Conceptual Model of Big Data Technologies Adoption in Smart Cities of the European Union

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Abstract

Big data technologies enable cities to develop towards a smart city. However, the adoption of big data technologies is challenging, which is why it is essential to identify factors that influence the adoption of big data technologies in cities. The main goal of the paper is to propose a conceptual model of big data technologies adoption in smart cities of the European Union. In order to derive the conceptual model following is done: i) overview of the previous Technology-Organisation-Environment framework - based research on the adoption of selected information and communications technologies crucial for the development of smart cities, and ii) selection of factors based on the critical examination of the previous research. Selected factors, Absorptive Capacity, Technology Readiness, Compatibility, City Managements Support, the Existence of Smart City Strategy and Stakeholders Support, were incorporated into the conceptual model of big data technologies adoption in smart cities of the European Union.

Keywords: smart city, big data technologies, adoption, TOE framework
JEL classification: O33, R00

Paper type: Research article
Received: Jul 9, 2020
Accepted: Jul 27, 2020

Introduction

According to the European Parliament's Industry Research and Energy Committee (2014), smart city is a city seeking to address public issues using recent information and communication technologies supported by city management and other stakeholders. Adoption of various information and communication technologies enables cities to develop towards a smart city. Ideally, a city adopts big data technologies that facilitate the operation of different smart solutions based on data processing and analysis. Big data technologies refer to various solutions and tools that enable rapid generation of large amounts of various types of data, acquisition, storage and fast analysis of such data. Based on the results of big data analysis, city management can get insights, make conclusions about the urban environment and make decisions to improve the quality of life in the city.

However, the adoption of more sophisticated technologies such as big data technologies is challenging, which is why it is crucial to identify factors that influence the adoption of big data technologies in cities. For cities, big data technologies represent innovation. According to Rogers (2003), adoption of technology or innovation can be defined as a decision to make full use of technology (innovation) as the best course of action available. Acceptance and integration of a technology precede use of technology. Hence, it can be said that they are also part of technology adoption. The adoption of big data technology in cities is, therefore, a process of acceptance, integration and use of big data technologies in cities.

Previous research has addressed general topics related to big data technologies, such as costs as risks of selecting big data technologies or review of current solutions and tools for managing big data, for example, Chen et al. (2014). Moreover, there is a limited number of scientific papers that assess the factors of big data technologies adoption from an organisational perspective, such as Lai et al. (2018) and Chen et al. (2015).

The main goal of the paper is to propose a conceptual model of big data technologies adoption in smart cities of the European Union. Hence, this paper connects the fields of smart cities, big data technologies and technology adoption by identifying factors that influence the adoption of big data technologies in European Union cities.

Tornatzky et al. (1990) developed the Technology-Organization-Environment Framework (TOE) for explaining the process of innovation's adoption at the organisational level. A unique set of technological, organisational and environmental factors influence the adoption of a particular technology. Such a set of factors is often called the technology adoption configuration. Hence, TOE Framework assumes that there is a unique set of factors for different technologies that influence its' adoption. TOE framework is widely applicable and explains the adoption technologies in different contexts, including different forms of organisations operating in the private and public sector, as will be presented in the next sections of this paper.

After the Introduction section, the Methodology section presents a brief description of the literature review phases. Results and Discussion describe findings of the literature review, selection of factors and the result of building the conceptual model of big data technologies adoption in cities of the European Union. Paper ends with the Conclusion.

Methodology

In order to derive the conceptual model following is done: i) overview of the previous Technology-Organisation-Environment framework - based research on the adoption of selected information and communications technologies crucial for the development of smart cities, and ii) selection of factors based on the critical examination of the previous research.

For this study, the literature review was done on relevant TOE Framework - based research on the adoption of selected information and communications technologies crucial for the development of smart cities. The literature review is done in three phases: 1) search of the literature, 2) selection of papers, and 3) review and analysis of relevant papers. The review process took place in 2016, and it was repeated in April 2020.

Articles across journals from multiple disciplines and databases were searched, including those indexed in the Web of Science, Science Direct, Emerald, and Google Scholar database. Main keywords to search were "big data", "technology adoption" and "TOE". Other searched keywords included technologies related to big data, such as cloud computing and RFID technology. The searching process is limited to the papers published from 2009 to 2019.

Thirty-five relevant articles have been selected for the critical examination. Finally, the content of the relevant papers was reviewed and analysed. This was done by creating a table that helped to identify the most common factors for each of the three contexts of the TOE framework based on previously searched literature. After that it was possible to specify and critically examine the factors appearing in the contexts, as well as to select and adjust factors to explain big data technologies adoption.

The results of the literature review are selected factors, as well as the proposed conceptual model of big data technologies adoption in smart cities of the European Union which is presented in the Results and Discussion section.

Literature review

In order to explain the adoption of big data technologies in smart cities of the European Union TOE framework is used. The overview of the previous TOE – based research explaining the adoption of various information and communication technologies was done. The focus is at information and communication technologies which are related to big data technologies and technologies which enable the development of smart cities.

Table 1 shows the previous TOE – based research on adopting technologies important for developing smart cities. For each of technologies adoption, authors predicted influence of technological, organisational and environmental factors. An asterisk indicates confirmed positive or negative influence of an indicator on the adoption of technology.

It can be seen that TOE was used in order to explain the adoption of data management solutions, such as big data analytics (Chen et al., 2015; Lai et al., 2018), business intelligence and knowledge management systems (Lautenbach et al., 2017; Lee et al., 2009; Mudzana & Kotze, 2015.; Ramdani et al., 2009; Rouhani et al., 2018). Technologies that enable the development of smart cities by its implementation in city's infrastructure or by managing city's data such as the Internet of Things (Ching-Wen & Ching-Chiang, 2017), RFID technologies (Aboelmaged & Hashem, 2018; Hossain et al., 2017; Shi & Yan, 2016; Thiesse et al., 2011; Wang et al., 2010; Weia et al., 2015), smart grids technologies (Dedrick et al., 2015; Kim et al., 2014) and mobile technologies (Lin, 2016; San-Martin et al., 2016) are also subjects of research. Usage of TOE framework often helps to explain the adoption of technologies which complement big data technologies, such as cloud computing (Abdollahzadehgan et al., 2013; Gutierrez et al., 2015; Hassan et al., 2017a; Nkhoma & Dang, 2013; Senyo et al., 2016; Tashkandi & Al-Jabri, 2015).

Additionally, the adoption of information and communications technologies related to big data technologies is often described by the integration of TOE framework and the Diffusion of Innovation theory (DOI), such as the adoption of Internet of Things (Satar et al., 2017), RFID technology (Chong & Chang, 2012; Khan et al., 2017; Weia et al., 2015), cloud computing (Low et al., 2011; Oliveira et al., 2014; Seham, 2017; Sheikh et al., 2017) and green information technologies (Bose et al., 2011). Previous research is mainly related to the adoption of various information and communication technologies in different activities of the private sector. When it comes to research samples, they include organisations evenly spread across small, medium and large organisations.

Technological context of the adoption of different information and communications technologies is often described by factors which, by its' content, describe *technological readiness*, existing technological capabilities in forms of infrastructures, competencies and expertise, as well as *compatibility* which is originally a part of the DOI theory. When DOI concepts are included in the TOE context, such a model can be called TOE-DOI integrated model.

Various factors are included in the organisational context of the adoption of various information and communication technologies. They are mainly related to *management support*, *absorptive capacity* and *size* of an organisation.

Influence of different stakeholders is often estimated in order to describe the environmental context of the adoption of different ICTs. Examples are *support* or *pressure* from *legislation bodies, partners* or *competitors*.

Methods, which are used in order to estimate a research model based on TOE mostly includes data collection through structured questionnaires or survey. Target respondents are often members of middle or top management. Estimation of a model is often performed by using methods such as partial least squares - structural equation modelling, factor analysis or regressions.

The purpose of the literature review is to argue the use of the TOE framework and selection of a particular factor in order to derive the conceptual model of big data technologies adoption in cities. Additionally, the findings of the research review can be used to justify the use of methods in later phases of the research, particularly data collection and evaluation of the proposed research model.

Table 1
Previous TOE-based Research – Proposed Factors of Adopting Technologies Important for Developing Smart Cities

Technology	Source	Technological Context	Organisational Context	Environmental Context
Big Data analytics	Lai et al. (2018)	perceived benefits*	top management support*	competitors' adoption, government policy and supply chain connectivity** *moderators*
	Chen et al. (2015)	perceived benefits*, technological compatibility*	organisational readiness*; top management support as mediator*	competitive pressure*, regulatory environment
Business intelligence or Knowledge	Rouhani et al. (2018)	perceived tangible* & intangible benefits*, perceived costs, perceived complexity*	firm size*, organizational readiness*, strategy*	industry competition*, competitors absorptive capacity*

Management Systems	Lautenbach et al. (2017)	data-related infrastructure capabilities *, data quality and data management challenges	top management support*, talent management challenges	external market factors and competitive intensity *, regulatory compliance pressure
	Mudzana & Kotze (2015)	Information Technology (IT) infrastructure *, perceived benefit*, IT expertise	firm size	competitive pressure*, lack of trading partners
	Lee et al. (2009)	organisational IT competence, compatibility, complexity, relative advantage	cross-department interaction, top management's opinions & behaviours	social culture
	Ramdani (2009)	perceived relative advantage *, compatibility, complexity, ability to experiment *	size*, top management support *, organisational readiness *	competitive pressure
Internet of Things	Ching-Wen & Ching-Chiang (2017)	technological infrastructure*, technology integration, IT expertise*	perceived benefits*, management support*, organisational readiness	government policies*, supporting industries*, competitive pressure*
RFID technology	Aboelmaged & Hashem (2018)	technical advantages*, technical complexity*	organisational capacity *, organisational resistance	environmental uncertainty
	Hossain et al. (2017)	technology readiness, interoperability*	organisational readiness*, market scope	competitive market pressure*, the inconsistency of markets' data structure*
	Shi & Yan (2016)	technological complexity*, compatibility*, perceived effectiveness*, cost*	organisational size*, upper management support*, technological knowledge*, trust between enterprises*, employee resistance	competitive pressure, uncertainty*, government support
	Weia et al. (2015)	IT infrastructure*	managerial capability*, absorptive capacity*	environmental uncertainty*
	Wang et al. (2010)	relative advantage, complexity*, compatibility*	top management support, firm size, technology competence	competitive pressure*, trading partner pressure*, information intensity*
	Thiesse et al. (2011)	benefit perceptions*, perceived technology costs*, compatibility, complexity	firm size, top management support*, employees' fears	Benefits for supply chain*, forces within the supply chain*, external pressure
Smart Grid technology	Dedrick (2015)	perceived benefits, costs	size, management support, experience in working with PCS, technical expertise, technology champion, organisational culture, private property	competitive pressure, client relationships, external information sources
	Kim et al. (2014)	Perceived benefits, perceived cost, perceived risks	decision-makers support, firm size, centralised decision-making	forced, mimetic, normative isomorphism
Mobile technologies	Lin (2016)	capabilities, maintenance, manageability, complexity	top management support*, firm position organisational innovativeness*	consumer needs*, competitive pressure, information readiness, market trends*
	San-Martin et al. (2016)	technological competence*	companies' innovativeness*, employee support*	Appropriate management of customer information
Cloud Computing	Hassan et al. (2017a)	perceived benefits	top management support, IT resources*	external pressure*
	Senyo et al. (2016)	Relative advantage*, security concern*, technology readiness*	top management support*	competitive pressure*, trading partners' pressure*

	Gutierrez et al. (2015)	relative advantage, compatibility, complexity*	Top management support, firm size, technology readiness*	competitive pressure*, trading partner pressure*
	Tashkandi & Al-Jabri (2015)	relative advantage*, complexity*, data concern*, compatibility, vendor lock-in	top management support	regulatory policies, government pressure, peer pressure
	Nkhoma & Dang (2013)	perceived benefits, perceived technology barriers		perceived environment benefits
	Abdollahzadehgan et al. (2013)	relative advantage, complexity, compatibility	top management support, firm size, technology readiness	competitive pressure, trading partner pressure
Open Data	Wang & Lo (2016)	perceived benefits*, perceived barriers	organisational readiness*	external pressures*
E-Business	Rondović et al. (2019)	existing IT infrastructure, IT integration*, IT expertise	organisational characteristics*, management and organisational readiness, economic and social expectations	external demands and pressures, external support*, regulation
	Mohtaramzadeh et al. (2018)	cost of adoption*	top management support*	competitive pressure*, government support*
	Hussein & Baharudin (2017)	relative advantage*, IT competency*	Financial support, information intensity	
	Chatzoglou & Chatzoudes (2016)	IT infrastructure*, Internet skills*	firm size*, firm scope*, adoption cost, CEOs knowledge	competitive pressure, government support*, client readiness*
	Ifinedo (2012)	relative advantage, compatibility, complexity	management support*, organisational IT competence	IS vendor support/pressure, financial resources availability, external pressure*, firm size, industry type
E-Procurement	Hassan et al. (2017b)	perceived relative advantage*, compatibility, complexity	management support, employees' knowledge	external pressure from suppliers and competitors*
Enterprise Resources Planning	Noorliza & Soliman (2017)	relative advantage, compatibility, complexity, trialability, observability	top management support, organisational readiness, IS experience, size	Competitive pressure, external IS support
	Pan & Jang (2008)	IT infrastructure, technology readiness*	size*, perceived barriers*	production and operations improvements*, products/services improvements, competitive pressure, regulation policies
Open Source Systems	Jaafar & Yahya (2014)	perceived relative advantage*, compatibility and trialability*, complexity*	management support*, knowledge and expertise*	technology skills and services, platform long term viability
Social Media	Zhang & Xiao (2017)	technology competence*, perceived benefits*	top management support*	citizen readiness*

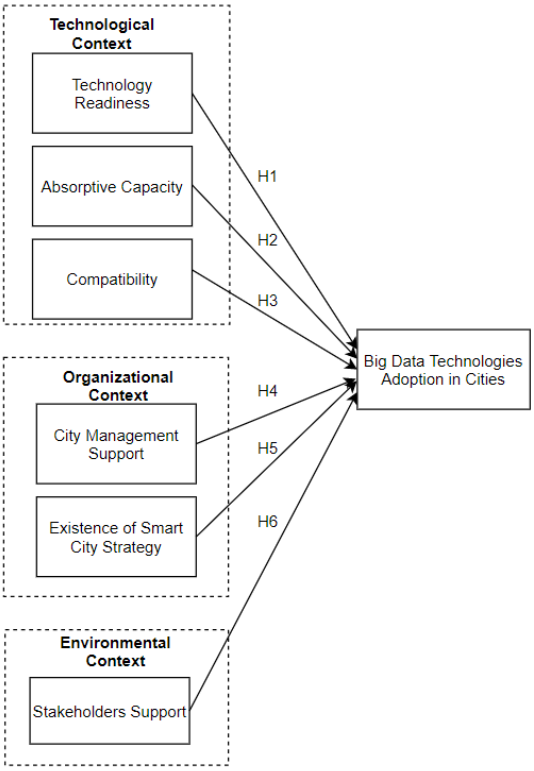
Source: Author

Building Conceptual Model of Big Data Technologies Adoption in Cities of the European Union

The most commonly used approach in studying the adoption of information and communication technologies is to select and describe factors that influence the adoption of technology. Based on the conducted literature review, the author has further selected and explained potential factors influencing big data technologies adoption in cities of the European Union. At the end of the section, the conceptual model is presented.

Figure 1 shows the proposed conceptual model of big data technologies adoption in cities of the European Union. Technological context of big data technologies adoption in smart cities of the European Union consists of Technology Readiness, Absorptive Capacity of a city and Compatibility of a city's technological infrastructure. Organisational factors of big data technologies adoption in cities are City management support and the Existence of a Smart City Strategy. Stakeholder support has been taken into account as the most important environmental variable.

Figure 1
Conceptual Model of Big Data Technology Adoption in Cities based on TOE Framework



Source: Author's Illustration

Technology Readiness

TOE framework assumes that the existing technology infrastructure significantly affects the diffusion of technology in the organisation (Tornatzky et al., 1990). The technological infrastructure of an organisation consists of the existing hardware, software, and network technologies of an organisation necessary for the adoption of new information and communication technologies (Bhattacherjee & Hikmet, 2008). In addition to technological infrastructure, the IT infrastructure of an organisation can also include technical and managerial knowledge of IT human resources (Zhu et al., 2006). The role of IT human resources is to support the adoption of new technologies.

Based on the literature review, it is possible to conclude that particular previous research considers only certain aspects of technological readiness. For example, employees' existing knowledge is an intangible aspect of technology readiness. It is often represented by *IT human resources*, *IT expertise*, and *IS expertise*. Physical information and communication infrastructure is a tangible aspect of technology readiness. In previous research, it is often called as *technology infrastructure* and *IT infrastructure*. Organisational readiness includes both technology and financial readiness of an organisation. The financial aspect of technology adoption is sometimes described separately from technology readiness *as internal financial resources*, *financial support* or *external financial support*.

It has been confirmed that organisation which have developed aspects of technological readiness are more successful in adopting various information and communication technologies (Ching-Wen & Ching-Chiang, 2017; Hassan et al., 2017a; Hossain & Baharudin, 2017; Lautenbach et al., 2017). Success examples are equally represented in the private and public sector.

For the purpose of this research, *technology readiness* refers to (1) existing knowledge city/town employees have, (2) physical information and communication infrastructure of a city/town and (3) financial resources needed to adopt new technology - including big data-related technologies seamlessly. The assumption is that a city is more technologically ready if it hires personnel with analytical skills that include data mining expertise and knowledge of methodologies for data processing, data integration, and data management. Furthermore, a city should have physical ICT infrastructure which can be upgraded with current data technologies such as big data technologies, as well as related technologies such as RFID or cloud technologies. Finally, a city is more technologically ready for big data technologies adoption if it has financial resources to upgrade the city with recent technologies. Following hypothesis is proposed:

H1: Technology readiness has a positive effect on big data technologies adoption in cities.

Absorptive Capacity

Absorptive capacity of knowledge is the ability of an organisation, as well as city, to recognise the value or potential of recent, external knowledge and adapt it for different purposes. An organisation in which knowledge and information are shared among functional units is more flexible and responds more quickly to market needs. The absorption capacity of the organisation is also affected by the success of the organisation's communication with the external environment.

Absorptive capacity allows an organisation to predict the potential of innovative information and communication technologies more accurately. Big data technology is a disruptive innovation full of uncertainty, which is why it requires the absorptive capacity of a city to recognise the potential value of introducing big data technologies into the city's infrastructure. Absorptive capacity of a city is determined by the experience of a city gained by the previous adoption of various information and communication technologies. Therefore, it can be assumed that cities with previous experience and knowledge in the adoption of big data-related technologies, such as cloud computing or RFID technology, have capacities for adopting and using big data technologies compared to cities that do not have such experience.

Although absorptive capacity has been used in different contexts and at different levels of analysis, there are only a few studies in which some aspects of absorptive capacity have been used in models of adoption of information and communication technologies. For example, Rouhani et al. (2018) mention the absorptive capacity of competitors as a significant factor of business intelligence system adoption, and Weia et al. (2015) used absorptive capacity in the RFID technology adoption model.

For the purpose of this paper, absorptive capacity is used at the higher organisational level, a city. It implies the ability of a city to recognise the value of recent knowledge and adopt it for various purposes. It is assumed that the absorptive capacity of a city is higher if city employees are motivated to use available information sources regarding current services a city provides. Furthermore, city departments should be aware of the importance of cross-departmental support for problem-solving. Developed cross-departmental communication of ideas and concepts, and quick information flow between city departments means a higher absorptive capacity of a city. Absorptive capacity of a city could also be higher if city employees absorb new knowledge, link existing knowledge with new insights, apply it in their practical work and make it available for the future. Finally, a city's decision-makers and other employees should be aware of new technologies, which are regularly reconsidered and adapted to make city services more effective. Therefore, the following hypothesis is proposed:

H2: Absorptive capacity has positive effect on the big data technologies adoption in cities.

Compatibility

According to the DOI theory, compatibility is the degree to which an innovation is perceived as consistent with existing values, past experiences, and needs of potential adopters (Rogers, 2003). Existing values, behaviour patterns and experiences of an organisation should be consistent with newly adopted innovative information and communication technologies. Organisations that perceive technology more compatible with existing beliefs and work practices have higher predispositions for the successful adoption of new technologies.

Compatibility has been used in adoption models of different technologies in different industries. However, research has shown that it is a significant factor in the adoption of big data analytics (Chen et al., 2015), open data (Wang & Lo, 2016), open-source systems (Jaafar & Yahya, 2014), business applications (Ramdani et al., 2013), and in some cases, the adoption of cloud computing (Abdollahzadehgan et al., 2013; Gutierrez et al., 2015) and RFID technology (Wang et al., 2010).

For the purpose of this research, big data compatibility is defined as the degree to which big data technology is perceived as being consistent with the existing infrastructure, practices and needs of a city. It is assumed that compatibility is higher if big data technology can be incorporated into the existing technological infrastructure of a city seamlessly. In addition, changes introduced by the development of big data technologies should be consistent with existing practices and experiences of a city with implementations of similar technologies, as well as needs of a city. Following hypothesis is proposed:

H3: Compatibility has a positive effect on the big data technologies adoption in cities.

City Management Support

Management support refers to the degree of support that management provides in adopting technological innovations in an organisation (Abdollahzadehgan et al., 2013). Management allocates resources needed to adopt particular technology after being informed about the benefits of the technology for the organisation. Involvement of top management in managing IT projects is reflected in the more successful selection and promotion of information and communication technologies in organisations (Salleh et al., 2007). Management can encourage members of the organisation to accept changes (Abdollahzadehgan et al., 2013) and thus to adopt innovative information and communication technology. Moreover, management should provide the financial, technical and human resources needed to adopt the technology and manage them optimally.

Management support was shown to be an important factor in the adoption of various information and communication technologies. For example, it is confirmed that top management support significantly influences the adoption of big data analytics (Lai et al., 2018), RFID technology (Shi & Yan, 2016; Thiesse et al., 2011), the Internet of Things (Ching-Wen & Ching-Chiang, 2017), business intelligence systems (Lautenbach et al., 2017) and mobile technologies (Lin, 2016).

For the purpose of this research, municipalities, city council, and city administration are responsible for city management, and therefore they are the leading promoters of technological initiatives in a city. City management support is defined as the degree to which municipalities, city council, and city administration is involved and supports big data technologies adoption in a city.

City management support is higher if municipalities, city council and city administration provide strong leadership and are dedicated to the processes of technology adoption in the city. They should also promote technology initiatives, determine implementation steps and select specific technological solutions to be implemented. Moreover, city management support is perceived higher if they are ready to accept the financial and organisational risks relating to the adoption of technology. Finally, city management should engage citizens in technological innovation incentives and communicate the benefits of technology. Following hypothesis is proposed:

H4: City management support has a positive effect on the big data technologies adoption in cities.

Existence of Smart City Strategy

Smart city strategy refers to a strategy that promotes smart city initiatives and encourages efficient resource management and development of a city. Articulating and communicating smart city strategy stimulates changes and helps the adoption of big data technologies in cities. City management should actively develop smart city strategy aimed at improvement of more efficient city resources management based on the challenges regarding city infrastructure and city needs.

A prerequisite for the existence of a smart city strategy is the awareness of city management about the benefits of adopting innovative information and communication technologies in the city infrastructure. When defining a smart city strategy, management of European city should align a city's strategy with the country's and European Union's goals and the strategy related to city technology development.

Previous researches do not include the existence of strategy as a factor of innovation adoption. However, the development of a smart city should be planned strategically. Smart city strategies reflect urban development policies that involve significant investments and have a large impact on cities. Therefore, this research assumes a positive influence of the existence of a smart city strategy on the big data technologies adoption in cities. Hence, the following hypothesis is proposed:

H5: Existence of a smart city strategy has a positive effect on the big data technologies adoption in cities.

Stakeholder support

Smart city stakeholders are all subjects, organisations or individuals who are interested in smart city initiatives or affected by them. In previous research, stakeholders support usually appears as an individual factor or as *external support* of technology adoption. For example, *external support* was used as a factor to explain the adoption of e-business (Rondović et al., 2019) and *external pressure* was used to explain the adoption of cloud computing (Hassan et al., 2017a) and e-procurement (Hassan et al., 2017b). Government support and government policies were used to explain the adoption of big data analytics (Lai et al., 2018), the Internet of Things (Ching-Wen & Ching-Chiang, 2017) and RFID technology (Shi & Yan, 2016).

For the purpose of this research, it is assumed that stakeholders support positively influences the adoption of big data technologies in cities. Stakeholders support in the context of big data technology adoption for cities refers to stakeholders that (1) provide technology and technological solutions, (2) incorporate technology into their processes or (3) facilitate technological and policy frameworks related to technology adoption. Similar classification of the stakeholders was proposed by ITU-T Focus Group on Smart Sustainable Cities (2015), which was adapted for the purpose of this research. Therefore, the following hypothesis is proposed:

H6: Stakeholders support has a positive effect on the big data technologies adoption in cities.

Conclusion

The main goal of the paper was to propose a conceptual model of big data technologies adoption in smart cities of the European Union. Based on previous research, the conceptual model of big data technologies adoption in smart cities of the European Union has been proposed. As the result, the model follows general guidelines of TOE framework and includes six endogenous factors: Absorptive Capacity, Technology Readiness and Compatibility as technological factors, City Managements Support and the Existence of Smart City Strategy as organisational factors, and Stakeholders Support as an environmental factor. Hence, the goal of the paper is fulfilled.

Limitation of this work comes from the lack of scientific literature in the area of big data technologies adoption. In order to derive a conceptual model, the author had to select papers which are related to the adoption of various information and communication technologies which are complementing or are related to big data technologies.

However, deriving such a model at the city level is the main scientific contribution of this research. The model served as a basis for empirical research. For the future work, the results of later phases of the research, including data collection and examination of the proposed conceptual research model will be published. Furthermore, once the model is estimated, it is possible to provide practical recommendations to decision-makers in cities regarding factors that will be confirmed as significant. This can contribute to the effective adoption of big data technology in cities of the European Union.

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