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Abstract. Big data transform all kinds of businesses, including property management. Although the application of big data has great potential, it also presents challenges. The purpose of this paper is to investigate the big data capabilities and to identify some of the obstacles and opportunities associated with them in the context of property management. The applied approach of the research is content analysis of scientific publications, practical examples and case studies, concerning the present applications of big data in the property management sector. The findings show that big data have an increasing impact on the assessment and understanding of property markets. The study is useful for other researchers, who work in the field of big data, including property management professionals and practitioners. The main conclusion of the study is that big data provide better decision-making and greater transparency in the property management industry, ensuring a more efficient experience for both professionals and customers.

INTRODUCTION

Information technologies have led to significant changes in many areas and quickly integrate into property management. The progress in computing power and the development of new data sources reveal a number of opportunities for the sector. The changes cover almost all areas of property management, starting with building a business model, managing human resources or cost optimization. The number of companies that are trying to handle the speed, depth and scope of these changes is also growing.

The concept of „big data" is one of the latest technology developments that gain popularity in property markets in many countries. Its purpose is to automate the analysis of huge amounts of data from multiple sources of information. In this way, companies have the opportunity to optimize their time, financial costs, and achieve more accurate results that are not influenced by a human factor.

The increased interest in big data is also highlighted by the media attention. According to recent publication in Forbes, big data are expected to improve the transparency and efficiency of property markets [1]. The CIO magazine presents big data as technology that disrupts property management [2]. The Financial Review points out that there is a change in the way of thinking in the sector as a result of the big data capabilities [3]. Moreover, more investors use science and big data to make more sustainable investments [4].

Although the use of big data has great potential, it also creates some difficulties. The purpose of this paper is to explore the big data capabilities and to identify some of the barriers and opportunities associated with them in the context of property management.

BIG DATA – BASIC ASPECTS OF THE TERM

The term "big data" can be hardly defined. Big data refer to a huge amount of data that cannot easily be handled by traditional software. Winson-Geideman and Krause define it as a collective term for larger interconnected

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databases, as well as related processes for extracting useful knowledge [5]. Although there are many definitions of big data, almost all of them have three common features: big data volume, data processing speed and data coverage [6].

The review of the scientific literature shows that a number of authors focus on the complex nature of big data. Special attention is paid to the expected benefits of extracting knowledge from these data. Since the access to them is meaningless without the appropriate tools for management, analysis and storage, most of the authors have the opinion that the application of big data in organizations requires new processing applications and technologies that provide almost instant results from their analysis. In addition, the presence of experts is also important for providing reliable interpretations.

The speed and analysis are key components of property management. Big data offer these attributes through big data analytics [7]. Property management includes a wide range of data and complex analyses require a lot of time. Therefore, big data enable property organizations, agents and professionals to focus on their core roles and leave the analysis to technology. This is achieved through "data centricity", which places more accessible, reliable and relevant data at the heart of the decision making to increase productivity [8]. Big data enable property organizations to integrate financial, marketing, sales and consumer surveys to gain a comprehensive view of the business outcomes and achieve overall organizational goals.

PROBLEMS RELATED TO BIG DATA

The concept of big data is related to both the data themselves and the adaptation of different technologies for their collection, storage, analysis and visualization. The data sources are many and varied in their essence. However, not all collected data are useful for the business. Companies that lack data differentiation have problems in identifying and retrieving components that are related to the company's current and future goals. The lack of such resources leads to the risk of missing valuable information that can improve their final results and better position them in the competitive market.

The development of a strategy to deal with data flows can be a huge advantage. Each of the features of big data (volume, velocity, variety, veracity and value) leads to multiple interrelated problems that require a proactive strategy. For example, data collection and storage are interconnected, because a large amount of data can be collected only when the storage capacity is rapidly developed. Most companies collect as much data as they can store. Cloud-based storage options alleviate some of these problems. When changing the data collection needs, their storage can be adapted relatively quickly to meet the new requirements.

Another problem is related to data analysis. It is often exacerbated by difficulties, related to the staff. Until recently, there has been a clear distinction between IT and computer support personnel and property management activities. Currently, lots of companies are seeking to hire professionals, who have technical skills and expertise in the sector to analyze, evaluate, interpret and extract the value of big data. Smaller companies, that do not have resources to hire such specialists, can benefit from multiple cloud services that offer computational operations. In this way, large data sets can be stored and analyzed remotely.

Additional problems with big data are related to their visualization. They include the selected data, the way they are visualized and the particular context. Data can be represented in many ways, manipulated or misinterpreted. Excessive confidence in the visual presentation may lead to simplified and even incorrect conclusions, which are not supported by a more detailed understanding of the data.

Moreover, attention should be paid to the protection of personal data. The recently adopted General Data Protection Regulation (GDPR) sets out how companies should manage the personal data of citizens of the European Union. Companies, that have such data, have to ensure the highest level of protection of their privacy. According to GDPR, companies should provide a written notice for the collection of personal data from EU customers. Customers need to explicitly agree to the collection of their data and companies must specify the exact purpose for which the data will be used.

POTENTIAL OF BIG DATA IN PROPERTY MANAGEMENT

Despite the stated problems, big data have the potential to be a major incentive for evidence-based decision-making in property management. The usefulness of big data can be categorized in two interrelated areas: (1) operational efficiency improvement and (2) effective use of big data for attracting and retaining customers.

1. Operational efficiency improvement

In many cases, the big data, generated by the Internet and Things (IoT), provide the greatest opportunities for the property sector. The Internet of Things is a merger of multiple technologies that produce continuous streams of data, interacting with each other over the Internet. Wireless communications, GPS, smart buildings and machine learning are part of the Internet of Things. For example, the location of sensors in buildings provides information on their use and energy consumption.

All this information generates a new generation of smart buildings and smart systems that achieve much greater functional efficiency. New buildings such as the Edge in Amsterdam use the data collected by computer technologies, built into lighting and ventilation to optimize the overall performance of the building and improve indoor working environment [9]. The existing buildings, equipped with new technologies, have similar benefits. For example, the "New York Times" offices have implemented a system of sensors, embedded in lighting and motorized window shades that are used to monitor the temperature and lighting. As a result, savings of 70% have been achieved [10].

The data collected by these systems are analyzed in real time. The analysis is relatively simple, because the data are most often in a structured format. This makes the forecasting of data for building systems very reliable. Additionally, this technology expands the infrastructure of smart buildings in a way that allows them to be part of a larger network, representing smart campus or even smart city.

Network security systems offer efficiency in terms of access to buildings. A building, that uses virtual smartphone authentication technology, provides access for users without the use of keys or cards. Visitors can be preselected and given access via an email barcode. The data, shared between the smartphone, the server, and the access reader are encrypted to improve security and access to any remote-controlled entry point. This saves the change of access cards and keys, which further reduces security costs [11].

Alongside smart systems and network security, another useful innovation in the sector is the Internet connectivity of buildings. It is one of the main criteria for users with technical knowledge. This in turn determines the particular importance of the availability of reliable and sustainable relationships [12]. For example, the startup company WiredScore offers a property rating system that certifies the digital infrastructure of buildings. The highest rating is given by those, providing the largest number of Internet service providers, abundance and sustainability of the telecommunications infrastructure, easy installation and maintenance capacity for new telecommunication services [13].

However, the greater degree of interconnectivity is cost-related, as buildings become more vulnerable to cyber attacks that disrupt or disable entire systems [14]. In this regard, risk management, especially with regard to technology, is becoming a major problem for companies that are victims of such activities. The higher the dependence on Internet of Things in terms of rationalizing operations and improving efficiency, the greater the need for cybersecurity.

2. Attracting and retaining customers

Attracting and retaining customers is required for the end results of investors. In the age of big data, it is related to focusing on efficiency and performance, caused by the use of integrated systems for heating, ventilation and air conditioning (HVAC) and network security systems. Creating and maintaining spaces, that improve the customer experience by increasing productivity and developing a cohesive working environment, are examples of the potential benefits of big data. Much of this potential is due to the constant use of mobile phones.

The distribution of smartphones allows for more detailed information about tenants and potential clients. Big data, for example, provide information on locations in shopping centers, of which there are crowds of people, where they come from, and in some cases the reason to be there. It should be noted that there is a difference between tracking the number of passing people and tracking their identity. In many cases, systems remain almost completely anonymous, because they track only the number of people. In some cases, there is limited tracking, for example when people use public wi-fi by providing an email address or accepting conditions that allow tracking and collecting additional information. In other cases, individuals allow permission for more detailed tracking by sharing personal information, providing access to social media profiles or using applications. Thus, the traders get access to valuable information, including demographics, different kinds of preferences and contact information such as email addresses and mobile phone numbers. This allows direct targeting of customized ads.

Property management can realize benefits similar to those in commerce. The use of an access card by a tenant when entering a particular building allows tracking of his (her) movements. This way it can be found how the building is used. Real-time presence and stay time can be tracked with the use of wi-fi, and sensors embedded in the floor can record foot traffic [15]. This information, combined with predictive modeling, can be helpful in determining the types of space required, their placement and the time they are most likely to be used.

Despite the fact that big data have a significant role in improving customer experience, they also hinder risks that may negatively affect tenants and landlords relationships. In order to be useful, big data should be reduced to a usable

form. Their limitation should not compromise privacy. Data breaches are relatively common and the larger the data, the greater the potential problem.

ADDITIONAL ARGUMENTS RELATED TO BIG DATA

Big data and related technologies influence property management in some other ways that have significant consequences for the sector.

1. Creation of new work positions

The use of big data means switching from data self-processing and analysis in an Excel spreadsheet to the time of data professionals, who can manage volumes of continuous data streams and evaluate their significance for the organization. Working with big data is different from working with data, traditionally used in the property management. Companies, which do not have data specialists, may be losers in a highly competitive field. Other new types of work positions, which occur in connection with big data, include data engineer, data architect, data manager and data visualizer.

2. More detailed analysis in decision making

Finding and acquiring properties for purchase or lease that meet the needs of long-term tenants, can be aided by the inclusion of big data in sophisticated analytical programs that foresee macroeconomic trends, demographic changes, property prices and labor availability. This information can be added to a risk and return model to guide corporate strategies and decision making.

3. Collection and aggregation of data

Collecting and aggregating property data is becoming a separate industry. Companies such as Real Capital Analytics and CoStar are among the first to see the benefits of collecting, standardizing and automating property data such as transaction prices, interest rates, concessions and operating costs. These companies evolve from simple collection, aggregation and dissemination of data to the creation of their own set of proprietary metrics that can be involved in strategic decision-making. Real Capital Analytics for example launched its latest benchmark in 2017 – an assessment of capital liquidity. It is intended to assess the depth and breadth of capital and liquidity of a given market [16].

Data aggregators are an indispensable part of the property management. Most of them focus primarily on traditional sources of data. Some companies develop specialized products related to property management. Walk Score for example, offers a series of indicators that measure walkability, public transport and bicycle access to neighborhoods [17]. Similarly, Streetlight Data provides transport analyses, including travel time, travel distribution and business and personal travel comparisons [18]. Other data aggregators combine different data sources to create unique products that target a particular segment of the industry. For example, CrediFi combines information on properties, loans and mapping with financial data to provide detailed information to property creditors [19].

4. Blockchain technology

The widespread use of big data and associated technologies is a prerequisite for the growing role of the blockchain technology in storing and managing property data. Blockchain is a digitized distributed registry that constantly records and shares data in a reliable and consistent format. In the field of property management, the blockchain has the potential to rationalize transactions, eliminate the need for third parties, increase the reliability of public registers and reduce fraud. Its role in managing smart contracts is growing. For example, a rental agreement for a room may be entered into the register and the parties may agree that it will be executed at a certain time and date for a certain amount of money. The tenant pays the rental charge into a digital wallet of cryptocurrency. In case he occupies the room at the agreed time, the money is transferred automatically from his wallet to the owner [20].

The adaptation of blockchain technology across the industry is a challenge, but some companies are already investing in its potential. One of the first market participants is Ubiquity [21], which offers a block-based platform for property registration and Flip [22], which provides a market for residential leasing services, storing records in blockchain format [23]. Text mining techniques may be used when analyzing big data in property management [24]. Rule mining in property management is a sphere which is going to be developed in forthcoming years [25, 26].

Analysis of behavior of property management companies [27] is useful for further application of specific software. Each software uses database management system and one or several databases. Furthermore, analysis of the database efficiency has to be carried out [28]. Cluster analysis of customers of property management companies may lead to creating better marketing strategies [29, 30]. The newly created software for big data analysis in property management needs specific evaluation [31]. The evaluation process will show its usefulness and value for end users. The functionality of the property management software is quite wide. One of the aspects is electricity consumption

forecasting [32]. Buildings with complex architecture needs specific architectural modeling [33, 34, 35]. Afterwards these complex buildings may have sensors which generate streams of data that has to be analyzed [36, 37]. Property management software is usually used as intranet application. But in many cases, it is open to internet. In these cases, security certificates are recommended for usage [38, 39]. Real estate management using the results of big data analysis changes [40, 41]. Knowledge database is created as a result of big data analysis in property management [42, 43, 44].

CONCLUSION

Digital data generated in property management is primarily used to analyze building systems and improve operational efficiency. However, there is growing interest in using wi-fi and sensors. Their application is related to:

1. tracking the movement of people in buildings to improve the type and location of amenities in them;
2. tracking and more efficient management of tenant energy consumption;
3. providing navigation in buildings through smartphones.

Collecting and analyzing data increases operational efficiency by saving money and environmental resources. However, problems related to security of personal data and effective data management are obstacles to their widespread use. Despite the availability of solutions, relating to the collection, storage, analysis and presentation of data, some problems concerning the protection and disclosure of information are more difficult to overcome, as they are subject to changing laws and social pressure. For this reason, the companies are cautious when considering the inclusion of big data in the decision-making process.

Innovations brought about by the big data change the property management. Some of the most important findings, presented in this article, deserve the attention of the sector as a whole and can be used for further research.

- Big data are dynamic and multidimensional. Their management can be a challenge, but their use provides a deeper understanding of some of the major property problems.
- The concept of big data is not only related to the data themselves, but also to the tools created to work with them. Collecting, storing, analyzing and visualizing of data present unique challenges that require innovative solutions.
- Small data are also important. Property markets are local. Sometimes data must be selected and sorted to make big data meaningful.
- Tenants and landlords should approach data collection with a clear understanding of the laws for their protection and transparency. If possible, data should only be provided as a whole and systems should be deployed to ensure their security.
- Big data stimulate the emergence of new technologies and professions that affect property management. For example, blockchain technology is expected to have an increasing role in data management and property transactions. The need for job positions such as data specialists, data managers, and data visualizers will continue to grow.

The use of more sophisticated technologies in building equipment allows not only for controlling energy consumption, but also for wider applications, that provide more knowledge to landlords for the use of their properties by tenants. In addition, merging complex data sets, driven by machine learning and forecasting, is expected to affect property investment.

Property managers are in the process of studying the benefits and difficulties of collecting and analyzing different sets of data from their properties. To remain leaders in the industry, property companies need to start using the potential of big data and related technologies. The integration of big data into a sector, based on local information and personal relationships, is progressive. Companies that take advantage of big data opportunities will gain significant benefits.

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