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A qualitative study investigating the associations between advantages and strategies to cloud computing adoption in manufacturing in Poland

1. Introduction and current research

Cloud computing application to manufacturing, and cloud manufacturing (CMfg) can be viewed as important issues in the "digitization" of the manufacturing industry, which refers to changes of the established patterns caused by the digital transformation and complementary innovations in the economy and society.[3] Digitization of the manufacturing industry is to contribute to increasing the share of the manufacturing sector, and reproduce the success of Germany and Austria, who have been able to maintain the share of the manufacturing sector over the past 20 years.[4] It has been achieved by the following key activities:[5]

- high level of security and robustness in the development and production processes as the basis for the production of high-quality products;
- comprehensive automation with high process quality that allows production with high unit numbers, whereby also product variants are supported;
- extremely effective use of new technologies (in particular IT tools for engineering, product validation, production planning, commissioning and production).

M. Sanchez quotes the opinion of Kane, Palmer, Phillips, Kiron, & Buckley[6] that maturing digital businesses are focused on integrating digital technologies,

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3 M.A. Sanchez, How Internet of Things Is Transforming Project Management, [in:] Z.H. Gontar (Ed.), *Smart Grid Analytics for Sustainability and Urbanization*, IGI Global, Hershey, 2018.

4 T. Zimmermann, Industry 4.0: Nothing Is More Steady Than Change, [in:] Z.H. Gontar (Ed.), *Smart Grid Analytics for Sustainability and Urbanization*, IGI Global, Hershey, 2018.

5 Ibid.

6 G.C. Kane, D. Palmer, A.N. Phillips, D. Kiron, N. Buckley, *Strategy, not Technology, Drives Digital Transformation: Becoming a Digitally Mature Enterprise*. 2015. http://sloanreview.mit.edu/projects/strategy-drives-digital-transformation/ (accessed: 23.1.2019).

such as social, mobile, analytics and cloud, in the service of transforming how their businesses work.[7]

Our study concerns the investigations of the state of knowledge of IT experts working in manufacturing enterprises in this field. To investigate the knowledge of IT managers, we adopt the association rules approach.

The following research questions were considered:
RQ1: What are the main primary and secondary advantages of cloud computing adoption in manufacturing enterprises?
RQ2: How do primary advantages influence the secondary advantages of the cloud solutions adoption?
RQ3: What is the map of relationships between the primary and secondary advantages in the light of global trends in the domain under investigation?

2. Advantages of cloud computing services adoption

To determine the state of experts' perception about the strengths and strategies for migration of the IT systems to the cloud in manufacturing enterprises, we performed an empirical study of this topic, questioning IT managers from randomly selected 400 manufacturing companies in Poland about the implementation of the solutions based on the computational cloud. It should be noted that these data relate to the opinion of IT managers in this respect, rather than the real benefits that emerged as a result of the implementation of the cloud solutions (although it cannot be ruled out that these opinions may have appeared on the basis of observations of the real benefits from specific implementations). The respondents were more interested in the technical benefits of IT rather than business benefits. Perhaps this is the result of "professional distortion" of IT managers, but it also points to the underestimated aspect of the digital transformation of the manufacturing industry, i.e. the possibility of using new business models, services added to the manufactured products, generally – integration of IT solutions with products or services. We will return to these issues in the following paragraphs.

The lists of advantages and the number of their occurrences in the respondents' selections used in the study are presented in Figure 1. The list was developed on the basis of the research on the subject literature, and our expert knowledge.

[7] Ibid. 3.

An uneven distribution of benefits is visible. Through associative analysis, we tried to capture the dependencies between the benefits and the strategies, and on this basis identify the primary and secondary benefits and plot a map of the links between them.

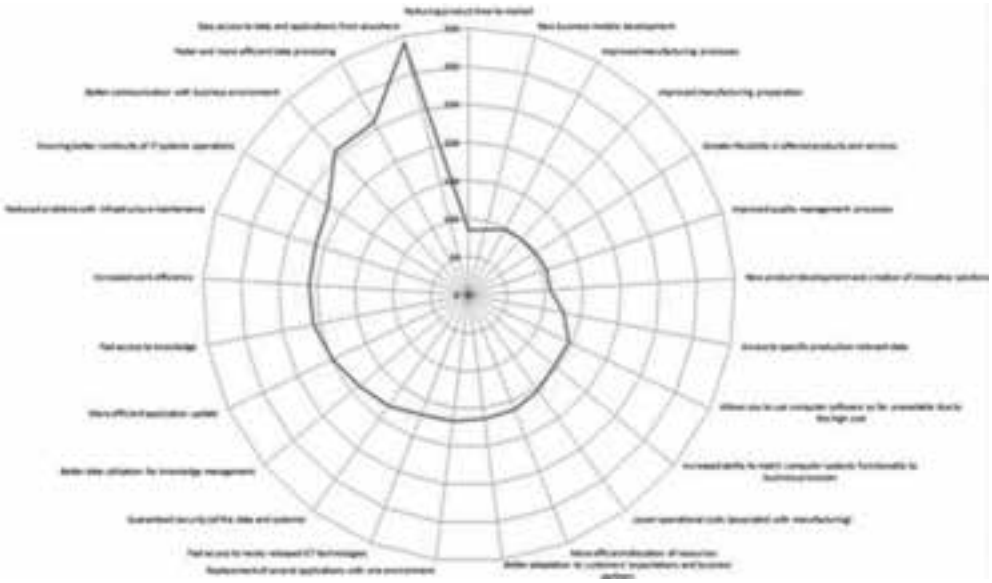

Figure 1. Migration to the cloud: a list of advantages used in the study and the number of their occurrences in the respondents' selections

Source: Own study.

The respondents were supposed to choose all the perceived benefits and problems from the given list (multiple choice query). In the advantages analysis from the total number of 400 received responses, 10 questionnaires were rejected as containing none or all the answers (chosen all the 25 benefits categories).

Table 1 also contains the number of occurrences of each category in cloud adoption advantages in the choices of the respondents.

The goal of the research is to structure the obtained expert knowledge, determine the primary and secondary benefits, and develop a map of these benefits

The benefits have been structured according to the factors presented in table 2.

In the next part, we present the results of the research on the impact of these variables on the experts' opinions about the importance of the advantages of migration of IT systems to the computational cloud. Part 3 contains association rules analysis revealing interdependences between the factor variables.

Table 1. Migration to the cloud: a list of input factors used in the study

Factors	*Possible choices of the respondents*
x_1: Size of the firm	a. Micro (0–9 employees) b. Small (10–49 employees) c. Medium (50–249 employees) d. Large (more than 249 employees)
x_2: Has the firm developed its business strategy?	a. Yes b. No c. I don't know/hard to say
x_3: Has the firm developed its IT strategy?	a. Yes, compatible with the business strategy b. Yes, independent from the business strategy c. Yes, but I don't know if compatible with / independent from the business strategy d. No, doesn't have any business strategy
x_4: Structure of capital	a. 100% of domestic capital b. Dominant share of domestic capital c. Dominant share of foreign capital d. 100% of foreign capital e. I don't know/hard to say
x_5: Implemented cloud solutions (more than e-mail and office tools)	a. Yes b. No

Source: Own study.

3. Association rules approach to the identification of factors influencing the perception of the advantages and strategies of the migration to the computational cloud

In the current section, the analysis is conducted referring to the factors influencing the managers' perception of particular advantages resulting from the migration of the enterprise's IT system to the computational cloud. The class association rules (CAR) approach will be used as the first step of the research to determine, for each of the categories shown in Table 1, the factors selected from Table 2 with the strongest associations with the categories: size of the firm, involvement of the highest management in the IT topics, structure of the capital, and experience of the problems with the actual migration to the cloud.

To determine the strength of the associations, the *a priori* algorithm of the association rules and classifier building in the Classification Based on Associations (CBA) framework were adopted.[8]

[8] B. Liu, Y. Ma, C.K. Wong, Classification Using Association Rules: Weaknesses and Enhancements, [in:] R.L. Grossman, C. Kamath, P. Kegelmeyer, V. Kumar, R.R. Namburu (Eds),

Let's denote as $\mathbf{x}_i = (x_{i1} \ldots x_{i5})$, $i = 1 \ldots N$, the i-th pattern of values of factor variables. Using patterns $\mathbf{x}_i$ all the rules of the form $\mathbf{x}_i \rightarrow c_i$ that satisfy specified minimum support and minimum confidence were developed, in the rule generation of the advantages categories (c_i).

After the above data preparation, two sets of association rules have been developed, for advantages categories:

$$\mathbf{x}_i \rightarrow c_i,\ i = 1,\ldots, K-1 \tag{1}$$

where K means the number of advantages categories. For each category, a set of CAR rules with high confidence is selected, which indicate factors having the main influence on the given categories.

The size and capital structure of the enterprise affects most the perception of the benefits of cloud computing by the experts in the field. In the next stage of the research, we distinguished those categories of benefits that have the most important associations with the above-mentioned factors and checked the strength of the association between the categories of benefits. To determine the strength of the associations between the categories, the classical *a priori* algorithm in the binary association rules framework was adopted.[9] The results are shown in figure 2.

Association analysis in the sense of binary association rules is aimed at finding the following implication: XY, $X \cap Y = 0$, where X and Y are sets of binary attributes called items (in our case – categories of benefits). Questionnaire results are treated as a set of transactions, where each questionnaire has a unique transaction ID and contains a subset of the items (categories of benefits). The rules are created on the basis of various measures of significance and interest, including support and confidence. The support of item set X is defined as the proportion of transactions in the data set which contains the item set. The confidence of a rule is defined as follows: conf $(X \Rightarrow Y)$ = supp $(X \cup Y)$/supp(X), and can be interpreted as an estimate of the conditional probability P (Y |X).

A priori algorithm refers to the two-step approach, i.e. finding frequent item sets which meet or exceed the minimum support, and using these item sets to generate association rules. In general, for the given d unique items, the total number of possible association rules is given by the following value:

Data Mining for Scientific and Engineering Applications. Massive Computing, vol 2. Springer, Boston, MA, 2001.

[9] R. Agrawal, T. Imieliński, A. Swami, *Mining association rules between sets of items in large databases*, Proceedings of the 1993 ACM SIGMOD international conference on Management of data – SIGMOD 1993, p. 207.

$$R = \sum_{k=1}^{d-1}\left[\binom{d}{k}\sum_{j=1}^{d-k}\binom{d-k}{j}\right] \tag{2}$$

The resulting set of associative rules representing associations between the benefit categories was then analyzed to distinguish the most valuable ones. They were used to build the map of associations for the given problem (Figure 2).

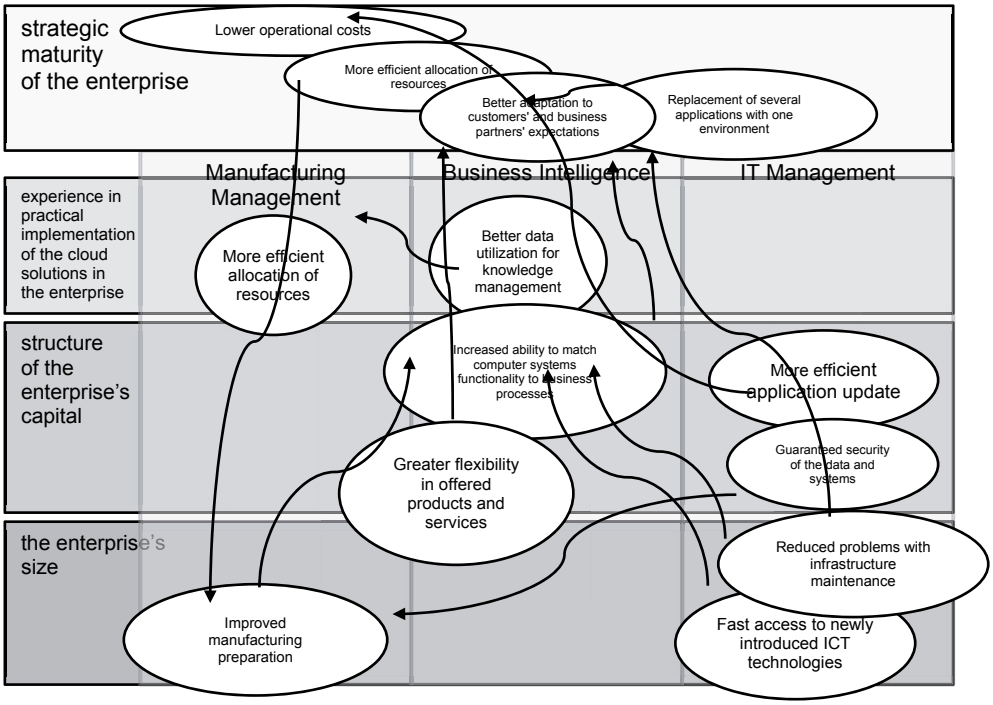

Figure 2. Migration to the cloud: a map of the list of advantages used in the study
Source: Own study.

Analyzing the associations between the advantages concerning cloud computing adoption in manufacturing in Figure 2, we can see that the most valuable benefits are spread evenly across the following categories: manufacturing management, business intelligence, and IT management. However, the experts in the field perceive the primary benefits of the cloud mainly in IT management, and they are: fast access to the newly introduced ICT technologies, reduced problems with IT infrastructure management, security of the data and of IT systems, efficiency in the systems upgrading, and introduction of one cloud environment instead of numbers of separate IT systems. The following categories are also

perceived as primary: flexibility in products and services offered, transforming data into knowledge (and in wisdom of the manufacturing enterprise), and efficiency in resources allocation. After satisfying the needs related to the categories mentioned above, the experts subsequently recognize the following benefits: decreasing operational costs, better adaptation to the needs of both clients and business partners, better matching to business processes, and improved manufacturing preparation.

Let's notice that the strategic maturity of the enterprise in an interesting way affects the managers' perception of particular advantages resulting from the migration of the enterprise's IT system to the computational cloud. Having the IT strategy compatible with the business strategy, the managers' perception concentrates mainly on automation of individual activities in the value chain on the basis of the analysis of the captured data, which led to an increase in the productivity of activities (lower operational costs associated with manufacturing). It is an old-fashioned reason why organizations adapt cloud technology in manufacturing processes, appealing to the 70s of the last century. The same observation can be applied to the situation when the IT strategy is independent of the business strategy (more efficient allocation of resources). When the experts in the field are not aware of the existing business strategy or do not attach importance to it, then they focus on the IT infrastructure (replacement of several applications with one cloud environment). It is interesting that the IT managers attach a relatively higher importance to modern business concepts based on the integration of IT technology with products/services in a situation where a business strategy is not explicitly defined in the manufacturing enterprise (better adaptation to customers' and business partners' expectations). This indicates the following interests: coordination and integration across activities with suppliers, channels, and customers on the basis of the Internet development, and maybe even integration with the product itself on the basis of the embedded sensors, processors, software, and connectivity in products through the computational cloud in which product data is stored and analyzed and some applications are run.

4. Conclusion

In the paper the problem of the advantages and strategies in cloud solutions adoption in manufacturing enterprises was discussed. The obtained results confirm the presence of global trends in manufacturing enterprises in Poland.

Experts in the field perceive integration of cloud solutions with the product itself through the computational cloud in which product data is stored and analyzed and some applications are run, as one of the most important benefits of the cloud in manufacturing enterprises. This is evidenced by the fact that "greater flexibility in offered products and services" has been recognized as one of the primary advantages. The other primary advantages prove, however, that experts in the field focus on the benefits of managing IT infrastructure (e.g. reduced problems with IT infrastructure management). Important for experts are also those benefits that can be associated with older trends, i.e. coordination and integration across activities with suppliers, channels, and customers on the basis of the Internet development (e.g. better adaptation to customers' and business partners' expectations), and automation of individual activities in the value chain on the basis of the analysis of the captured data, which led to an increase in the productivity of activities (e.g. lower operational costs, more efficient allocation resources, improved manufacturing preparation).

The research has also revealed a map of the relationships between the benefits, identifying the primary and secondary benefits and the links between them. However, this will require further investigations.

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Zastosowanie metod badań jakościowych w analizie korzyści z adaptacji chmury obliczeniowej w przemyśle wytwórczym w Polsce – podejście strategiczne

Streszczenie

Chmura obliczeniowa to przykład radykalnej zmiany w funkcjonowaniu przedsiębiorstw produkcyjnych poprzez absorpcję rozwiązań IT, gdzie powody, dla których organizacje wprowadzają nowe technologie informacyjne, ulegają systematycznej zmianie. Dość powszechnie przyjmuje się rozróżnienie trzech wyraźnych „fal" w tym obszarze:

- 1960–1970 – automatyzacja poszczególnych czynności w łańcuchu wartości na podstawie analizy przechwyconych danych, co doprowadziło do wzrostu produktywności działań;
- 1980–1990 – koordynacja i integracja działań związanych z dostawcami, kanałami dystrybucji i klientami, bazujące na rozwoju Internetu;
- obecnie – integracja z samym produktem na podstawie wbudowanych w produkt urządzeń (czujników, mikroprocesorów, nadajników) oraz oprogramowania w chmurze obliczeniowej, które pozwala na zapisywanie danych produktu, ich analizowane oraz zdalne uruchamiane określonych aplikacji.

Celem badań zaprezentowanych w artykule jest przeanalizowanie i strukturalizacja wiedzy ekspertów na temat zalet wdrażania chmury obliczeniowej w przedsiębiorstwach produkcyjnych w Polsce, a także analiza aspektu strategicznego tego procesu oraz porównanie uzyskanych wyników z tendencjami globalnymi wskazanymi powyżej. Badania przeprowadzono w latach 2017 i 2018 poprzez wspomagany komputerowo wywiad telefoniczny (ang. *Computer Assisted Telephone Interviews*, CATI) na grupie losowo wybranych 400 przedsiębiorstw produkcyjnych. Starano się zapewnić reprezentację przedsiębiorstw we wszystkich wybranych kategoriach, w tym ze względu na wielkość przedsiębiorstwa, źródło kapitału, strategiczne wykorzystanie IT itp. W artykule przedstawiono wyniki badań dotyczących zastosowania reguł asocjacyjnych i algorytmu *a priori* do wykrywania odpowiednich asocjacji.

Słowa kluczowe: chmura obliczeniowa, analiza asocjacyjna, absorpcja innowacji