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# The choice of cloud technology for big data

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*Abstract.* This article describes specific features of cloud technology types and their existing classifications, as well as the peculiarities of their implementation in the process of designing the DDS for Big Data Management. The application of the analytic hierarchy process for the choice of cloud technology within the project of DDS for Big Data Management is suggested and described within this paper. Multi-criteria decision making task with a defined set of options and criteria is solved.

*Key words:* Big Data, cloud services, decision making method, Decision Support System.

## INTRODUCTION

According to the data provided by Gartner, by 2018, 50 % of business ethics violations will occur through improper use of big data analytics, and first of all, through the inability to obtain business benefits from it. A vast amount of data, as well as its great diversity and the complexity of modern analytical methods only increase possible risks [1].

Analysts claim that by 2018 about 50 % of all the business ethics violations will be caused by the inability to properly use large amounts of information and the tools for processing it. The possible consequences may include loss of reputation, limitations in business operations, inefficient usage of resources and even legal sanctions.

Experts at Gartner advice that the analytical conclusions should be gradually correlated with the impact business decisions made on their basis have on the enterprise. Due to the lack of financial resources some organizations are unable to apply research results to their business activity. Furthermore, making a decision doesn't necessarily require investments into the engineering developments or complex analytical projects.

An enterprise needs a long-term strategy for the implementation of big data processing tools defining how the data in question will be processed and used. Thus the details of the future analysis should already be known on the stage of data acquisition.

Gartner analysts also emphasize the necessity to manage data as a corporate asset. A large amount of information comes from customers and consumers through various channels, but the businesses ignore its value and often lack clear models to monetize this resource. Even now banks and payment systems provide services for the retailers on the basis of data intended for users. Retailers in their turn share the information from the outlets with the suppliers in order to increase the turnover.

Whereas the factors of Big Data implementation, the obstacles that arise and the expected benefits vary between different branches, companies applying Big Data do this, according to IDC, with the aim of improving customer experience, making goods and services more innovative and optimizing business processes [2].

Decision Support Systems are the information systems, which are designed for solving managerial tasks and which help managers make reasonable, effective, high-quality decisions on the various levels of corporate management [3]. DSS allows to analyze comparatively large amounts of information automatically in the real-time mode. Unstructured and semi-structured multi-criteria tasks may be solved by means of DSS. DSS is an automated interactive system, enabling the decision-maker to reach high-quality decisions by applying models and data to define and solve various tasks. Corporate information systems in question use interactive queries, model decision-making situations and prepare reports in online-mode [3-4]. The main objective of the DSS is to improve the efficiency of the decisions made.

## THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

DDS is a set of intelligent, informed and engineering applications, used for the manipulation and analysis of data as well as for presenting the results of this analysis to the user [3]. Modern DSS allows to estimate the impact of the decisions made on the further development of business. Working with the Big Data is not similar to the ordinary business analytics process, where the result is achieved through the simple addition of data.

When working with the Big Data the result may be achieved in the process of their refinement by means of consecutive modeling: first the hypothesis is formed, then statistical, visual or semantic model is built on the basis of which the accuracy of this hypothesis may be evaluated and finally the next hypothesis is put forward [5–11]. This process requires a researcher either to interpret visual meanings, to create knowledge-based interactive queries or to develop adaptive machine learning algorithms able to achieve the desired result. The life cycle of such an algorithm may though be a rather short one [5].

Bill Inmon considers the concept of Big Data a new information technology [12]. Big Data is a technology, possessing the following characteristics:

- very large amounts of data may be processed;
- data storage devices are comparatively inexpensive;
- data is managed by "Roman Census" approach;
- data managed by means of Big Data is unstructured.

In order to implement the "Roman Census" method cloud technologies should be used.

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., communication networks, servers, data storage devices, application programs and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [13, 14].

As the world consulting companies unanimously predict, cloud technologies spreading and improving rapidly is one of the key trends that is very likely to have a profound influence on the global development in various fields of human activity in the following 5–8 years – not only in IT-industry, but also in business, finances, government administration, medicine etc.

Under the conditions of the advanced development in information communication technologies and another decline in the global economy, the technology, providing organizations and other subjects with all the necessary IT-resources online and thus enabling them to reduce the substantial expenses on their own IT-infrastructure, is considered to be a promising and cost-effective option for modernization, a worthwhile investment into the future [13–16].

The public cloud market is expected to grow up to 127.5$ by 2018, with the size of investments increasing by 22,8 % annually, which is 6 times larger than the figures predicted for the global IT-market development. It is also estimated that in 2018 the public cloud will be responsible for more than 50 % of growth in global expenses for software, servers and data storage systems [17].

Another factor contributing to the growth in cloud market is the increase in the number of companies, the leaders of which aim at developing the adaptability by providing their users with the larger scale of opportunities for work and combining functionality and upgraded programs without at the same time considerably increasing their expenses. Cloud technologies are nowadays increasingly used by many companies not as an addition to the IT-infrastructure, but as a complete replacement for local solutions.

Some companies, however, still hesitate about moving into 'the cloud'. What their authorities are mainly concerned about are the issues of data security, efficiency and the cost of integration. With regard to the first point, the question as to where the data will be stored tends to be the most pressing, since many companies find it absolutely unacceptable to store data outside their country. Furthermore, not everyone understands the payment process as well as the principles behind cloud services or is completely confident in their reliability. Some consumers believe that cloud storages cannot ensure information security.

Binding clients to a provider as well as facing some difficulties with providing Internet access for particular customers tend to be another problem. Cloud services still aren't profitable for clients, but the customer interest is very likely to rise in the course of time as new players appear on this market. This will depend on price reduction and the emergence of qualified experts in the field.

A new research by IDG Research Services provides some convincing evidence for the fact that digital transformation is a key to success in the competition of today's digital era [17]. Hybrid cloud technologies are the driving force of the digital business and their implementation offers a chance to achieve success much faster [18, 19]. Digital business leaders of today give hybrid cloud technologies the main priority. Now is the high time the potential of digital business and hybrid cloud was fulfilled.

## CHOICE OF CLOUD TECHNOLOGY FOR THE DSS PROJECT

Two types of DSS may be distinguished on the conceptual level, namely data-driven DSS and data-oriented DSS, the latter being focused on data access and manipulation [3, 4, 20]. The topicality of these DSS increased dramatically with the emergence of the Big Data information technology [5–11].

DSS for data management provides the highest degree of functionality and decision support related to the analysis of the large amounts of data. That is why Big Data being by far the most promising technology should be applied when developing a project of such a DSS [4].

As an information technology, Big Data may be described by the following formal model [4, 21–27], which looks like:

$$BD = \langle Vol_{BD}, I_p, A_{BD}, T_{BD} \rangle, \quad (1)$$

where $Vol_{BD}$ – a set of volume types; $Ip$ – a set of data source (information products) types; $A_{BD}$ – a set of techniques for Big Data analysis; $T_{BD}$ – a set of Big Data processing techniques.

On the various stages of Big Data processing the following techniques may be applied, which looks like:

$$T_{BD} = \langle T_{NoSQL}, T_{SQL}, T_{Hadoop}, T_V \rangle, \quad (2)$$

where $T_{NoSQL}$ – NoSQL database technologies; $T_{Hadoop}$ – technologies for providing massively parallel processing; $T_{SQL}$ – technologies for structured data processing (SQL databases).

Special attention within this research will be paid to the technologies for providing massively parallel processing.

The main objective of this paper is to conduct research into cloud computing and to find an optimal design solution for the choice of cloud services model as a component of DDC for Big Data management.

In the modern academic literature cloud technologies are mainly classified into the following types according to their architecture and the character of services provided: IaaS – Infrastructure as a service, PaaS – platform as a Serice and SaaS – software as a service. [28, p.18]. Three types of cloud services are depicted in Fig. 1 [29–33].

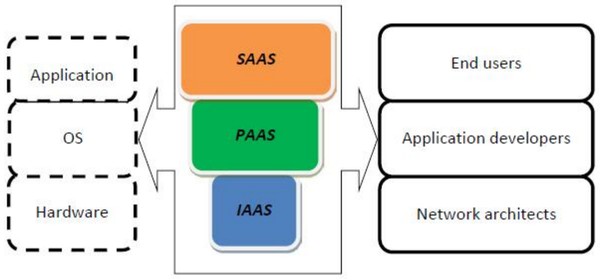


**Fig. 1.** Types of cloud services

IaaS is a cloud model which involves renting virtual servers for a fixed fee.

IaaS is a remote physical server, belonging to the third party (provider of the cloud services) and is being rented for a fixed monthly fee, determined by the third party. It should also be mentioned that IaaS cloud model involves renting servers only and not the software itself, which in its turn means that it is the renter not the IaaS service provider who is responsible for installing the operating system as well as the necessary software.

One of the main benefits of IaaS is a simple, fast and comparatively painless procedure of changing processing capacities of the server, which ensures a flawless process of transferring to another infrastructure in order to save valuable financial resources.

Like the majority of other cloud technologies IaaS is naturally a business-oriented model:

- no need to purchase expensive server hardware, incurring considerable one-off costs;
- no hardware upgrades required;
- no expenses on scheduled/unscheduled server maintenance needed;
- no need to work on improving server processing capacities;
- no bills for the electricity consumed by the server are to be covered;
- no extra server rooms with proper ventilation system needed.

Like many other technologies, IaaS inevitably has a number of drawbacks:

- an obligatory monthly fee for using the IaaS;
- any improvements in server processing capacity will imminently result in the increase of the fee paid;
- cases of copyright and license agreement violation will result in legal consequences for the renter of the IaaS, not for the provider of the services.

PaaS is a cloud model, according to which cloud service provider manages both technologies (server hardware) and information infrastructure (software) [34–36]. Units of software provided include operating systems, database management systems as well as test systems.

PaaS makes the process of server administration much easier for a particular user, since it's the third party (cloud services provider) who is to manage these operations.

The customer is no longer responsible for:

- installing the operating system and the database management systems;
- configuring the database management systems and the operating system;
- further functioning of the operating system and the database management systems.

The third party (cloud services provider) is ultimately responsible for the PaaS cloud computing environment administration.

The benefits of using PaaS cloud model tend to be obvious:

- no need to purchase servers or data processing centers;
- no need for the customer to hire system administrator, whose services may if necessary be outsourced;
- no legal issues concerning the use of unlicensed software (operating systems or paid database management systems in particular)
- the customer is free to choose and install necessary applications;
- software for testing and development is provided by the PaaS administrator.

A number of inconveniences may still be distinguished, none of which, though tends to be critical:

- renting a PaaS working environment turns out to be comparatively more expensive than a cloud model IaaS;
- there are some restrictions on the choice of particular operating systems, not all the cloud providers support less common systems;
- unlicensed application installed by the client violates copyright and intellectual property laws and may thus lead to legal actions.

SaaS is a cloud model, embodying ultimate comfort and convenience for the customer. According to the SaaS ideology, servers with a set of necessary software are hosted by a third-party provider.

The advantages of the SaaS model are as follows:

- no need to install software on the customer's PCs;
- reduction of costs for system deployment: no need for a local server, system administrator or extra server rooms;
- no need to hire technical support experts;

- high usability: intuitive interface; Internet access and proper browser settings are the only prerequisites for communication;
- transparent and well-organized payment process;
- complete multiplatform, enabling the customer to install a Linux family operating system and thus reduce the software expenses;
- availability of the modules enabling off-line operation, especially under the conditions of no or constantly interrupted Internet connection.

The following disadvantages of SaaS may be distinguished:

- insufficient scalability level;
- the model is designed for solving typical tasks;
- need for stable and preferably high-speed Internet connection;
- insufficient level of data privacy.
- Potential leakage of secret information which may considerably damage the company's business tends to be the key objection against the SaaS cloud model.

The actions of both parties in the case of secret information leakage as well as their responsibility are to be settled by means of legal agreements.

The fact that the security level of servers hosted by a cloud services provider in case of a break-in is considerably higher serves as an argument in favour of SaaS.

We thus have the case of multi-criteria decision making task with a defined set of options and criteria. The process of cloud technology choice in the DSS project for Big Data management will be described further in this paper.

Suppose a customer has to choose a cloud technology among one of the following models – SaaS, IaaS and PaaS. The basic criteria taken into consideration by the developer of DSS for Big Data management are as follows: price, degree of administrative complexity and privacy. Before choosing the best solution, all the options are to be examined.

Various systematic procedures are applied in the process of complex problem solving, one of them is the analytic hierarchy process. This method is based on the principles of synthesis and decomposition, implementation of which allows to reduce the number of possible mistakes while collecting the information from the experts [37]. Analytic hierarchy process is a systematic procedure based on the hierarchical representation of the elements defining the root of the problem [37–42]. The problem is being decomposed into simpler components and the decision-maker, then estimates the relative degree of interaction between them within the hierarchical structure.

The problem in question in the majority of cases comes down to providing an explanation for the choice of one option from the set of all the possible alternatives characterized by a complex hierarchy of aspects and criteria. The lowest level of the hierarchy is a leaf level (level of the alternatives themselves) and the previous one is directly associated with it – this level is dedicated to assessing the quality of the possible alternatives.For this purpose, the objective tree is further used (Fig. 2).

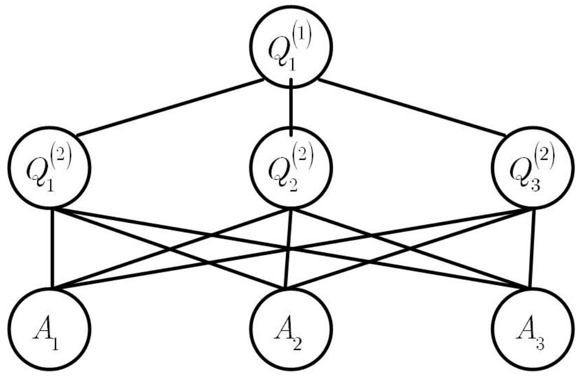


**Fig. 2.** The hierarchy of alternatives and criteria

Fig. 1 depicts the hierarchy where $Q_j^{(i)}$ – the nodes of the hierarchy except for leaves which correspond to the set of cloud technologies; $i$ – number of the particular level within the hierarchy (for the root node of the hierarchy $i$ = 1); $j$ – index of the node located within $i$ a level.

The root node of the hierarchy $Q_1^{(1)}$ corresponds to the objective of choosing a cloud technology, namely the cloud technology, which tends to be the most appropriate from the user's perspective.

Aspects (Criteria) are located on the second level of the hierarchy: $Q_1^{(2)}$ – the price, $Q_2^{(2)}$ – the degree of administrative complexity, $Q_3^{(2)}$ – privacy.

On the leaves level of the hierarchy are located cloud technology (alternatives): $A_1$ – SaaS, $A_2$ – IaaS, $A_3$ – PaaS.

The matrices of pairwise comparison $A_j^{(i)}$ have been created for all the nodes of the hierarchy $Q_j^{(i)}$ except for leaves by applying the method of pairwise comparison. The main eigenvectors $x_j^{(i)}$ have been calculated for each of the matrices [43].

Nine-point rating scale has been used by experts in the process of evaluation (Table 1) [43].

**Table 1.** Rating scale for expert evaluation

| Points (b) | Description |
|---|---|
| 1 | Equal importance |
| 3 | Noticeable superiority |
| 5 | Considerable superiority |
| 7 | Substantial superiority |
| 9 | Complete superiority |
| 2,4,6,8 | Intermediate values (applied in borderline cases) |
| 1/*b* | Inverse values |

Eigenvector value $x_i$ is calculated according to the following formula [42], which looks like:

$$x_i = \frac{\sqrt[n]{\left(\prod_{j=1}^{n} a_{ij}\right)}}{\sum_{i=1}^{n} \sqrt[n]{\left(\prod_{j=1}^{n} a_{ij}\right)}}, \qquad (3)$$

where $x_i$ – eigenvector value; $a_{ij}$ – rating by an expert – degree of criteria *i* dominance over the criteria *j*.

According to the results of expert evaluation a table reflecting the importance of various criteria for the cloud technology choice ( $Q_1^{(1)}$ ) has been created (Table 2).

**Table 2.** Criteria importance with regard to the root node of the hierarchy

| $Q_1^{(1)}$ | $Q_1^{(2)}$ | $Q_2^{(2)}$ | $Q_3^{(2)}$ | $x_1^{(1)}$ |
|---|---|---|---|---|
| $Q_1^{(2)}$ | $a_{11}$ | $a_{12}$ | $a_{13}$ | $x_1$ |
| $Q_2^{(2)}$ | $a_{21}$ | $a_{22}$ | $a_{23}$ | $x_2$ |
| $Q_3^{(2)}$ | $a_{31}$ | $a_{32}$ | $a_{33}$ | $x_3$ |

By applying the method of pairwise comparison on this stage we get the matrix of the following structure, which looks like:

$$A_1^{(1)} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}, \quad (4)$$

where $a_{ij}$ – rating by an expert – degree of criteria *i* dominance over the criteria *j*. $a_{ij} = 1/a_{ji}$ for if the criteria *i* is $a_{ij}$ times "better" than the criteria *j*, it is then obvious that the criteria *j* is $a_{ji}$ times "worse" than the criteria *i* [43].

By each time comparing in pairs, three alternatives, according to three criteria and three criteria with regard to the importance of their influence on the main objective (Fig. 2) we get three 3×3 matrices for the lower level of hierarchy and one 3×3 matrix for the focus node of the hierarchy.

We can now create a criteria comparison matrix depicting the importance of various criteria with regard to one another (Table 3).

**Table 3.** Criteria comparison matrix

| Criteria | Price | Degree of administrative complexity | Privacy |
|---|---|---|---|
| Price | 1 | 3 | 1/3 |
| Degree of administrative complexity | 1/3 | 1 | 1/5 |
| Privacy | 3 | 5 | 1 |

The results obtained by comparing each pair of alternatives according to each of the criteria are presented in the Tables 4–6.

**Table 4.** Results of comparison according to the price criterion

| | SaaS | IaaS | PaaS |
|---|---|---|---|
| SaaS | 1 | 7 | 4 |
| IaaS | 1/7 | 1 | 1/2 |
| PaaS | 1/4 | 2 | 1 |

**Table 5.** Results of comparison according to the degree of administrative complexity

| | SaaS | IaaS | PaaS |
|---|---|---|---|
| SaaS | 1 | 2 | 4 |
| IaaS | 1/2 | 1 | 2 |
| PaaS | 1/4 | 1/2 | 1 |

**Table 6.** Results of comparison according to the privacy criterion

| | SaaS | IaaS | PaaS |
|---|---|---|---|
| SaaS | 1 | 4 | 2 |
| IaaS | 1/4 | 1 | 1/2 |
| PaaS | 1/2 | 2 | 1 |

Now the eigenvector of the comparison matrix is to be calculated and normalized. The results of these calculations as well as the weight of each criterion are presented in the Table 7.

**Table 7.** Vectors and criteria weight calculation

| Criteria | Price | Degree of admini-strative comp-lexity | Priva-cy | Vec-tor | Crite-rion weight |
|---|---|---|---|---|---|
| Price | 1 | 3 | 1/3 | 1,00 | 0,26 |
| Degree of admini-strative comp-lexity | 1/3 | 1 | 1/5 | 0,41 | 0,10 |
| Privacy | 3 | 5 | 1 | 2,47 | 0,64 |
| Total | | | | 3,87 | |

Normalized vectors calculated for the alternatives according to each of the criteria are presented in the Tables 8–10.

**Table 8.** Normalized vectors calculation according to the price criterion

| | SaaS | IaaS | PaaS | Vector | Price |
|---|---|---|---|---|---|
| SaaS | 1 | 7 | 4 | 3,0366 | 0,715298925 |
| IaaS | 1/7 | 1 | 1/2 | 0,4149 | 0,097736973 |
| PaaS | 1/4 | 2 | 1 | 0,7937 | 0,186964103 |
| Total | | | | 4,2452 | |

**Table 9.** Normalized vectors calculation according to the degree of administrative complexity

| | SaaS | IaaS | PaaS | Vector | Degree of administrative complexity |
|---|---|---|---|---|---|
| SaaS | 1 | 2 | 4 | 2 | 0,571428571 |
| IaaS | 1/2 | 1 | 2 | 1 | 0,285714286 |
| PaaS | 1/4 | 1/2 | 1 | 0,5 | 0,142857143 |
| Total | | | | 3,5 | |

**Table 10.** Normalized vectors calculation according to the privacy criterion

| | SaaS | IaaS | PaaS | Vector | Privacy |
|---|---|---|---|---|---|
| SaaS | 1 | 4 | 2 | 2 | 0,571428571 |
| IaaS | 1/4 | 1 | 1/2 | 0,5 | 0,142857143 |
| PaaS | 1/2 | 2 | 1 | 1 | 0,285714286 |
| Total | | | | 3,5 | |

The best alternative is now to be defined by means of importance criterion synthesis (Table 11).

**Table 11.** Comparison of the alternatives

| | Price | Degree of administrative complexity | Privacy | Total grade |
|---|---|---|---|---|
| SaaS | 0,7152989 | 0,2043711 | 0,0583919 | 0,243349 |
| IaaS | 0,0977369 | 0,0279248 | 0,0079788 | 0,033250 |
| PaaS | 0,1869641 | 0,0534183 | 0,0152626 | 0,063606 |

SaaS, cloud technology can therefore be considered the best alternative for the project of DSS development for Big Data Management, since it has the biggest total weight.

Thus, by applying the analytic hierarchy method the SaaS, cloud technology has been defined as the best option for the DDS project from the user’s perspective.

## CONCLUSION

Under the conditions of the advanced development in information communication technologies and another decline in the global economy, cloud technology, providing organizations and other subjects with all the necessary IT-resources online and thus enabling them to reduce the substantial expenses on their own IT-infrastructure, is considered to be a promising and cost-effective option for modernization, a worthwhile investment into the future.

Regardless of the model chosen, be it IaaS, PaaS or SaaS, switching to the cloud should by no means be accompanied by the decrease in the security level. Transferring data to be processed by the provider, we are to be sure that they are processed in strict accordance with the established technological process, taking into consideration both organizational and technological requirements for safety assurance. Data protection in the cloud therefore begins on the customer side and ends on the provider side. The choice of the security methods as well as of business processes for transferring to the cloud should be based on the analysis of possible risks.

In the course of this research the objective tree has been built by applying previously developed a formal model of Big Data information technology. The most appropriate cloud technology meeting all the selection criteria formulated by the developer of DSS for Big Data Management constitutes the focus node of the hierarchy. The efficiency of the analytic hierarchy process for decision making and reasoning has been proved practically.

Thus, by applying the analytic hierarchy method the SaaS, cloud technology has been defined as the best component for the project of DDS for Big Data Management from the user’s perspective. This alternative tends to be a better one in terms of price, privacy and the degree of administrative complexity (in this case, simplicity). Ratings by the decision-maker have been taken into consideration when reaching the final decision.

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