Scientific Journal of Silesian University of Technology. Series Transport
Zeszyty Naukowe Politechniki Śląskiej. Seria Transport

Volume 115 **2022**

p-ISSN: 0209-3324

e-ISSN: 2450-1549

DOI: https://DOI:.org/10.20858/sjsutst.2022.115.11

Journal homepage: http://sjsutst.polsl.pl

Article citation information:
Sharma, M.K. Cloud manufacturing: identifications and prioritization of opportunities using AHP. *Scientific Journal of Silesian University of Technology. Series Transport*. 2022, **115**, 161-173. ISSN: 0209-3324. DOI: https://DOI:.org/10.20858/sjsutst.2022.115.11.

Mohneesh Kumar SHARMA[1]

CLOUD MANUFACTURING: IDENTIFICATIONS AND PRIORITIZATION OF OPPORTUNITIES USING AHP

Summary. The origin of a cost-efficient, service-oriented, customer-centric, manufacturing system called cloud manufacturing has evolved due to advancements in cyber systems and the availability of internet facilities worldwide. However, there is a significant number of opportunities before the adoption of cloud manufacturing. Through literature survey, expert opinions from academicians and industrialists, various opportunities, namely, pay-as-use, scalability, cost efficiency, flexibility, autonomy, low-risk backup and recovery, low startup cost and location independence associated with the espousal of cloud manufacturing are identified. Further, the Analytic Hierarchy Process (AHP) model is applied to find the weights and prioritize these opportunities, thereby finding the significant key opportunities. Moreover, the consistency ratio is calculated for the accuracy and consistency of the results. As the obtained value of consistency ratio is less than .1, it shows that the result obtained is consistent and accurate. The managerial implication of these outcomes is that the results would indirectly help entrepreneurs in the adoption of cloud manufacturing.

Keywords: cloud manufacturing, opportunities, pay-per-use, scalability, analytic hierarchy process

[1] Department of Mechanical Engineering, Delhi Technological University, New Delhi 110042, India. Email: simplymohneesh@gmail.com. ORCID: https://orcid.org/0000-0003-3347-9700

1. INTRODUCTION

Recent advancements in technologies and customized requirements of customers and manufacturing industries have gone through significant changes leading to a highly competitive environment globally. Cost, customization, flexibility, reliability, and quality are the key factors that enterprises must improve to sustain in the global market. Following the path of networking some of the manufacturing models were introduced, namely, Agile Manufacturing (AM) [1, 2], Network Manufacturing (NM) [3, 4], Manufacturing Grid (MG) [5, 6], Virtual Manufacturing (VM) [7, 8], Additive Manufacturing [9, 10], and Smart Manufacturing (SM) [11, 12], which have changed the manufacturing process significantly. The cloud computing model helps in enabling a user secure and convenient on-demand network access to a shared pool of computing resources like storage, network, applications services, etc. [13]. Moreover, the virtualization and service-oriented characteristics of cloud computing make manufacturing suitable for customization. Gibson et al. (2012) explained the benefits of service models of cloud computing [14]. When services like SaaS, PaaS, and IaaS of cloud computing are applied to manufacturing, then the new manufacturing model obtained is called Cloud Manufacturing [15].

Cloud manufacturing is preferred over other manufacturing systems due to its cost efficiency, pay as per requirement and scalability. Ghomi et al. (2019) provided an overview of cloud manufacturing challenges, recent advancements, issues related to research, and its future trend [16].

Since this manufacturing model is growing at a significant pace, its merits should not be left unknown. Knowledge regarding positive aspects of the manufacturing model helps in its future development and eases its adoption. Narwane et al. (2019) presented a review on issues related to manufacturing and its adoption, they also highlighted the application of the manufacturing model for various industries and sectors [17]. Abubakar et al. (2014) studied the issues related to the adoption of cloud computing for small and medium-sized enterprises in developing countries of the Saharan Africa [19]. Zhang et al. (2020) developed a service platform to increase the competitiveness among small and medium scale industries regarding cloud manufacturing [21]. Abd et al. (2018) compared the current adoption of the manufacturing model with the ideal manufacturing model [22]. Brief studies have been done in past papers on the merits of cloud manufacturing; however, no study deals with its prioritization. Hence, this endeavour is made to identify the opportunities of cloud manufacturing and their prioritization.

Cloud manufacturing is based on shared manufacturing infrastructure, services, and resources through a cloud platform. It uses algorithms to make intelligent decisions and provides the most optimized way for sustainable and robust manufacturing [23]. The recent advancements in technology have made manufacturing more flexible, resourceful, efficient, and customized. Given that cloud manufacturing is still an explored field in developed countries and a new concept to be adopted by developing countries, this study aims to identify the benefits of cloud manufacturing for improving the existing model of cloud manufacturing in developed countries and the initial adoption of cloud manufacturing model in developing countries. Further, it is to identify the opportunities of the cloud manufacturing model and prioritize them to provide prior information on the benefits of this manufacturing model to entrepreneurs interested in its adoption, especially in developing countries. This paper mainly discusses the opportunities of cloud manufacturing. Hence, identification of opportunities is done and through AHP key opportunities are obtained.

The brief of this paper is as follows:
1. Identification of cloud manufacturing opportunities.
2. Application of the AHP approach for prioritization of opportunities.
3. Analysis, result, discussion and conclusion.

2. OPPORTUNITIES

In this section, the opportunities of cloud manufacturing is discussed. Significant factors supporting the adoption of cloud manufacturing are pay-per-use, scalability, cost efficiency, flexibility, autonomy, low-risk backup and recovery, low startup cost, and location independence. All the opportunities are discussed in the section below and finally listed in Table 1.

2.1. Pay-Per-Use or Pay-As-You-Go Service

A user can request services as and when required and can pay according to the "pay-per-use" model, where he pays for the time he has availed of the services, resources, or infrastructure. This scheme is managed by a cloud platform [23]. Pay-as-you-go facility can be availed by users without having any direct interaction with the service provider [24]. The pay-as-you-go model ensures the exchange of services between the manufacturing providers and consumers [25]. It also promotes the paying scheme named pay-as-you-go to the customers [26, 27].

2.2. Scalability

Cloud manufacturing facilitates the user to run a production system on market demand [23]. It provides the facility of scaling where the user can scale (up or down) the use of resources according to his needs [24]. Removal, modification, and addition of resources can be done as required [25]. Cloud manufacturing makes it easier to scale up or down their production according to customer demand [28].

2.3. Cost Efficiency

The support of the Internet, IoT (Internet of things), and Big Data to manufacturing lowers the entry cost for smaller firms. Moreover, with the optimized use of resources, this manufacturing system has become the most cost-efficient manufacturing system in recent times [29]. Cloud manufacturing leads to an increase in the usage of manufacturing resources through outsourcing [25]. By adopting cloud manufacturing, the cost of manufacturing can be reduced [30].

2.4. Flexibility

Cloud manufacturing can adapt to unpredicted changes in circumstances [23]. Further, it can also adapt and respond to changing customer demands [25]. Cloud manufacturing can generate new types of classes of manufacturing processes and deliver manufactured products to clients [28].

2.5. Autonomy

Every manufacturing provider and customer is an independent identity and works independently without having a direct link between them. For cost reduction in operating costs, considerable autonomy is needed in the administration [31]. Service agents provide this autonomy [32].

2.6. Low-risk Backup and Recovery

Cloud manufacturing reduces the risk for small-scale enterprises as all the tasks are outsourced to other companies through the cloud platform [27]. Data storage by the provider makes the data safe with a recovery functionality in case of an emergency. Sharing the benefits among manufacturers lowers the risk factor [30].

2.7. Low Startup Cost

Being that there is no infrastructure or machinery, and the user owns the software, working on the pay-as-use model makes it free from upfront investment for start-ups. Cloud Manufacturing lowers startup and operating costs [27]. Infrastructure and administration costs are also reduced resulting in lower upgrading and maintenance costs [28].

2.8. Location Independence

Independence from locational constraints for the user and the provider takes the freedom of this system to another level. Work can be performed anywhere and at any time. Tasks can be done from suitable enterprises located at any place, thus making this model location independent. Since the system is independent of location, the customer is not required to be concerned about the location of the resources he is using [33]. There is a sense of locational independence where the customer has no control over the location of the service provider [34].

Tab. 1.

Opportunities in espousal cloud manufacturing

S.No.	Opportunities	References
O_1	Pay-per-use or Instant service	[23-27]
O_2	Scalability	[23,24,25,28]
O_3	Cost efficiency	[25,29,30]
O_4	Flexibility	[23,25,28]
O_5	Autonomy	[31,32]
O_6	Low-risk backup and recovery	[27,30]
O_7	Low startup cost	[27,28]
O_8	Location independence	[33,34]

3. RESEARCH METHODOLOGY

In this article, the Analytic Hierarchy Process (AHP), one of the popular MCDM techniques, is used to prioritize identified opportunities in the adoption of cloud manufacturing. A consistency ratio to identify whether the results obtained are robust and consistent is obtained for the validation. For the stepwise application of this method, the flowchart is displayed in Figure 1. AHP can be applied to many sectors in the industry for selection making, decision making, and prioritization [35]. Hu et al. (2019, 2020) used it in the selection of manufacturers in cloud manufacturing [36, 37]. Sevinc et al. (2018) used to solve issues SMEs face transitioning to Industry 4.0. Mian et al. (2020) applied SWOT-AHP to quantify and rank the opportunities and challenges for sustainability education in Industry 4.0. While Metin Da˘gdeviren (2008) used the AHP–PROMETHEE integrated approach for decision making in equipment selection [38-40]. Prioritization of challenges to Industry 4.0 for the supply chain is obtained with the help of AHP [41]. The cloud manufacturing concept is quite new so finding experts in this field is difficult; however, a total of 30 experts from the industry and academics (10 industrialists, 10 mechanical engineering academicians, 6 computer science academicians, and 4 industrial engineering academicians) were used for this study. After discussion, a total of 8 opportunities were finalized and detailed questionnaires (Appendix-1) were sent to the experts for filling. After collecting the responses, an average was obtained to get the final average pairwise matrix.

Steps to apply the AHP approach are as follows:

Step 1: Develop a structural hierarchy

Step 2: Develop an average pairwise comparison matrix

Experts were asked to fill the survey questionnaires where they have to do a pairwise comparison of attribute i with attribute j on a scale of 1, 3,5,7,9. Then all questionnaire matrices are collected and the average matrix Aij is obtained.

$$Aij= \begin{bmatrix} a_{11} \ldots\ldots a_{1j} \ldots\ldots\ldots\ldots a_{1n} \\ a_{i1} \ldots\ldots\ldots a_{ij} \ldots\ldots\ldots\ldots a_{1j} \\ a_{n1} \ldots\ldots\ldots a_{nj} \ldots\ldots\ldots .a_{nn} \end{bmatrix}$$

Step 3: Develop normalized decision matrix

$$cij= aij / \sum_{j=1}^{n} aij \tag{1}$$

where i=1,2,3,4……. n and j=1,2,3,4…………. n

Step 4: Develop weighted normalized decision matrix

$$w_i = \sum_{j=1}^{n} cij \quad \text{where i=1,2,3,4……. N} \tag{2}$$

Step 5: Calculate eigenvector and row matrix

$$E = N^{th} \text{ rootvalue } / N^{th} \text{ rootvalue} \tag{3}$$

$$\text{Row matrix} = \sum_{j=1}^{n} aij * ej1 \tag{4}$$

Step 6: Calculate the maximum eigenvalue, λ_{max}.

$$\lambda_{max} = \text{Rowmatrix} / E \tag{5}$$

Step 7: Obtain the Consistency Index (CI) and Consistency Ratio (CR).

$$CI= (\lambda_{max} - n)/ (n-1) \tag{6}$$

$$CR=CI/RI \tag{7}$$

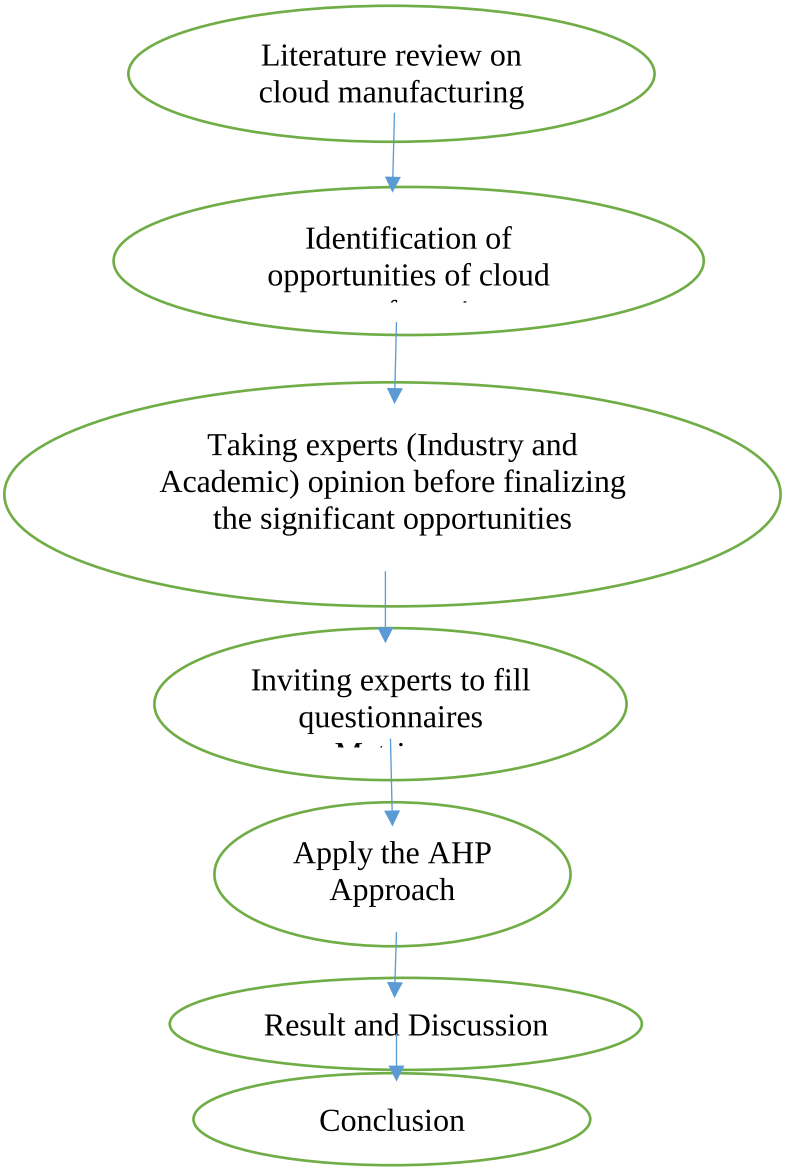

Fig. 1. Research methodology flowchart

Tab. 2.

Random Index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.85	0.9	1.12	1.24	1.32	1.41	1.45	1.51

Where n and RI denote the order of matrix and Randomly Generated Consistency Index, respectively.

4. RESULTS AND DISCUSSION

This section discusses the prioritization of opportunities and the consistency of results obtained. The consistency ratio is obtained for the validation of the result. After averaging all the individual matrices obtained from the experts, a final average pairwise comparison matrix is obtained followed by the procedure of the AHP approach given in section 3. For all calculation purposes, the matrices are linked in Microsoft Excel to obtain error-free and accurate results.

After the average pairwise comparison matrix is obtained for opportunities as shown in Table 3, normalization is done to get the normalized decision matrix (Table 4). Thereafter, further steps are followed regarding the AHP approach to obtain a weighted normalized decision matrix (Table 5) for weights of opportunities. Finally, ranking is done based on weights obtained (Table 6).

For the final result obtained, Cost-efficient (O_3) has the highest positive value; therefore, it is the most critical opportunity in this category. Pay-per-use (O_1), Scalability (O_2), and Flexibility (0_4) secured the 2nd, 3rd, and 4th places, respectively, in the category as per their weights obtained. Low-risk Backup and Recovery (O_6) and Low Startup Cost (O_7) are ranked 5th and 6th; however, since the differences in weights are very less so they can be assumed at the same level if required. Location Independence (O_8) factor obtained the lowest weight and is ranked 8th among all. All the above rankings are shown in Table 6.

Table 7 is used to calculate the consistency ratio. The obtained value of λmax (Table 7) and random index (Table 2) is finally used to calculate the value of Consistency Ratio (CR). The obtained value of CR is .07, which is less than .10, implying that the result is accurate and consistent.

Tab. 3.

Average pairwise comparison matrix

	O_1	O_2	O_3	O_4	O_5	O_6	O_7	O_8
O_1	1.00	1.67	0.29	3.00	6.33	5.00	5.00	6.33
O_2	0.78	1.00	0.29	3.00	5.00	3.00	3.00	6.33
O_3	3.67	3.67	1.00	3.67	5.67	5.00	5.00	6.33
O_4	0.33	0.33	0.33	1.00	3.00	3.00	3.00	5.67
O_5	0.16	0.20	0.20	0.33	1.00	0.29	0.29	3.00
O_6	0.20	0.33	0.20	0.33	3.67	1.00	1.67	3.00
O_7	0.20	0.33	0.20	0.33	3.67	0.78	1.00	3.00
O_8	0.16	0.15	0.15	0.20	0.33	0.33	0.33	1.00

Tab. 4.

Normalized decision matrix

	O_1	O_2	O_3	O_4	O_5	O_6	O_7	O_8
O_1	0.154	0.217	0.108	0.253	0.221	0.272	0.259	0.183
O_2	0.119	0.130	0.108	0.253	0.174	0.163	0.156	0.183
O_3	0.564	0.478	0.377	0.309	0.198	0.272	0.259	0.183

O_4	0.051	0.043	0.125	0.084	0.105	0.163	0.156	0.163
O_5	0.025	0.026	0.075	0.028	0.035	0.016	0.015	0.087
O_6	0.031	0.043	0.075	0.028	0.128	0.054	0.086	0.087
O_7	0.031	0.043	0.075	0.028	0.128	0.042	0.052	0.087
O_8	0.025	0.019	0.055	0.017	0.012	0.018	0.017	0.029

Tab. 5.

Weighted normalized decision matrix

	O_1	O_2	O_3	O_4	O_5	O_6	O_7	O_8	Weighted sum value	Weight
O_1	0.154	0.217	0.108	0.253	0.221	0.272	0.259	0.183	1.667	0.2084
O_2	0.119	0.130	0.108	0.253	0.174	0.163	0.156	0.183	1.287	0.1609
O_3	0.564	0.478	0.377	0.309	0.198	0.272	0.259	0.183	2.640	0.3300
O_4	0.051	0.043	0.125	0.084	0.105	0.163	0.156	0.163	0.889	0.1112
O_5	0.025	0.026	0.075	0.028	0.035	0.016	0.015	0.087	0.306	0.0383
O_6	0.031	0.043	0.075	0.028	0.128	0.054	0.086	0.087	0.532	0.0665
O_7	0.031	0.043	0.075	0.028	0.128	0.042	0.052	0.087	0.486	0.0607
O_8	0.025	0.019	0.055	0.017	0.012	0.018	0.017	0.029	0.192	0.0240

Tab. 6.

Ranking matrix

	Weight	Rank
O_1	0.2084	2
O_2	0.1609	3
O_3	0.3300	1
O_4	0.1112	4
O_5	0.0383	7
O_6	0.0665	5
O_7	0.0607	6
O_8	0.0240	8

Tab. 7.

Calculation of consistency

	O_1	O_2	O_3	O_4	O_5	O_6	O_7	O_8	Weighted value (WV)	Weight (W)	R=WV/W
O_1	1.00	1.67	0.29	3.00	6.33	5.00	5.00	6.33	1.92	0.2084	9.231725
O_2	0.78	1.00	0.29	3.00	5.00	3.00	3.00	6.33	1.46	0.1609	9.096636
O_3	3.67	3.67	1.00	3.67	5.67	5.00	5.00	6.33	3.10	0.3300	9.391174
O_4	0.33	0.33	0.33	1.00	3.00	3.00	3.00	5.67	0.97	0.1112	8.754888
O_5	0.16	0.20	0.20	0.33	1.00	0.29	0.29	3.00	0.31	0.0383	8.092786
O_6	0.20	0.33	0.20	0.33	3.67	1.00	1.67	3.00	0.57	0.0665	8.555815
O_7	0.20	0.33	0.20	0.33	3.67	0.78	1.00	3.00	0.51	0.0607	8.468272
O_8	0.16	0.15	0.15	0.20	0.33	0.33	0.33	1.00	0.21	0.0240	8.595446

λmax=8.77 RI=1.41

CI= (8.77-8)/7 = .11 CR=.11/1.41= .07

In the values obtained above, λmax is the eigenvalue of the final matrix obtained from Table 7. RI is a random index obtained from Table 2 as the number of factors is 8, thus corresponding to the number 8 value, 1.41, is taken for calculation. Consistency index (CI) is obtained by applying equation 6. Finally, CR is the ratio of consistency index to random index, which signifies how much the observed values and the calculated values are related, and by applying equation 7 and it came out to .07, which means the observed value is very close to the calculated value, so the result obtained is accurate.

As costs remain the most important criteria for almost all the manufacturing systems, therefore, from the result obtained in section 4, Cost-efficient (O_3) emerged as the most critical opportunity in this category. While Pay-per-use (O_1) became the next most important opportunity as paying heavy amounts at one time for small or medium scale industries is critical; therefore, the facility to pay as per requirement attracts them. Scalability (O_2), the facility of scaling where the user can scale (up or down) the use of resources according to his needs secured the 3rd place. Flexibility (0_4), the ability to adapt and respond to the changing customer demands secured the 4th place. Lastly, the Location Independence (O_8) factor is the least important criterion on the list.

5. CONCLUSION

To provide easy decision-making for entrepreneurs for the adoption of cloud manufacturing, opportunities are identified and prioritization of these parameters is obtained. Identification of these opportunities was obtained by experts' opinions and a survey was conducted to get raw data from experts from different fields, namely, industrial, computer, and mechanical and also from professions such as the academics and the industry to obtain the ranking using the MDCM method. Identified opportunities in the context of cloud manufacturing are, namely pay-as-use, scalability, cost efficiency, flexibility, autonomy, low-risk backup and recovery, low startup cost, and location independence. With the application of AHP on data obtained from the survey, weights are calculated and ranking is obtained. Results show that cost efficiency is the biggest opportunity in the adoption of cloud manufacturing. Furthermore, the calculated consistency ratio for opportunities is .07, which is less than .10, indicating accuracy and consistency of results. Cloud manufacturing process originated in China and spread to countries like Japan, the U.S, Canada, Germany, France Russia, and some countries in Latin America. This study provides prior information regarding the significant factors of the process to entrepreneurs of developing countries, especially for small-scale industries for easy and smooth adoption of the cloud manufacturing process. Conclusively, process cost efficiency, scalability, and pay-as-use qualities would surely attract new industrialists for its setup in developing countries.

References

1. Gunasekaran Angappa. 1999. "Agile manufacturing: a framework for research and development". *International journal of production economics* 62(1-2): 87-105.
2. Sindhwani Rahul, Vasdev Malhotra. 2017. "A framework to enhance agile manufacturing system: a total interpretive structural modelling (TISM) approach". *Benchmarking: An International Journal*.
3. Cheng Yang, Sami Farooq, John Johansen. 2011. "Manufacturing network evolution: a manufacturing plant perspective". *International Journal of Operations & Production Management*.
4. Cheng Tao, Jie Zhang, Chunhua Hu, Bo Wu, Shuzi Yang. 2001. "Intelligent machine tools in a distributed network manufacturing mode environment". *The International Journal of Advanced Manufacturing Technology* 17(3): 221-232.
5. Fan Yushun, Dazhe Zhao, Liqin Zhang, Shuangxi Huang, Bo Liu. 2003. "Manufacturing grid: needs, concept, and architecture". In: *International conference on grid and cooperative computing*: 653-656. Springer, Berlin, Heidelberg.
6. Tao Fei, Ye Fa Hu, Zu De Zhou. 2008. "Study on manufacturing grid & its resource service optimal-selection system". *The International Journal of Advanced Manufacturing Technology* 37(9): 1022-1041.
7. Shukla Chetan, Michelle Vazquez, Frank Chen. 1996. "Virtual manufacturing: an overview". *Computers & Industrial Engineering* 31(1-2): 79-82.
8. Lee Wing Bun, Chi Fai Cheung, J. G. Li. 2001."Applications of virtual manufacturing in materials processing". *Journal of materials processing technology* 113(1-3): 416-423.
9. Guo Nannan, Ming C. Leu. 2013. "Additive manufacturing: technology, applications and research needs". *Frontiers of mechanical engineering* 8(3): 215-243.
10. Wong Kaufui V., Aldo Hernandez. 2012. "A review of additive manufacturing". *International scholarly research notices* 2012.
11. Kusiak Andrew. 2018. "Smart manufacturing". *International Journal of Production Research* 56(1-2): 508-517.
12. Wang Jinjiang, Yulin Ma, Laibin Zhang, Robert X. Gao, Dazhong Wu. 2018. "Deep learning for smart manufacturing: Methods and applications". *Journal of manufacturing systems* 48: 144-156.

13. Mell Peter, Tim Grance. 2011. "The NIST definition of cloud computing". Recommendations of the National Institute of Standards and Technology. NIST National Institute of Standards and Technology U.S. Department of Commerce. *Special Publication 800-145.*
14. Gibson Joel, Robin Rondeau, Darren Eveleigh, Qing Tan. 2012. "Benefits and challenges of three cloud computing service models". In: *2012 Fourth International Conference on Computational Aspects of Social Networks (CASoN)*: 198-205. IEEE.
15. Xu Xun. 2012. "From cloud computing to cloud manufacturing". *Robotics and computer-integrated manufacturing* 28(1): 75-86.
16. Ghomi Einollah Jafarnejad, Amir Masoud Rahmani, Nooruldeen Nasih Qader. 2019. "Cloud manufacturing: challenges, recent advances, open research issues, and future trends". *The International Journal of Advanced Manufacturing Technology* 102(9): 3613-3639.
17. Narwane Vaibhav S., Balkrishna E. Narkhede, Bhaskar B. Gardas, Rakesh D. Raut. 2019. "Cloud manufacturing issues and its adoption: past, present, and future". *International Journal of Management Concepts and Philosophy* 12(2): 168-199.
18. Issues and its adoption: past, present, and future. *International Journal of Management Concepts and Philosophy* 12(2): 168-199.
19. AbubakarA. D., Julian M. Bass, Ian Allison. 2014. "Cloud computing: Adoption issues for sub-saharan African SMEs". *The Electronic Journal of Information Systems in Developing Countries* 62(1): 1-17.
20. Huang Biqing, Chenghai Li, Chao Yin, Xinpei Zhao. 2013. "Cloud manufacturing service platform for small-and medium-sized enterprises". *The International Journal of Advanced Manufacturing Technology* 65(9): 1261-1272.
21. Zhang Zhenjie, Yuanming Zhang, Jiawei Lu, Fei Gao, Gang Xiao. 2020. "A novel complex manufacturing business process decomposition approach in cloud manufacturing". *Computers & Industrial Engineering* 144: 106442.
22. Abd Rahman, M.N., B. Medjahed, E. Orady, M.R. Muhamad, R. Abdullah, A.S.M. Jaya. 2018. "A review of cloud manufacturing: Issues and opportunities". *Journal of Advanced Manufacturing Technology (JAMT)* 12(1): 61-76.
23. Fisher Oliver, Nicholas Watson, Laura Porcu, Darren Bacon, Martin Rigley, Rachel L. Gomes. 2018. "Cloud manufacturing as a sustainable process manufacturing route". *Journal of manufacturing systems* 47: 53-68.
24. Jula Amin, Elankovan Sundararajan, Zalinda Othman. 2014. "Cloud computing service composition: A systematic literature review". *Expert systems with applications* 41(8): 3809-3824.
25. Adamson Göran, Lihui Wang, Magnus Holm, Philip Moore. 2017. "Cloud manufacturing–a critical review of recent development and future trends". *International Journal of Computer Integrated Manufacturing* 30(4-5): 347-380.
26. Xu X. "Cloud manufacturing: A new paradigm for manufacturing businesses". 2013. *Australian Journal of Multi-Disciplinary Engineering* 9(2): 105-116.
27. Wang Peng, Robert X. Gao, Zhaoyan Fan. 2015. "Cloud computing for cloud manufacturing: benefits and limitations". *Journal of Manufacturing Science and Engineering* 137(4).
28. Tao Fei, Lin Zhang, V. C. Venkatesh, Y. Luo, Ying Cheng. 2011. "Cloud manufacturing: a computing and service-oriented manufacturing model". *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture* 225(10): 1969-1976.

29. Marston Sean, Zhi Li, Subhajyoti Bandyopadhyay, Juheng Zhang, Anand Ghalsasi. 2011. "Cloud computing—The business perspective". *Decision support systems* 51(1): 176-189.
30. Wang Xi Vincent, Xun W. Xu. "An interoperable solution for cloud manufacturing". 2013. *Robotics and computer-integrated manufacturing* 29(4): 232-247.
31. Agrawal Divyakant, Amr El Abbadi, Sudipto Das, Aaron J. Elmore. "Database scalability, elasticity, and autonomy in the cloud". 2011. In: *International Conference on Database Systems for Advanced Applications*: 2-15. Springer, Berlin, Heidelberg.
32. Zhao Chun, Xiao Luo, Lin Zhang. "Modeling of service agents for simulation in cloud manufacturing". 2020. *Robotics and Computer-Integrated Manufacturing* 64: 101910.
33. Wattal Suneel, Ajay Kumar. 2014. "Cloud computing-an emerging trend in information technology". In: *2014 international conference on issues and challenges in intelligent computing techniques (ICICT)*: 168-173. IEEE.
34. Zissis Dimitrios, Dimitrios Lekkas. 2012. "Addressing cloud computing security issues". *Future Generation computer systems* 28(3): 583-592.
35. Saaty Thomas L. 1994. "How to make a decision: the analytic hierarchy process". *Interfaces* 24(6): 19-43.
36. Hu Yanjuan, Feifan Zhu, Lin Zhang, Yongkui Lui, Zhanli Wang. 2019. "Scheduling of manufacturers based on chaos optimization algorithm in cloud manufacturing". *Robotics and Computer-Integrated Manufacturing* 58: 13-20.
37. Hu Yanjuan, Lizhe Wu, Chao Shi, Yilin Wang, Feifan Zhu. 2020. "Research on optimal decision-making of cloud manufacturing service provider based on grey correlation analysis and TOPSIS". *International Journal of Production Research* 58(3): 748-757.
38. Sevinc Ali, Şeyda Gür, Tamer Eren. 2018. "Analysis of the difficulties of SMEs in industry 4.0 applications by analytical hierarchy process and analytical network process". *Processes* 6(12): 264.
39. Mian Syed Hammad, Bashir Salah, Wadea Ameen, Khaja Moiduddin, Hisham Alkhalefah. 2020. "Adapting universities for sustainability education in industry 4.0: Channel of challenges and opportunities". *Sustainability* 12(15): 6100.
40. Dağdeviren, Metin. 2008. "Decision making in equipment selection: an integrated approach with AHP and PROMETHEE". *Journal of intelligent manufacturing* 19(4): 397-406.
41. Luthra Sunil, Sachin Kumar Mangla. 2018. "Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies". *Process Safety and Environmental Protection* 117: 168-179.

APPENDIX-1

Survey questionnaire (to be filled by experts)

You are supposed to compare two opportunities at a time (that is, in pairs). The scores of comparisons are 1, 3, 5, 7, 9. Scores are assigned as:

Equal importance	1
Moderate importance	3
Strong importance	5
Very strong importance	7
Extreme importance	9

For example, if you are comparing opportunity (O_1) of a row with opportunity (O_2) of the column and assigned value **5**, it means that opportunity O_1 is of strong importance than opportunity O_2.

NOTE: No need to fill cells with value 1.

Opportunities in the espousal cloud manufacturing

		Opportunities in column i								
Opportunities in row i		0_1	0_2	0_3	0_4	0_5	0_6	0_7	0_8	0_9
	0_1	1								
	0_2		1							
	0_3			1						
	0_4				1					
	0_5					1				
	0_6						1			
	0_7							1		
	0_8								1	
	0_9									1

Table 1

No	**Opportunities**
O_1	Pay-per-use or Instant service
O_2	Scalability
O_3	Cost efficiency
O_4	Flexibility
O_5	Autonomy
O_6	Low-risk backup and recovery
O_7	Low startup cost
O_8	Location independence

Received 15.02.2022; accepted in revised form 30.03.2022