



The motivations for and barriers to cloud technologies in the field of transportation¹

Simon Nagy* 

* PhD student, Department of Transport Technology and Economics, Faculty of Transportation Engineering and Vehicle Engineering, Budapest University of Technology and Economics; Transportation engineer, National Data Economy Knowledge Centre, Neumann Nonprofit Ltd. E-mail: nagy.simon@kjk.bme.hu, nagy.simon@natuk.hu

Abstract

Cloud technologies have gained high popularity in recent years. Due to the digital transformation in past decades, information- and infocommunication technologies (ICT) have become highly recognized in all sectors. Cloud technologies have appeared as scalable, agile, secured and global solutions. Next to their advantages, however, several barriers have been identified. In this paper, we review the main cloud computing models and the advantages of and barriers to cloud technologies, as well as their application in the special case of transportation. Based on the review, we introduce the role of the National Data Economy Knowledge Centre in transportation development, especially focusing on proposed cloud applications.

Keywords

cloud computing, urban transportation, information technology.

1. Introduction

More than half of the world's population lives in cities, according to the United Nations (UN, 2018). City governments are facing several major problems, one of which is the operation, maintenance, and development of urban transportation systems. Urban transportation systems consist of passenger and freight subsectors (Mehrotra et al., 2018, 491–518). Transportation services are also classified as air, road, rail, and water-based systems. In this paper, we consider *road and rail transportation, in both the freight and passenger subsector*.

This paper argues that there are several advantages of and barriers to cloud computing, while the transportation system is a complex application environment. High heterogeneity is

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identified in the context of stakeholders and data sources, as well as methods of data collection, storage, and processing. I concluded that cloud technologies are key to addressing the increasing magnitude and complexity of transportation data. Finally, I briefly introduce the role, and proposed projects of the National Data Economy Knowledge Centre, as a possible solution for the challenges described.

2. The background and concept of cloud computing

The concept of smart cities has emerged in the last decades. Although there is still no generally accepted definition, approaches (Meijer & Bolívar, 2015, 391–408) show several similarities, for example:

- smart city concepts are used to identify a large spectrum of *heterogeneous* solutions, and *city programmes* (Dameri, 2013, 2544–2551),
- smart cities are identified as *complex systems*; one of their subsystems is smart mobility (Nagy & Csiszár, 2020, 117–127),
- smart cities are energy efficient, and aim to minimize negative externalities; *green mobility* is identified in the context of transportation (Lazaroiu & Roscia, 2012, 326–332) and
- smart cities aim to achieve a higher quality of life, as well as a more sustainable operation through the application of various ICT solutions.

Cloud computing is one of the many instruments in ICTs. Generally, cloud computing is defined as a “model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources” (Mell & Grance, 2011, 1–7). It could best be described as a framework, utilising network capacities including and incorporating several solutions and services. Solutions and services share numerous characteristics (Stieninger & Nedbal, 2014, 59–68; Moghaddam et al., 2015, 1–6), such as:

- *on-demand self-service*, meaning that no active interaction is required,
- *broad, and cross-platform network access*, as cloud computing services are distributed on the network and available for all operating systems, both desktop and mobile.
- *rapid elasticity* or *agility*, meaning resources are rapidly and automatically deployed, depending on the demand, resulting in a dynamic and autonomous agile service,
- *measured service*, enabling dynamic measurement and monitoring of service performance,
- *isolation* of services, serving security and performance goals, and
- *distribution*, as cloud computing services are globally distributed using various IT resources.

Cloud computing includes several services models (Youseff et al., 2008, 1–10). *Software-as-a-Service* (SaaS) is a software delivery model which provides the user with access to business functions remotely, through the cloud (Sun et al., 2007, 558–569). SaaS applications are accessible from various devices through an interface or from a browser. Users do not manage the back-end cloud infrastructure. *Platform-as-a-Service* (PaaS) is a cloud software environment, which unites data and communication between computing elements, and provides a universal platform. Finally, *Infrastructure-as-a-Service* (IaaS) provides hardware (computational resource) virtually and on-demand.

Cloud services are deployed in multiple forms (Savu, 2011, 1–4). *Private clouds* provide exclusive infrastructure to an organisation, which are either maintained internally or by the service provider. Private clouds are only accessible for the organization. *Community* or *public clouds* are shared across a specific community. The infrastructure is used by different entities, which can be both individual users and organisations. Public clouds usually utilize the biggest infrastructure. Finally, *hybrid clouds* are a composition of two or more clouds, where some clouds remain private, but are bound to public and/or community clouds.

3. Information systems and data management of the transportation sector

Transportation is a special field in which all types of entities are found as stakeholders, from individuals (passengers) through private small companies to multinational private and big public companies. The high heterogeneity of stakeholders results a wide variety of information systems, from data collection through data processing and analysis to data utilization.

Similarly, to information systems (and stakeholder types), there are many instruments of data collection. First there is *crowdsourcing* (Misra et al., 2014, 1–8; Saxton et al., 2013, 2–20), which utilises social computing, using a network of collaborators to solve a problem; one type of crowdsourcing is *web-based*, which fits into cloud systems well, and enables cloud technologies to be applied. Machine-based data collection is represented by *sensors*, which are used for many applications, such as traffic volume count, speed data and, licence plate recognition. The data collected by sensors are stored in the databases of companies' information systems and can be migrated into cloud storage. Another popular mode of data collection is *surveys to identify the optimum service configuration*. In this context, we introduce the two most popular types: (i) *stated preference* (SP) (Hensher, 1994, 107–133), and (ii) *revealed preference* (RP). In SP data collection, the individual is either asked to rate or rank their preferences among a set of combinations of attributes, or to choose *one* combination of attributes. Preference modelling is based on the principle that every consumer seeks to maximise utility, and the benefits they gain from all products and service and the underlying utility functions can be measured with sufficient certainty if the attributes and their levels (e.g., speed, frequency, price and comfort) are presented in a statistically balanced design (Richter, 1966, 635–645). RP define utility functions by building models from observing actual consumer behaviour. Both are often used in transport planning for mode choice modelling, mobility management, mobility plan design *inter alia*, and in this context avoid the frequent criticism that smart cities are designed and built without adequate input from the systems' existing and potential users.

3.1. Smart cities, smart mobility, and big data

In the past decade or so, new concepts emerged, namely *smart cities*, *smart mobility*, and *big data*. Smart cities are cities which utilise ICTs in order to achieve a higher level of sustainability and quality of life (Nagy & Csiszár, 2020, 117–127; Vecchio et al., 2019). Smart cities are complex systems, with various, interconnected application subsystems, one of which is smart mobility. Big data and smart mobility are interrelated as well. Big data is defined as a complex technological environment, which enables the collection, processing, and utilization of datasets which are so large and complex that conventional database-management systems cannot process them.

Next to the heterogeneity of organizations and data collection methods introduced above, the *heterogeneity of data* is an important factor. One of the main challenges of the application

of big data and cloud computing is that data are collected from various sources (Neilson et al., 2019, 35–44). Some sources, such as roadside sensors produce easy-to-use data. Other sources, for example user activity collected by smartphones, require processing before usage.

As vehicle and transportation technology advances, new opportunities emerge for data collection. One of the most relevant advances are *vehicular networks* and *connected vehicle technologies* (Ali et al., 2015, 1–4). Data can be directly from vehicles, as they are equipped with sensors and communication systems.

4. Adoption of cloud computing in transportation

Migration of enterprise information systems into the cloud is advantageous for all stakeholders, though multiple barriers and challenging tasks are observed. Heterogeneity is observed in the context of

- stakeholder size,
- complexity of ICTs used by the stakeholders, containing a wide variety of devices with different operating systems, different data collection methods,
- collected and handled data, ranging from security-critical to non-critical, as well as from public to personal/private,
- network access and bandwidth, which is also influenced by the proportion of citizens having access to a mobile network, and the proportion of open-access Wi-Fi networks in metro areas,
- legal environment of data collection and handling, etc.

Therefore, to apply cloud technologies on a broad basis, different adoption strategies are required. Furthermore, adoption cannot be done exclusively by considering technological and IT aspects. In this section, I review the main advantages of and barriers to cloud technologies in transportation.

4.1. Advantages of cloud technologies

Cloud computing has several key advantages (Avram, 2014, 529–534; Ullah & Babar, 2019, 81–118). First, computational resources are scalable. Through software APIs, cloud-based services are scaled up and down dynamically, resulting in a cost-effective and rapidly deployable service model (Dubey & Wagle, 2007, 1–12).

Cloud computing processes also have high agility, meaning almost immediate access for hardware resources, without the need for expensive investments. Temporary resources can easily be deployed for research and development purposes. In this way it lowers or removes the barriers to IT development.

Cloud applications drastically reduce the cost of entry in order for smaller organisations to benefit from computing-intensive business applications. These applications were only available earlier for companies with high hardware capacity.

Using cloud resources and applications also means that, next to the globalisation of an enterprise, its data globalises as well. Cloud service providers have data centres around the world, which are inter-connected. Corporate data can therefore be accessed through the network, or even transferred to the closest data centre if needed. This results in reduced globalisation costs, as the firm does not need to carry their data.

Cloud services are also safe and secured. Although security, or rather uncertainty, is understood as a barrier, cloud platforms are secured in various ways (Muttik & Barton, 2009, 1–6). Potential threats are eliminated using complex methods, such as filtering, malware protection, blockchain and DDoS protection, as well as various security protocols.

4.2. Barriers of cloud technologies

The first barrier to be mentioned is security. Although cloud platforms and services are secured by various methods, uncertainty among potential users is significant. Cloud services are exposed by attacks on APIs, publishers and web portals, as well as interfaces (Hussain et al., 2017, 57–65). Attacks can be aimed at hardware, software and data. Ristenpart et al. (2009, 199–212) concludes, that risks arise from sharing physical infrastructure among users. In the context of transportation, security is especially important. Data from various sources are collected and stored, much of which can be security-critical, such as traffic collection of license plate numbers, tracking passenger movements through their end-devices etc.

Operating a cloud system requires staff on the organizations' side as well. Migrating data and certain functions into the cloud is a complex and novel field. Cloud architects, DevOps engineers, and cloud engineers have to hold specific and advanced skills. In this case, the organisation must choose to either hire its own cloud engineer employees or hire a third party to manage its cloud system, which also includes data management.

Legal issues can also be observed, especially in the context of data and information privacy. Although cloud service providers can deploy better security mechanisms in their service than individual users or organizations; platform sharing, lack of data control and third-party services make security a major worry (Cheng & Lai, 2012, 241–251).

5. Discussion – role of the National Data Economy Knowledge Centre

In the previous sections, I introduced cloud services and computing models and the complexity of the transportation sector, as well as the main advantages and barriers. I identified that privacy and security are major issues.

In Hungary, the transportation division of the National Data Economy Knowledge Centre carries out research and innovation in this direction. In order to solve the problems of high heterogeneity, we introduced two major projects.

- *a complex road traffic information system*, which contains installation and operational standards for roadside and vehicle sensors,
- *a smart transportation integration framework*, which introduces a novel method for the application of cloud computing with the special aim of enhancing the integration level of urban transportation.
- The simultaneous deployment of these projects has the following impacts:
 - standardization of databases, as the integration framework introduces a framework for data storage,
 - high level of data security, as databases are managed by the National Data Economy Knowledge Centre,
 - decision support in the context of transportation development, maintenance and operation, and
 - data availability for research and development tasks.

It is beyond the scope of this study to decide whether an existing, commercial cloud service (e.g. Microsoft Azure, Amazon Web Service etc.) should be used or an entirely new network should be designed and deployed by the National Data Economy Knowledge Centre.

6. Conclusion

Information technologies have advanced greatly in recent years. In this paper, I reviewed cloud computing, and the related concepts of big data and smart cities. The application of cloud computing is advantageous yet challenging. All barriers arise from sharing physical infrastructure amongst users. In the context of transportation, the solution can be the inclusion of a national control organization, as with National Data Economy Knowledge Centre in Hungary. The cloud system must be deployed and supervised by the National Data Economy Knowledge Centre to ensure secure operation. By using cloud computing methods, the integration level of transportation can be enhanced. Integration is defined between organisations and between subsectors. The utilisation of cloud technologies enables decision support for operation, maintenance and development tasks, as well as data for research and development purposes.

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