TASC.
The Academy for Smarter Communities

IoT Platforms for Cities:
a Comparative Survey

Theodoor van der Klaauw

January 2019

RAINMAKING

Executive Summary

Thousands of city governments all over the world are currently running their first Internet of Things (IoT) smart city projects. As they do so, software platforms get introduced that help manage data flows, support application development, and provide basic analytics. However, the IoT platform selection process is challenging and differs per community – that is if the selection process exists at all, with many customers of IoT solutions accepting the vertically integrated software that comes with a given vendor, putting cities at risk of vendor lock-ins. Some city governments prefer to collaborate with smaller IoT platform vendors that can provide strong support and appear sufficiently agile to customize to local requirements and ecosystems better and faster; other cities prioritise the scalability, end to end security, and usability offered by larger technology vendors. Either way, most public and many private organizations emphasize the need for an open ecosystem approach.

Perhaps the most notable difference between vendor approaches and platform solutions is the degree of openness. What distinguishes open source platforms, is the royalty-free source code which enables governments to develop, modify, and tailor solutions to meet specific local needs, and reduce vendor dependence. To speed the adoption of urban IoT platforms, open standards are developed. However, stakeholders articulate that existing open source based solutions are often incomprehensive, immature, or lack the demanded support. Alternatively, city governments can make the systematic and architectural decision to use proprietary solutions. Most popular vendors offer Application Enablement Platforms (AEPs) that enable business partners and IoT application builders with software components to build or add their own solutions ‘on top of’ the platform, whereas other vendors decide to market an end-to-end management platform. Policymakers mention public expertise and the ability to help create a digital strategy, provide technical and service support, and the opportunity to outsource software maintenance as major benefits. However, lack of clarity on data ownership, storage, and the future fate of data collected at large, the sensitivities that come with data privacy and regulatory compliance, risks of vendor lock-ins, limited assessment capacity of what’s ‘happening under the hood’, as well as limitations on customizability, pose substantial challenges determining the choice, timing and scale of platform adoption, especially where it concerns software platforms offered by larger vendors or platforms with a closed character.

To create an improved understanding among stakeholders, this comparative study evaluates different IoT platform solutions in terms of integration & interoperability, functional capabilities, business & delivery models, as well as partner strategies & ecosystem. Other decision factors that have been emphasized by public entities and that are given consideration in this study include portfolio comprehensiveness, platform security, user experience, scalability, and a vendor's expertise in, and focus on, the urban space. Open-standard based IoT developer platform FIWARE is popular due to its high interoperability, low costs, and easy scalability, whereas competing vendors such as Microsoft, IBM, and Amazon offer proprietary alternatives that are primarily appreciated for the broad functionalities, partner ecosystem and security. Cisco and Huawei offer the most comprehensive city operating IoT platforms, with Cisco in particular having taken an open ecosystem approach, yet concerns over vendor lock-in, among others, remain.

Theodoor van der Klaauw & Bas Boorsma

The Academy for Smarter Communities (TASC)

www.tasc.world

Industry Overview: Facts & Figures

- In 2018, Smart City overtook leading vertical Smart Manufacturing with respectively 23% against 17% of all IoT projects performed worldwide.
- The total value created by Smart City projects worldwide accounts for approximately 67% of the total value created by Smart Manufacturing.
- Europe is the largest contributor of government- and municipality-driven initiatives (45%), followed by the Americas (35%) and APEC (20%).
- Smart city use cases in the domains of traffic management & mobility (35%), energy & utilities (30%), and security & street surveillance (15%) have the highest adoption rate.
- In most recent years, the average yearly churn of startups in the Smart City space was 15%. To illustrate: startup churn rates in SaaS and consumer goods are respectively 5,5% and 9%.
- In 2017, more than 2100 IoT startups have collectively raised $57 billion venture funding, of which $7 billion by 250 software platform startups.
- Out of approximately 450 software platform vendors, at least 80 currently provide a solution for the smart city segment.
- Samsung, Qualcomm, LG, Huawei, and Intel are the top five patent holders in the IoT industry today, together controlling over 13,000 patents.
- Roughly 75% of IoT adopters turn to outside firms for help in strategy, planning, development, implementation, and/or management.
- In 2019, approximately 40% of governments will use IoT to derive value from city infrastructures such as roads, streetlights, and traffic signals.
- By the year 2020, an urban area with 1 million inhabitants is expected to generate 200 million GB of data per day.

Used sources, as displayed in the reference list: Dell (2018), Forbes (2018), IDC (2017), IoT Analytics (2018), Recurly (2018), Venture Scanner (2018).

Introduction

The adoption of the Internet of Things (IoT), referring to devices, sensors and actuators that are embedded in previously disconnected physical objects, is maturing, and its application in public domain a reality. IoT technologies can be used by public and private organizations to improve the livability, quality, and sustainability of our homes, our communities, our cities. To coordinate, secure and manage the vast amount of data generated across different urban domains, IoT and data platforms play a central role. Because these platforms provide the middleware, or software layer, that connects IoT devices and endpoints (e.g. sensors and actuators) with web services and applications, they can also be referred to as Application Enablement Platforms (AEPs) or IoT developer platforms. Due to their differences in terms of purpose and design, IoT platforms can be divided into consumer-, industrial-, and enterprise-focused segments. For instance, consumer platforms provide solutions for individuals and families at home; industrial platforms for robust, high risk environments such as ports and oil platforms; whereas conventional urban infrastructures require the intelligent use of enterprise solutions.

Within the ever larger array of so-called IoT and data platforms on the market, aimed to facilitate smart city architectures, choices differ greatly in terms of value proposition and actual performance. Due to the lack of industry transparency and objective information provisioning, public and private stakeholders are challenged to make consistent, well-informed and sustainable managerial decisions with regard to their urban digitalization efforts. This study aims to help building a comparative understanding of different vendors and solutions, and how they fit with needs and preferences that city management articulate. The findings that are presented in this survey are to a large extent the accumulation of expertise gathered within the TASC-community.

This survey has been commissioned by TASC, the academy for smarter communities. TASC is born out of an ambition to create smarter and more livable communities – and to facilitate those that lead such efforts. To that end, TASC provides high-end Smarter Community Masterclasses to advance the skills and competencies of professionals, practitioners, executives and elected leaders in this new discipline. TASC is a partnership between Rainmaking Innovation Ltd and the DOLL Living Lab (Gate 21).

Methodology

When analyzing IoT platforms for cities, different perspectives should be considered. The findings in this comparative study are based on the experience and knowledge shared by city leaders as well as smart city experts from private sector enterprise (i.e. Cisco, Huawei, IBM, Microsoft) and not for profit organizations (i.e. DOLL Living Lab, Imec, Open & Agile Smart Cities, FIWARE). In order to harvest the insights of these leaders, face to face interviews were conducted across companies of relevance, cities, NGOs and academia. Public executives interviewed included CIOs, CTOs, chief innovation officers and smart city program leaders. Private sector leaders interviewed typically included managing directors, senior managers and senior product specialists. Because of their innovative and leading work in the urban digitalization space, the survey has targeted authorities from the cities of Amsterdam, Antwerp, Copenhagen, Jaipur, Kansas City, Palo Alto, Reykjavik, San Diego, Santander, Singapore, and Tampere. The results from the interviews are complemented by information derived from technology-focused discussions held during the Smart City Expo World Congress 2018 and online resources and literature on IoT and smart cities.

The measured *Technological criteria* of IoT platforms in this study are:

- Functional Capabilities;
- Interoperability & Integration;
- Scalability;
- Security;
- Usability.

The measured *Organizational criteria* of solution vendors in this study are:

- Subscription Model & Platform Costs;
- Partner & Ecosystem Strategies;
- Portfolio Comprehensiveness;
- Vendor Expertise & City-focus.

<u>Functional Capabilities</u>

The capabilities of IoT platforms can briefly be divided into three core layers:

- device development and management;
- data ingestion, processing, analytics, and visualization;

- application development and deployment.

This section focuses on the ability of IoT platforms to facilitate fast and simple device control and connectivity, effective data management, and capabilities to enable the development of complex or city-specific platform applications.

Interoperability & Integration

As urban digitalization roadmaps evolve, more systems and applications need to be integrated. Vertical integration refers to the integration of IT-systems at various levels within the same value chain, such as smart street lights, a middleware software platform, and vendor applications that provide insights in local energy consumption. Horizontal integration refers to the integration of IT-systems for and across various city processes and domains, such as traffic route information based on real-time air quality data. Integratable and interoperable smart city platforms grow in popularity since they enable users to share ecosystem-wide information between various systems and across processes, limit costs, optimize decision-making, create new and combine existing solutions. Vendors are assessed on provided device and service support, speed and ease of roll-out, and integration capabilities with existing and legacy urban systems. Further, platform vendors are assessed on their ability to secure applications and data flows and on “tweakability,” or the ability to customize the set of platform functionalities. Policymakers emphasize that functionalities should be tailored to meet specific, local needs and limit unnecessary costs, which especially occur during the scalability phase. To conclude this section, because inexperienced and less IT-savvy people should be able to participate in a city’s digitalization journey, the usability of IoT and data platforms is tested in the survey as well.

Subscription Model & Platform Costs

Whereas a platform’s ability to support and adopt different technologies and vendors is key to measure future proofness and performance, the actual technology stack seems less relevant. More importantly, urban CIOs articulate, IoT solutions should help governments to do what they already intended to do, at lower costs. Therefore, vendors are assessed on the degree to which solutions are scalable and drive efficiencies – be it cost efficiencies as well as environmental and social benefits – at a cost of platform and platform use that itself is transparent, predictable and affordable. The points of analysis that are used in this section are delivery model (e.g. public or private cloud,

on-premise), financing models or programs (e.g. licensing, pay per use), life-cycle costs, and required upfront investments.

Partnership Strategy & Ecosystem

Ultimately, policymakers and CIOs agree that no single platform will be able to offer the best end-to-end platform solution across all urban domains. Hence, a partner ecosystem should be selected, rather than a single vendor. To understand how these collaborative urban ecosystems develop, the degree of platform openness must be addressed. Application Enablement Platform (AEP) vendors position themselves as open and collaborative players since their modular and standardized building blocks integrate well with and can easily be used to develop third-party solutions. Like proprietary AEPs, open source platforms provide the ability to cities to easily manage and scale IoT projects, but at close to zero cost and no risk of vendor lock-in. Although industry collaboration on standards and certification should guarantee a certain degree of quality, critics say that security is insufficiently incorporated in the design of current open source solutions, and question the possibility to add this later on. Another reason that prevents cities from developing and using open source IoT platforms is the lack of technical and service support.

For different reasons, many policymakers of some pioneering urban areas, in the US and Europe (more so in the latter), consider open source a universal panacea and dismiss any proprietary solution. In many other cities across the globe, however, proprietary solutions have been central to the exercise, sometimes with high degrees of interoperability, facilitating open ecosystem collaboration, and yet in other situations seeing cities locked into proprietary protocols entirely, end to end. The majority of cities and communities remain undecided on which approach to take, and most conduct a handful of pilots, and wait for results elsewhere. The increasing market demand for open platforms is recognized by private organizations as well, who frequently advertise with interoperable, city-friendly data platforms, and large partnership ecosystems. That said, dissatisfaction with the amount of partner-consortia that exclusively support and work within their own standards foster the debate on the importance of open standards in the IoT and data platform space.

The portfolio comprehensiveness and expertise in, and focus on cities of IoT vendors help to determine their degree of sustainable value delivery.

Open Source Vendor and Solution Analysis

European Innovation Partnership on Smart Cities and Communities (EIP-SCC) is a stakeholder driven initiative, stimulated and supported by the European Commission, that aims to improve urban life through more sustainable integrated solutions. EIP-SCC addresses city-specific challenges by focusing on different 'action clusters'. One of the clusters is integrated infrastructure and processes, which includes urban data platforms. To speed the adoption, at scale, and ensure that 300 million European citizens are served with competent city management and citizen engagement platforms by 2025, urban standards and open data governance are highlighted as priority areas. Intensive collaboration happens between EIP-SCC and the systemic standardization approach to empower smart cities and communities (ESPRESSO), funded by EU's Horizon 2020 program.

To create useful and effective open standards, a thorough understanding of city business processes, performance indicators, and information models is necessary. The complex relationship between technology standards and city governance emphasizes the importance of stakeholder cooperation. The goal of collaborative efforts between the EU, international non-profit organizations such as Open and Agile Communities (OASC), SynchroniCity and 100+ global cities and communities is to co-create a global smart city data and services market. Recent developments show how application builders can use real-time data accessed via marketplaces such as Marketplace.city and Digital Catapult (powered by FIWARE) to build, test and replicate their solutions across cities compatible with open-standards. The FIWARE Foundation was founded as a non-profit association with the mission to build an open sustainable ecosystem around public, royalty-free and implementation-driven software platform standards. The term "open", when used in the context of IoT platforms, often refers to the degree a vendor provides software developers with access to self-developed, and third-party microservices and functional capabilities.

FIWARE Open Source Platform

Pros: Open, Interoperable, Integrable, Scalable platform at Low costs.

Cons: Lack of vendor expertise; Low platform security & Comprehensiveness.

FIWARE's Open Source Platform is a framework of software building blocks that can be assembled to accelerate the development of smart solutions, for instance in cities. One of the important differences between FIWARE and IoT platforms developed by technology vendors is the degree of openness and interoperability. Based on the philosophy that technology should be accessible for everyone and not owned by anyone, platform interoperability, modularity, and customizability are the underlying platform principles. FIWARE building blocks are 100% open source and can be easily embedded by ecosystem partners in the design of their solutions and reduce vendor lock-in risks. Furthermore, stakeholders value how IoT data can be easily merged with data from other relevant sources, and the fact that the use of FIWARE platform components is royalty-free. In addition to the growing interest in open source software, European subsidies form another important reason for cities to develop FIWARE-powered or compatible platforms. One security expert criticizes the FIWARE architecture for "not being secured by design", and questions the possibility to add this later on. Further, a platinum FIWARE partner expresses their challenges in terms of visualization, geospatial analysis, and usability. Moreover, policymakers would like to see more advanced end-to-end solutions, and benchmark projects before considering to implement the FIWARE open source platform. Platinum partners NEC (CCOC platform), Telefonica (City Thinking), Orange (Business Services), Atos (MyCity), and Engineering have deployed only a limited number of FIWARE-powered cloud-based city operating systems, mainly in Southern-European cities such as Santander, Madrid, Lisbon, Valencia, and Barcelona. In addition, CEDUS deployed their City Enabler Platform in Antwerp, Copenhagen, and Helsinki, based on a micro-services architecture and various FIWARE Generic Enablers, and aims to collect all urban data from heterogeneous sources (legacy systems, sensors, open data, private data) in a single access point. Because many open-standard based solutions are either incomprehensive, immature, or lack any form of support, cities seem hesitant to develop and implement FIWARE-powered platforms at scale.

When comparing open-standard based city management alternatives, stakeholders should be aware of the difference between FI-WARE-*compatible* and FIWARE-*powered* platforms. FIWARE-powered solutions use Context Broker as core component, whereas FIWARE-compatible platforms might only support the NGSI RESTful API. The best way for stakeholders to assess whether FIWARE is in the DNA of a vendor's city management solution architecture is to simply ask for the code.

Proprietary Vendor and Solution Analysis

AT&T Dataflow

Pros: Strong partnership strategy, Vendor expertise, and City-focus.

Cons: Low platform openness, and Portfolio comprehensiveness.

AT&T's Dataflow is a cloud-hosted IoT network provider platform that extends network intelligence, enabling enterprises to manage, integrate, and consume connected device data in a single, holistic dashboard called Control Center (powered by Cisco Jasper). The company's IoT product suite is designed for different verticals such as aviation; seaports; and smart city, focusing on digital infrastructure, smart irrigation, and structure monitoring level. In San Diego, AT&T partners with Current (powered by GE) to provide operational insights, and create a platform that enables business clients to develop applications such as gunshot detection and traffic flow analysis. However, the right to develop applications is limited to business clients, which limits the openness and development speed of the Dataflow IoT platform.

AWS IoT Suite

Pros: Secure, Scalable, Functional, Integrable platform, at Low costs.

Cons: Low portfolio comprehensiveness.

AWS IoT Suite can be described as a generic solution portfolio, or application enablement platform (AEP), rather than a comprehensive city operation system. The suite offers four different IoT software building blocks: AWS IoT Core which lets connected devices interact with cloud applications and other devices; AWS IoT Device Management which enables users to onboard, organize, monitor, and remotely manage IoT devices at scale; AWS IoT Device Defender which continuously audits IoT configurations; and AWS IoT Analytics which facilitates sophisticated analytics on large volumes of IoT data. With functionalities like Security Groups and Trusted Advisor, AWS is highly valued for its platform security. Furthermore, stakeholders appreciate the vendor's solution integration, from edge to cloud, with services such as Lambda, Amazon Kinesis, and Amazon Machine Learning. Despite additional development costs, pricing and revenue model seem beneficial, especially for

large communities with high potential to scale. According to a senior manager with expertise in the urban communication and technology space, “AWS has a stronger partner ecosystem than Google, but cannot hold up to Microsoft’s”. AWS solutions have powered smart infrastructure projects such as PARK SMART, which provides real-time parking information to city governments and citizens; and Philips CityTouch, which enables users to monitor energy consumption and predict the need for repairment of street lights.

BOSCH IoT Suite

Pros: Open, Integrable platform with Strong device management capabilities.

Cons: Lack of functional capabilities; Unattractive subscription model.

BOSCH IoT Suite, developed by one of the largest multinational engineering and electronics companies in the world, offers open-standards based SaaS applications for connected mobility, industry, energy, home and building, and city. City leaders appreciate the strong device management and middleware capabilities, and modular and open development approach, which enables customers to simply tune the suite via API and develop IoT applications on top of the platform. Due to the basic interface and set of functionalities, BOSCH is dependent on partners for applications that meet customer needs in terms of, for instance, complex event processing or advanced analytics. However, a former executive within the Singapore government highlights that “the BOSCH platform has an unclear value proposition: there are pieces of solution but the company lacks to provide a full offer”. The Bosch IoT Suite is available via Bosch’s company-built IoT Cloud or as a fully managed, shared service on AWS (in a Beta version). IoT and city data is hosted in Germany to meet the GDPR compliance needs of European customers.

CISCO Kinetic for Cities

Pros: Comprehensive, Secure, Scalable platform solution provided by a vendor with a Strong partner ecosystem, Vendor expertise & City-focus.

Cons: Lack of customizability, and Client support.

CISCO’s Kinetic for Cities is an end-to-end data platform that consists of three different offerings. Connectivity solutions enable users to gather data from

sensors and IoT endpoints; the IoT platform transforms, ingests, normalizes, and transports data to applications and users; and the security portfolio provides access to a city's network and data platform. The Kinetic suite exists for different verticals such as manufacturing, oil & gas, transportation, retail, and cities. Their city-focused data platform ranks best among those verticals. Amongst 50+ deployments around the world, Jaipur in India is currently one of the largest deployments – both in terms of domain use cases addressed and the amount of devices connected. Access to an acknowledged partner ecosystem, equip Cisco to meet specific needs in the urban context. For instance, users appreciate the strong configuration capabilities with existing network and platform solutions, and the software modules that help to standardize and effectively converge different data types across different city domains. Compared to generic IoT platforms such as Microsoft's Azure, Cisco goes higher up the software stack since they offer a single interface, front-end application. The scalability on horizontal as well as vertical level facilitates cities in their integration process with innovative solutions in the future, which is one of the requirements to thrive in a fast-developing technology landscape. Furthermore, a CIO of an innovative city in the US articulates that "the platform robustness, security, and funding opportunities provided by Cisco are best in class".

Although Cisco clearly recognizes the importance of collaboration in the urban IT-landscape and claims that Kinetic for cities is an open data platform without collaborative restrictions, policymakers remain critical about the closed software approach. Cisco facilitates a high degree of interoperability and a vendor agnostic approach to vertical solution providers and/or access technologies, but the proprietary fundament of Kinetic remains problematic and a point of criticism for smart city leaders. For instance, one Managing Director responsible for the digitalization of an European city explains that "Cisco exclusively focused on profitable and widely adopted solutions, which resulted in low product customizability and effectiveness, and client support. For these reasons, cities hesitate to partner with Cisco in their urban digitalisation efforts.

DELOITTE CitySynergy

Pros: Strong functional capabilities, and Government decision support.

Cons: Lack of vendor expertise in the smart city software space.

DELOITTE's CitySynergy and Digital Command Center (DCC) are proprietary-managed services designed and developed to connect different city domains, improve government decision-making, and drive new operational efficiencies. The operating system, that has been first launched in Cascais, Portugal, promises to manage the complex environment in one single dashboard by providing functionalities such as integrated maps with assets and dependencies, customizable reports, real-time data analytics, and a series of open APIs. Mobility, public infrastructure management, civic protection, emergency management, and waste management have been selected as the four pilot domains. Deloitte utilizes their deep expertise in processes and operations to market a holistic, cloud-based city management solution, but a lack of deployments complicate the evaluation of platform performance. A co-founder of a non-profit organisation says that cautiousness is appropriate since "companies such as Deloitte can easily use their extensive knowledge about public decision-making to manipulate processes, and take advantage of solutions that are attractive to scale rather than solve local problems". The business model of CitySynergy is a shared upfront investment with local and regional governments, and thus requires full executive support.

GOOGLE Cloud Platform

Pros: Scalable solution with Strong functional capabilities.

Cons: Lack of city-focus; High platform costs.

GOOGLE Cloud Platform (GCP) is an application enablement platform offering building blocks to business partners such Google Maps; IoT Core and Edge, which can be used to integrate and manage devices and data; and Machine Learning engine at a fee per MB. The actual charge depends on the total volume sent from IoT endpoint to server. Compared to competitors such as Microsoft, Google offers a limited range of products and services in the IoT space. Examples on the company's website showcase a handful of vendors that use GCP, mainly focused on vehicle tracking, smart manufacturing, and smart parking. The lack of launching customers and implemented use cases at scale, their absence at the Smart City Expo World Congress 2018, the acquisition of smart thermostat company NEST, and the significant investment in Google Voice Assistant all suggest that Google positions strategically for the smart home appliances industry rather than they focus on the IoT software industry for cities and governments.

HUAWEI Smart City Solutions

Pros: Comprehensive city platform with Strong functional capabilities.

Cons: Closed solution; concerns about Security; Limited partner ecosystem.

HUAWEI Smart City Solutions is a proprietary and closed urban management platform, positioned as an end-to-end smart city solution, and is comparable to Cisco's Kinetic for Cities in most ways. The platform's architecture is built on top of data management, collaboration, and application enablement layers that are exclusively accessible for business partners, and are segmented by different models such as smart energy command, and transportation. Also, relatively unique use cases are developed such as tourism, and food quality control. Huawei has partnered with multiple Chinese metropolitan areas to test and run their cloud-based, intelligent smart city operation platform, and now promotes an expansion to cities and communities across the border. However, a smart city expert from Denmark argues that "specific functionalities, such as tracking identifiable citizens, show that Huawei has not succeeded to assess the underlying principles and values that Western policymakers demand". Although Huawei's technological solutions such as AI, Video, big data, and IoT are of high quality and prepare customers for the next decade, people-centric concerns with regard confidentiality and integrity of citizens' private data seem to prevent cities from partnering with the Chinese technology company. Due to a lack of launching customers and European partners, product information is limited, and platform customization costs are expected to be relatively high.

IBM Watson IoT Platform

Pros: Secure, Interoperable, Integrable IoT platform with Advanced functional capabilities provided by a vendor with a Strong partner ecosystem.

Cons: Low portfolio comprehensiveness at High costs.

IBM Watson IoT Platform offers premium industry-specific solutions such as IoT for automotive, insurance, manufacturing, and retail, but has not developed a specific management platform for cities. Stakeholders highly value the software platform because of its (cognitive) analytics capabilities, and support for innovative technologies such as Blockchain, AI, and Node-RED that are expected to provide value above and beyond their generic IoT platform, in the medium as well as the long term. In addition, multi-layered security capabilities are built into the architecture, which enable users to easily identify issues and

safeguard data, devices, and IT-systems. Next to strong functional capabilities, IBM brings a recognized partnership ecosystem and industry experience to the table, with public, private, and on-premise deployments across 175 countries.

In cooperation with the Port of Rotterdam (The Netherlands), IBM partners with Cisco Kinetic to provide a hybrid, multi-cloud environment that enables all ecosystem partners to leverage unique stakeholder capabilities such as advanced data analytics, networking, and device management, and prevent single vendor dependence. Although IBM's Watson solutions can be easily integrated with other systems and applications, the development of a smart city platform generally requires complex customization for third parties and is therefore difficult to scale. The combination of high development costs and limited data visualization capabilities seem to prevent most governments to partner with IBM in their urban digitalisation efforts at scale.

MICROSOFT IoT Suite

Pros: Open, Interoperable platform with Strong functional capabilities provided by a vendor with High domain expertise & City-focus.

Cons: Lack of portfolio comprehensiveness, Complicated pricing model.

MICROSOFT IoT Suite is an IoT developer platform that offers a variety of software building blocks, such as Azure IoT Edge, Stack, Hub, Digital Twins, and Maps. Microsoft takes on a collaborative, vertical go-to-market strategy towards urban digitalization, which has led to a clear value proposition as a solution enabler and integrator. Like with other AEPs, Azure's product portfolio can be used by the company's large partner ecosystem of certified device and software integrators to build scalable, end-to-end solutions, including city operation systems and dashboards. One operating system application is, for instance, developed by ecosystem partner LTI, whereas Bentley Systems offers a Azure-powered connected data environment solution. Customers describe the cloud-based Azure IoT Suite as comfortable to work with, mainly because of the high interoperability; strong built-in device and software integration, data management and analytics capabilities; and visualization tools. The fast and easy implementation, device management, and device-to-cloud communication enable Azure to act as a gateway in the IoT smart city ecosystem, deployed and appreciated by many city governments.

However, according to one Microsoft business partner “the pricing model is perhaps the least attractive of the offering since it is quite complex and moderately expensive”. The Azure suite is a swiss army knife that is amongst the top industry solutions, and customers can expect further improvement since Microsoft announced a $5 billion investment in IoT over the next four years. With this investment, the company wants to develop functionalities to support innovative technologies, and expand their customer base, including local and regional governments, smart homes and smart industry.

NOKIA IMPACT

Pros: Interoperable platform with an Attractive subscription model provided by vendor with a Strong city-focus.

Cons: Low degree of platform openness and a Lack of vendor expertise.

NOKIA IMPACT (Intelligent Management Platform for All Connected Things) is an integrated IoT platform featuring an comprehensive array of solutions in connectivity, device management, data collection and analytics, and application development. The company is commercializing its smart city use cases by developing blueprints, such as CCTV, parking, lighting, incident management, enabled by a strong IoT partner ecosystem. For instance, to accelerate the migration of service provider applications to the cloud, Nokia has a strategic partnership with AWS. Customers, such as Imec in Antwerp, really appreciate IMPACT for its strong video, AI, and data fusion capabilities, that allow them to integrate multiple sources to produce a more consistent, and accurate flow of city information. In addition, wireless connection of CCTVs and easy integration with third-party software vendors result in low deployment costs. Similar to AT&T, the right to develop applications is exclusively assigned to business clients, limiting the platform openness and development speed.

SAP Cloud Platform

Pros: Open, Scalable platform with Strong functional capabilities.

Cons: Incomprehensive city management solution that is difficult to Integrate with; Less attractive subscription model.

SAP Cloud Platform offers four different IoT solutions: device management, data synchronization, edge services, and application enablement. The open and flexible connectivity approach allows developers to build their own applications on the software platform. Compared to similar platforms such as Nokia IMPACT, stakeholders appreciate the built-in IoT edge and advanced analytics capabilities of SAP HANA, whereas one European CIO criticizes the city management platform for "not being horizontally integrated very well and the lack of interoperability, which results in isolated use cases and an incomplete solution". Standalone applications, such as water management or citizen engagement, and the confusing pricing model seem to prevent cities and communities to partner with SAP in their urban digitalisation efforts.

SIEMENS Mindsphere

Pros: Integrable IoT platform solution with Strong application development capabilities provided by a Highly expertised vendor.

Cons: Low performance on portfolio comprehensiveness and Subscription model attractiveness (at least of the standard portfolio).

SIEMENS Mindsphere is an industrial application 4.0 IoT operating system, which enables data from, amongst other things, factories, trains, lifts, and airports to be collected and analyzed. Recently, the company has released a cloud-based (public, private, or on-premise via AWS and Azure) software suite to help city governments manage domains such as mobility, air quality, and energy consumption, although advanced features lack at this stage. For instance, in Reykjavik, Siemens deployed a traffic control system to route information from a planning and monitoring perspective, whereas a joint venture deal has been signed with the Guangzhou Development District and Asian smart city vendor Asendas-Singbridge to deploy their City Air Management solution. Stakeholders working with the Mindsphere platform appreciate its easy application development (for business clients only), device management, and data-based service integration between Siemens and third-parties. For additional services such as Mindsphere Academy, Consulting, and Plant security an extra fee is charged.

Vendor performance based on Technological criteria:

	Functional capabilities	Interoperability & integration	Scalability	Security	User experience
AT&T	+	+	++	++	+
Amazon	++	++	+++	+++	++
Bosch	++	++	++	++	++
Cisco	+++	+	++	+++	+++
Deloitte	+++				
FIWARE	+	+++	+++	+	+
Google	++	++	+++	+++	++
Huawei	+++	+	++	+	+++
IBM	+++	++	++	+++	++
Microsoft	+++	++	+++	+++	++
Nokia	+	+	++	++	++
SAP	++	+	+++	+++	+
Siemens	+	+	++	++	++

Vendor performance based on Organizational criteria:

	Comprehen-siveness	Partnership strategy & ecosystem	Subscription model, costs	Vendor expertise & City-focus
AT&T	++	+	$$$	++
Amazon	+	++	$$	+
Bosch	++	++	$$	++
Cisco	+++	+++	$$$	+++
Deloitte	++	+++		
FIWARE	+	+	$	++
Google	+	++	$$$	+
Huawei	+++	+	$$$	+
IBM	+	+++	$$$	++
Microsoft	+	+++	$$	+++
Nokia	+++	+	$$	++
SAP	+	++	$$$	+
Siemens	+++	+	$$$	++

References

Datasmart (2015), *The Urban Internet of Things*, https://datasmart.ash.harvard.edu/news/article/the-urban-internet-of-things-727, 15 November 2018.

Dell (2018), *Technologies Digital Cities Roadshow*, https://www.delltechnologies.com/content/dam/delltechnologies/images/forum/emea/presentations/en-us/dubai/dt-01.pdf, 5 December 2018.

Forbes (2018), *10 Charts that will challenge your perspective on IoT*, https://www.forbes.com/sites/louiscolumbus/2018/06/06/10-charts-that-will-challenge-your-perspective-of-iots-growth/#6b1d98533ecc, 4 September 2018.

IoT Analytics (2018), *The top 10 IoT segments in 2018*, https://iot-analytics.com/top-10-iot-segments-2018-real-iot-projects, 4 September 2018.

IDC (2017), *FutureScape: Worldwide IoT 2017 Predictions*, https://www.idc.com/getdoc.jsp?containerId=US43162317, 4 October 2018.

ISG Provider Lens (2018), *IoT Quadrant Report*, https://www.cognizant.com/Resources/isg-iot-quadrant-report.pdf, 3 December 2018.

Medium (2018), *Price Comparison of IoT Platform Vendors*, https://medium.com/@iskerrett/price-comparison-of-iot-platform-vendors-b07ab4bbf0e, 4 October 2018.

McKinsey (2013), *Open data: Unlocking innovation & performance with liquid information*, https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/open-data-unlocking-innovation-and-performance-with-liquid-information, 15 November 2018.

Recularly Research (2018), *Is your churn rate within healthy range?*, https://info.recurly.com/research/churn-rate-benchmarks, 3 December 2018.

Venture Scanner (2018), *IoT Sector Overview Q2 2018*, http://www.venturescanner.com/blog/2018/internet-of-things-sector-overview-q2-2018, 13 September 2018.

Yonomi (2018), *Consumer, Entreprise & Industrial IoT platforms: What's the difference*, https://www.yonomi.co/blog/2018/5/10/consumer-enterprise-and-industrial-iot-platforms-whats-the-difference, 4 November 2018.