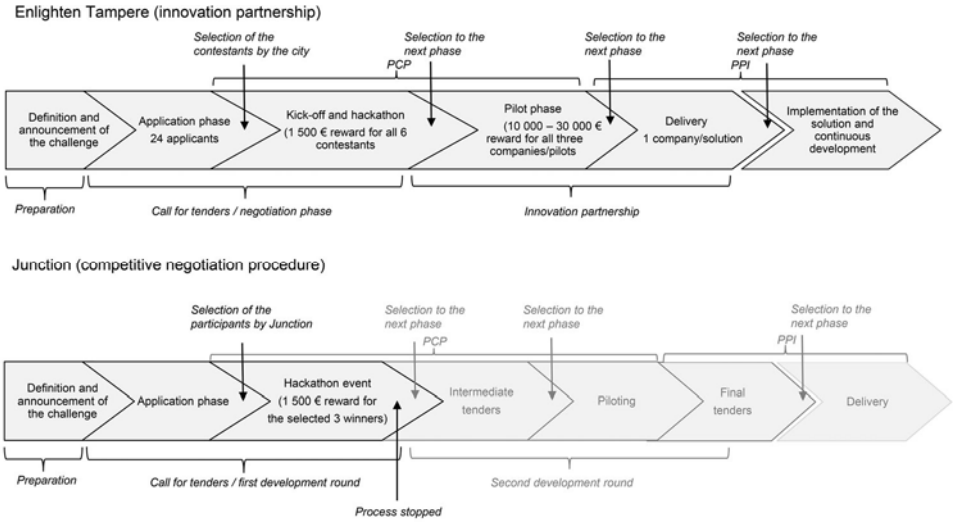

Figure 3. The Progression of Hackathons in Innovative procurement.

Organized by the City of Tampere's Smart Tampere program, Enlighten Tampere hackathon challenged business teams to innovate a smarter Tampere by utilizing data from the city's various operations, and in particular the street light network. Participants were also encouraged to create new, data-based service concepts for residents. The following four ideas were selected from Enlighten Tampere for testing 1) Use of imaging material to create a model where one can calculate every single light pole's level of illumination; 2) Strengthening the citizen engagement by giving the possibility to give feedback where lighting is needed (mobile application "Lights on!"); 3) The wireless communication system (e.g. Mesh network-based); 4) The lighting control system will be replaced to smart city sensor network e.g. by mesh -network devices.

The Enlighten Tampere pilot focused on developing functional profiles and automation entities in the test lighting system. Different automation profiles were used to study the advantages and disadvantages of using an automated lighting system. The piloting of the model provided concrete information on the requirements of the platform. Technical proof that dynamic control is possible using real-time external data sources. The pilot also provided information on the developer experience (DX) and requirements of the interface.

The Figure 4 below depicts the actual procurement process. The competitive dialogue process was selected as it is beneficial when greater flexibility is needed. The market dialogue allowed to collect more knowledge on optimal specifications and contractual terms when comparing what the market can offer versus what are the city requires. At the same time, the city could gradually amend the tender documentation. Discussions were held with almost 20 companies and the city received good information about the market and the Internet of Things and the platform economy. The market dialogue was clearly distinguished from the tendering process and carried out without compromising the risk of a fair and non-discriminatory treatment of tenderers.

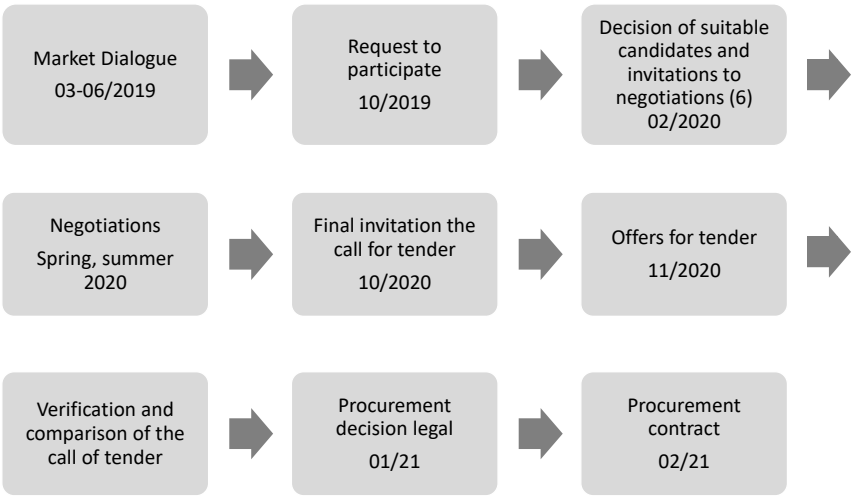

Figure 4. The progress of competitive dialogue in IoT Platform procurement.

The entity, IoT Platform and two implementations under this procurement are complex and the solution needs to be innovative as it is required to develop it further throughout the contract period of ten years. The procurement resulted in participation request documents as well as documents related to the invitation to tender, which other cities in Finland and abroad can utilize. The system requirements were defined to result in a solution that ensures the platform functions in a way that guarantees transparency, a multi-user ecosystem, specific supplier, and system independence, as well as scalability. IoT Platform

allows other ecosystem users to build applications that can be connected to the platform. Thus, it is possible to install third-party measuring and control equipment on the base.

The combination of the lighting control system and IoT platform procurement participated many stakeholders and different decision-making processes. The result was a time-consuming procurement process. Since IoT Platform was a completely new kind of service package to any city in Finland, there was nothing to benchmark or to learn on. Also, the city of Tampere did not have much experience of competitive dialogue as a procurement method nor the innovation partnership. During the procurement process several consultants were used for IoT requirement definition, but still it was not an easy task. The consultant was also used to evaluate the bids, especially to assess the developer experience, which proved to be a good way to gain clarity on the maturity of the platform interfaces.

4. The outcome of hackathons and competitive dialogue

IoT platform acts as a guide and enabler for innovative ways to see the city through the information gathered (Figure 5). The platform provides real-time and historical data on a reliable and harmoniously detailed view. The platform operates in real time to the extent required for use. Simultaneously, it is an open data platform capable of delivering data through open standards, standard data models, and standard interfaces. The platform provides information for various use cases and third parties who are entitled to receive it. The platform also enables data enrichment and data integration from different use cases (e.g., combining sensor location data with city map services).

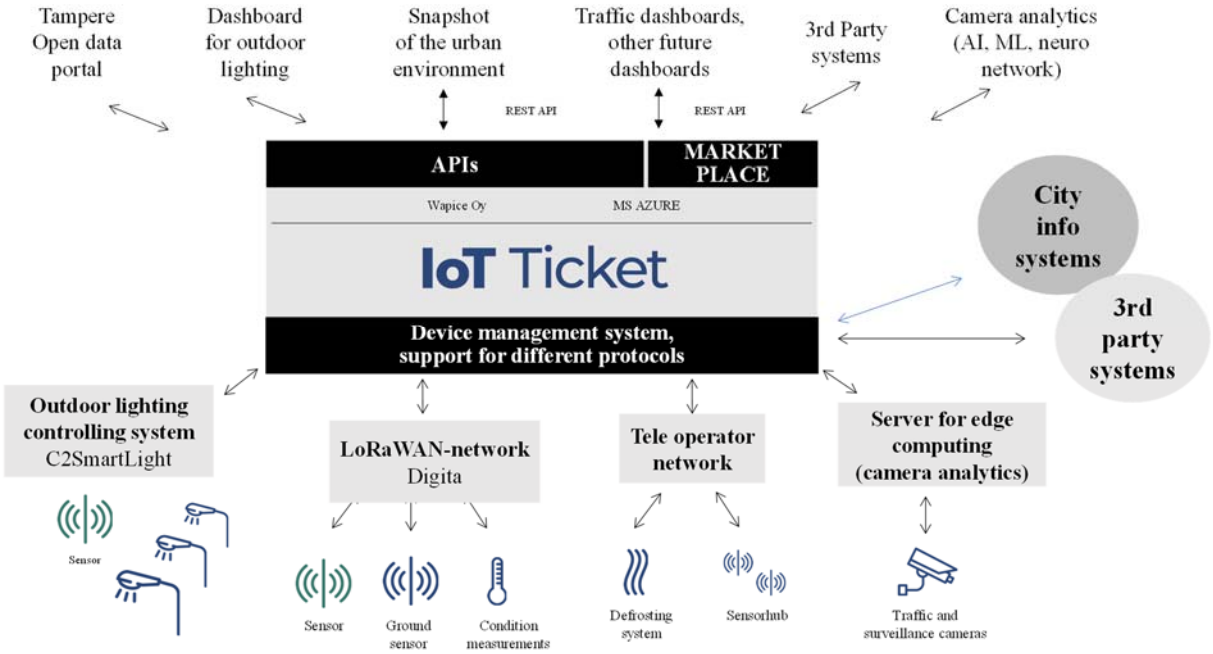

Figure 5. The IoT Platform architecture.

In urban development projects, such as the Stardust project, cooperation between cities involves the integration of data, which requires common data models and the use of interfaces. Different data can be downloaded from the platform in batches or in real time using interfaces and a marketplace. The data can also be semi-transparent, which can be shared with partners, and closed, which can be treated as anonymised as semi-transparent data. Data may also involve pricing and partners in data ecosystem can price their data.

IoT Platform controls the various sensors / actuators ("things") connected to the platform. The platform can read the data stream from these sensors and send messages back to the field devices. The

addition of new sensors and control devices also takes place via the platform. Communication between devices takes place automatically without human or manual process intervention. The platform works in two directions and thus allows control back to the operating environment.

5. Use cases of IoT Platform

In the first phase, IoT Platform is used for the city's outdoor lighting control system and the sensing solution that forms the basis of the snapshot of the urban environment. The pilot area already provided useful information about the functionality before the scaling of smart lighting for wider areas of the city. For the snapshot of the urban environment, different types of sensors, control devices and different data sources were added to the platform during summer and fall 2021. A possible new use case, which combines separate data streams, would be to control the lighting by information with the amount of light traffic so that more lighting is produced in areas where there are many people on the go.

Within ongoing Stardust project, the monitoring data of the solar power plant (energy production) and residential area (energy consumption) are collected. Several units from the University of Tampere are involved in utilizing the collected data.

After these first use cases, several other uses will be added to the platform during the contract period. An essential part of extending the use of IoT platform for data collection is the use of camera analytics edge computing servers to enable image recognition algorithms to be used locally in accordance with the General Data Protection Regulation (GDPR). An edge counting application generates statistics related to traffic counting and safety deviations based on connected camera streams. Edge calculation generates statistics on the number of identified objects and sends anonymized statistical information on edge calculation to the Tampere IoT platform. Edge computing servers are already installed and the use case planning for traffic counting purposes is ongoing.

6. Conclusions

The innovative procurement described in this paper has been a challenging process in many ways. Combination of the lighting control system and IoT platform procurement required the participation of many stakeholders and different decision-making processes. The result was a time-consuming procurement process. Since IoT Platform was a completely new kind of service package to any city in Finland, there was nothing to benchmark or to learn on. Also, the city of Tampere did not have much experience of competitive dialogue as a procurement method nor the innovation partnership. During the procurement process several consultants were used for IoT requirement definition.

The consultant was used to evaluate the bids, especially to assess the developer experience, which proved to be a good way to gain clarity on the maturity of the platform interfaces. Using hackathons and innovative procurement process to get more information for the requirements, on the other hand, were successful in several ways. The city got information for requirement definition for the actual IoT procurement process and the product of the innovative partnership was the Tampere.Finland application for the use of Tampere residents, and it already has more than 100,000 users.

All these brought a new kind of expertise to the city organization and brought organizations closer to each other. As a result of this cooperation, new use cases will be found for data streams, for example in improving and streamlining operations. In addition to the city's own activities, suitable use cases would also appear to be used to others, for example energy communities. Including a couple of use cases as part of the acquisition helped both the contracting entity and the tenderers to understand the whole of the procurement at a deeper level. During the deployment phase, it has been found that using a smaller pilot area is a good way to spot problems before scaling solutions across the city. The working collaboration needs transparency during the procurement phase as well as deployment phase and bringing up issues is important in the early phase.

However, there is still work to be done to create an ecosystem around IoT platform. To this end, the city and the Stardust project will build the necessary processes, brand, and contract bases to make joining the ecosystem as effortless as possible. The procurement process is a big and time-consuming process, especially when there is an entity, that includes several different technologies and uses cases. In the

absence of clear requirements for the IoT platform, the combination with use cases made sense. Now that there is more knowledge, it is easier to acquire the necessary pieces as their own acquisition projects; build and scale-up the future IoT platform as needed.

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References

[1] Airaksinen M and Kokkala M 2015 Smart City (*Espoo: VTT Research Highlights*) 12
[2] Hernández-Moral G Mulero-Palencia S Serna-González V I Rodríguez-Alonso C Sanz-Jimeno R Marinakis V Dimitropoulos N Mylona Z Antonucci D and Doukas H 2021 Big Data Value Chain: Multiple Perspectives for the Built Environment (*Energies* Basel: MPDI) 14 4624
[3] Lnenicka M Nikiforova A Luterek M Azeroual O Ukpabi D Valtenbergs V Machova R 2022 Transparency of open data ecosystems in smart cities: Definition and assessment of the maturity of transparency in 22 smart cities (*Sustainable Cities and Society* Elsevier) 82 103906
[4] Mohseni H Public engagement and smart city definitions: a classifying model for the evaluation of citizen power in 2025 Tehran 2021 (*GeoJournal* Springe) 86:1261–1274
[5] Pihlajaniemi H Juntunen E Luusua A Tarkka-Salin M Juntunen J 2016 SenCity:Piloting Intelligent Lighting and User-Oriented Services in Complex Smart City Environments (*34th International Conference on Education and Research in Computer Aided Architectural Design in Europe, eCAADe 24-26 August 2016)* pp. 669-680
[6] Sethukkarasi C Pal Amutha K Poonguzhali P and Sridevi S 2021 Data Distribution Platform for Smart City (*International Conference on Internet of Things and Intelligence Systems (IoTaIS) 23-24 November 2021)* pp 210-214
[7] Arman A Pierfrancesco B Bologna D Nesi P Pantaleo G and Paolucci M 2021 Automating IoT Data Ingestion Enabling Visual Representation (*Sensors* Basel: MPDI) 21 8429
[8] Perboli G Manfredi A Musso S and Rosano M 2019 A decentralized marketplace for M2M economy for Smart Cities 2019 (*IEEE 28th International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE) 12-14 June 2019* Napoli: Institute of Electrilac and Electronic Institute) pp 27-30
[9] Vítor G, Rito P and Sargento S 2021 Smart City Data Platform for Real-Time Processing and Data Sharing (*Symposium on Computers and Communications (ISCC) 5-8 September 2021)* pp 1-7
[10] Soe R-M Ruohomäki T and Patzig H 2022 Urban Open Platform for Borderless Smart Cities (Basel: MPDI *Applied Sciences*) 12 700
[11] Alvsvåg R 2021 A Concept for Smart City Data Marketplace using Enterprise Architecture and Service Design Approaches (*Trondheim: Norwegian University of Science and Technology*)
[12] Okwechime E, Duncan P and Edgar D 2018 Big data and smart cities: a public sector organizational learning perspective (Springer *Information Systems and e-Business Management*) 16(3) pp 601–625
[13] Chiehyeon L Kim KJ and Maglio P 2018 Smart cities with big data: Reference models, challenges, and considerations (Elsevier *Cities)* 82 pp 86-89
[14] https://data.tampere.fi/en_gb/
[15] Tampere City Board 2020 Carbon neutral Tampere (Tampere:
[16] Pihlajamaa M and Merisalo M Organizing innovation contests for public procurement of innovation: A case study of smart city hackathons in Tampere, Finland 2021 (*European Planning Studies* Elsevier) 29 10 pp 1906-1924
[17] https://smartstad.stockholm/IoT-stockholm/