INNOVATIONS IN BUSINESS AND STRATEGIC MANAGEMENT
2023, VOL. 1, ISSUE 1, pp. 12-16
https://doi.org/10.61577/ibsm.2023.100003

RESEAPRO JOURNALS

SHORT COMMUNICATION

OPEN ACCESS

The place of strategies in cyber-physical transformation of manufacturing companies

Bożena Gajdzik

Department of Industrial Informatics, Silesian University of Technology, Poland

ABSTRACT

The concept of Industry 4.0 has been with us for more than a decade. The idea for the concept called 'Industrie 4.0' came from the German government's High Tech Strategy project and was first used at the International Hannover Messe in 2011. The year 2013 was considered the beginning of the new industrial concept, at which time the final report of a working group operating in Germany to prepare, among other things, recommendations for smart industry was published [1]. In order to be implemented by companies, the concept must be embedded in their development strategies. The provision for cyber-physical transformation in development strategies will be relevant for decades to come. Large manufacturers are already making investments in the direction of smart manufacturing. These manufacturers include the world's largest steel producers. Manufacturing is moving towards smart production; maybe in a decade or two, the largest manufacturers of industrial products will be smart factories. The purpose of the research is to accept the place of the new development concept in the strategy of companies. Manufacturing companies that join Industry 4.0 should note this fact in their development strategies. The strategic goal(s) aimed at Industry 4.0 in manufacturing companies facilitate the various organizational divisions to implement new technologies, initially in the form of islands, and over time towards cyber-physical production systems (CPSs). Only CPSs can create smart factories, but in order to achieve this strategic goal, it is already necessary to record in the strategy that the company is investing in smart solutions. This paper provides an introduction to emphasize the importance of companies' strategies in building CPSs.

KEYWORDS

Strategy; Cyber-physical production system (CPS); Smart factory; Industry 4.0

ARTICLE HISTORY

Received 3 July 2023; Revised 25 September 2023; Accepted 3 October 2023

Introduction

Increasingly, smart manufacturing, based on the technologies of the fourth industrial revolution, is a development objective of industrial market leaders. This revolution ushered in the development of machines and equipment capable of autonomously exchanging data and learning by collecting data. Industry 4.0, as the concept of industrial development based on the technologies of the Fourth Industrial Revolution is called, is turning factories into smart factories [2]. Such factories are based on cyber-physical systems that use the Industrial internet of things (IoT), sensors, collaborative robots, computer prediction, mobile devices, the cloud, and other technologies that are considered innovations of the Fourth Industrial Revolution [3-5]. Planning for a smart factory requires a broader view, and it is helpful to know the trends that will influence the market as well as the directions set by policy over the next few decades. A strategic approach to the cyber-physical transformation of industry is a condition for change. The strategy begins the process of building cyber-physical systems (CPSs) in manufacturing companies. Lee et al. described the architecture of cyber-physical systems and pointed out the technological changes [6]. Without the prominence of Industry 4.0 technologies in company strategies, it is more difficult for these companies to realize these changes. This paper presents the importance of strategy in building CPS for manufacturing companies. It poses the questions that most often occur at the stage of strategic analysis and shares its own research carried out in the steel segment in Poland about the importance of Industry 4.0 technology in the strategic development of steel producers.

The Place of Strategies in Cyber-Physical Transformation of Manufacturing Companies

Each company that is serious about cyber-physical transformation should begin its journey of change with a development strategy. The strategy is the first and most important document of the ongoing industrial transformation. Developing a strategy for the transformation of a factory to Industry 4.0 requires the preparation of a number of IT and computer solutions that will improve production processes on the basis of the data collected. Manufacturing technologies are also changing and becoming more autonomous [7,8]. The new type of industry integrates people and digitally controlled machines with the internet and information technologies, and the whole is connected in a global network. Materials produced or used in production can always be identified, and they also have the ability to communicate independently with each other [6,9]. The technologies used by factories can be divided into four groups. The first includes those technologies that connect producers to the outside world. They are not primarily a source of information but are more of a source of specific activities. The second includes classic IT technologies that transform

***Correspondence:** Dr. Bożena Gajdzik, Department of Industrial Informatics, Silesian University of Technology, Poland, e-mail: Bozena.Gajdzik@polsl.pl

collected data into usable information. The third group includes operational technologies related to production in industries. In this group are: additive manufacturing, including 3D printing, robots, sensors, etc. The fourth group includes new technologies used in the value chain (blockchain, LCA). The four groups of technologies are being implemented continuously (long-term of changes) along with technological advances. The first group of technologies-communication technologies-appeared in Industry 3.0 and are constantly being developed (new computer-IT applications, more Internet users, new mobile devices). The development of the second group of technologies also began in the Third Industrial Revolution. According to Kagermann, digitalization appeared in Industry 3.0, and in Industry 4.0, it was considered the basis for developing Industry 4.0 [10]. The third and fourth groups of technologies are innovations of the Fourth Industrial Revolution as well as pillars of smart technologies. The technologies of the Third and Fourth Industrial Revolutions complement each other and form the pillars of Industry 4.0. In papers and reports are described different configurations of Industry 4.0 pillars with their respective technologies or technological features [8,11-17]. The main pillars of Industry 4.0 are: IoT and Internet of Services, big data with analytics, advanced simulation, cloud computing, universal integration, augmented reality, additive manufacturing, including 3D printing, artificial intelligence (AI) and learning machines, autonomous robots, cognitive computing, and cyber security [12,13,17].

By implementing new technologies, a company turns into a network of the industrial IoT, which brings together operational, IT, and cyber-physical systems. This whole thing is to be adapted to operate on platforms that are a combination of company-owned and industrial IoT. Factories (producers) that want to build Industry 4.0 are already investing in technologies that link digital and material production into cyber-physical production systems. The concept of Industry 4.0 is very much about the possibility of fusing (combining) or, as Peters said, 'marrying' two perspectives: cyber (smart sensors, mobile interfaces, computer analytics, autonomous process control systems, etc.), physical (high technology: full automation, intelligent robots, incremental technologies, etc.) [18]. The cyber-physical transformation of factories concerns all technological areas, and Industry 4.0 is nothing less than an attempt to consolidate them. In order for this consolidation to be realized, a development strategy is needed as a document that pins together the company's goals. The mission and vision should include a provision for a new strategic direction. According to Matt et al., digital transformation strategy is strongly linked to corporate strategy, which in turn sets operational and functional directions [19]. Operational strategy is connected with products, markets, processes, and networks, and functional strategy is connected with financial, IT, HR, etc. Ghobakhloo proposed six levels of strategy in companies targeting Industry 4.0: (i) strategic management, (ii) marketing strategy, (iii) human resources strategy, (iv) IT maturity strategy, (v) smart manufacturing strategy, and (vi) smart supply chain management strategy [20].

There is no universal path for implementing smart manufacturing strategies because the smart manufacturing environment is constantly improving. Various models used to measure readiness for Industry 4.0 have been presented, such as the commonly emphasized models developed by the National Academy of Science and Engineering (Acatech) [21] and the University of Warwick [22], as well as some other models [23-29]. Maturity models consider strategy as a road map for the planning of Industry 4.0 activities in an enterprise [20,29]. The development strategy starts with an analysis of the manufacturer's current and future situation on the market. Based on the strategic analysis, the organizations answer some questions. Here are some questions: What are the strengths, weaknesses, opportunities, and threats to planning company activities in Industry 4.0? What pillars of Industry 4.0 are needed for smart manufacturing in the company? How can the pillars of Industry 4.0 be transformed to improve production, but also, more broadly, the entire business (small steps or big steps)? Is the company's current offering sufficiently competitive in terms of the technological possibilities of Industry 4.0? Is its vision of development on the basis of Industry 4.0 technology consistent with the strategies of consumer markets in the areas of communication and collaboration and, above all, in the personalization of products? What direction should be developed to meet new customer needs? The list of questions is open-ended and grows longer as we go deeper and deeper into the strategy of building smart manufacturing. However, the factory in the cyber-physical transformation must go beyond the company and bet on the personalization of products. In sectors where the technology life cycle is counted in decades (steel, mining, and the energy industry), changes are slower than in consumer goods sectors (clothing, shoes, cars, and household appliances). Consumer markets are increasingly involved in product prototyping and production planning [30,31].

Before strategic investments in factories are made, a very sound technology audit must be realized. The technological audit assesses the technological potential of the company, together with the procedures in place and the investment needs. Data on machinery must be complemented with data on computer systems that link processes through access to data, which is the key to speed of decision-making [32]. The technological audit should provide answers to the following questions: What manufacturing technologies and computer systems does the company have? What is the phasing of technology by life cycle? What are the opportunities for the factory to invest in new technologies? What technologies are considered key to business development? What are the areas of possible application of technological innovations in the factory? What benefits can be expected from the implementation of technological changes? To get answers to the following questions, a benchmarking analysis should be added to the factory's technology audit. What innovations have competitors introduced? What business benefits have been achieved by the company that created the 'smart' bet, which is the industry leader? Is industry innovation forward-looking? What technologies are in the testing phase in the industry (TRL levels)? When will the technologies being tested be commercial? [30]

In the stage of analyzing the situation, companies can make use of available technological platforms and statistical databases, e.g., on the type of sectoral innovations, investment expenditures, the level of digitization of sectors, the degree of automation and robotization of industries, and studies on tested technologies (studies posted on Industry 4.0 portals and from international databases, e.g., EPO, Eurostat, and

https://doi.org/10.61577/ibsm.2023.100003

RESEAPRO JOURNALS

WIPO, as well as from reports of national and foreign governmental institutions, including thematic reports developed by the European Commission).

After the analysis, companies can proceed to implement plans. Implementation of strategic goals is spread over years. Gajdzik et al. cited timelines for the implementation of companies' transformation strategies in Industry 4.0 [30]. Implementing transformation strategies for Industry 4.0, in the core part of the changes, means investing in new technologies that will create, in the future, cyber-physical systems. Companies are starting their transformation to Industry 4.0 with pilot and core projects. The first projects are planned for a period of 3 to 5 years [30]. The results of the first projects are validated by learning mechanisms. Many authors have described roadmapping for strategy in their publications [33-37]. The implementation of Industry 4.0 strategy in companies, in addition to technological innovation, is based on many organizational, process, chain, and personnel changes (reorganization of the human factor) [36,38,39]. According to Erol et al., there are three stages for Industry 4.0 transformation are met: first stage: envision (common understanding of Industry 4.0 and company-specific Industry 4.0 vision); second stage: enable (road mapping of Industry 4.0 strategy) and identification of internal and external success factors); third stage: enact (preparation of transformation and proposal of Industry 4.0 projects) [40].

The path for companies to reach Industry 4.0 is long and branching. A decade after the emergence of Industry 4.0 concept, the European Commission proposed the next level of development called Industry 5.0 [41], followed by another concept that is already called Industry 6.0 [42]. Industry 5.0, according to the EC document [41], is based on a sustainable, human-centric and resilient, and Industry 6.0 will be developed in the direction of hyper-connecting industries to industries, highly mass customization, highly mass personalization of services and products with the attachment of a dynamic supply chain management concept, and highly customized class- one lot size thinking where all the information can drift all across the countries [43]. Deep and speedy changes mean that companies must constantly keep track of changes in the environment and update strategic directions for transformation.

To summarize the scientific arguments carried out, the author of this publication proposed a model for the strategic transformation of companies in their activities in Industry 4.0. The model, presented in Figure 1, is illustrative and indicates the place of strategy in the cyber-physical transformation of enterprises under the conditions of the popularized concept of Industry 4.0. At the input to the model are the pillars of Industry 4.0, and at the output are cyber-physical systems—smart factories—that operate in agile supply chains. The strategy focuses on business processes with Industry 4.0 initiatives of the company [44,45].

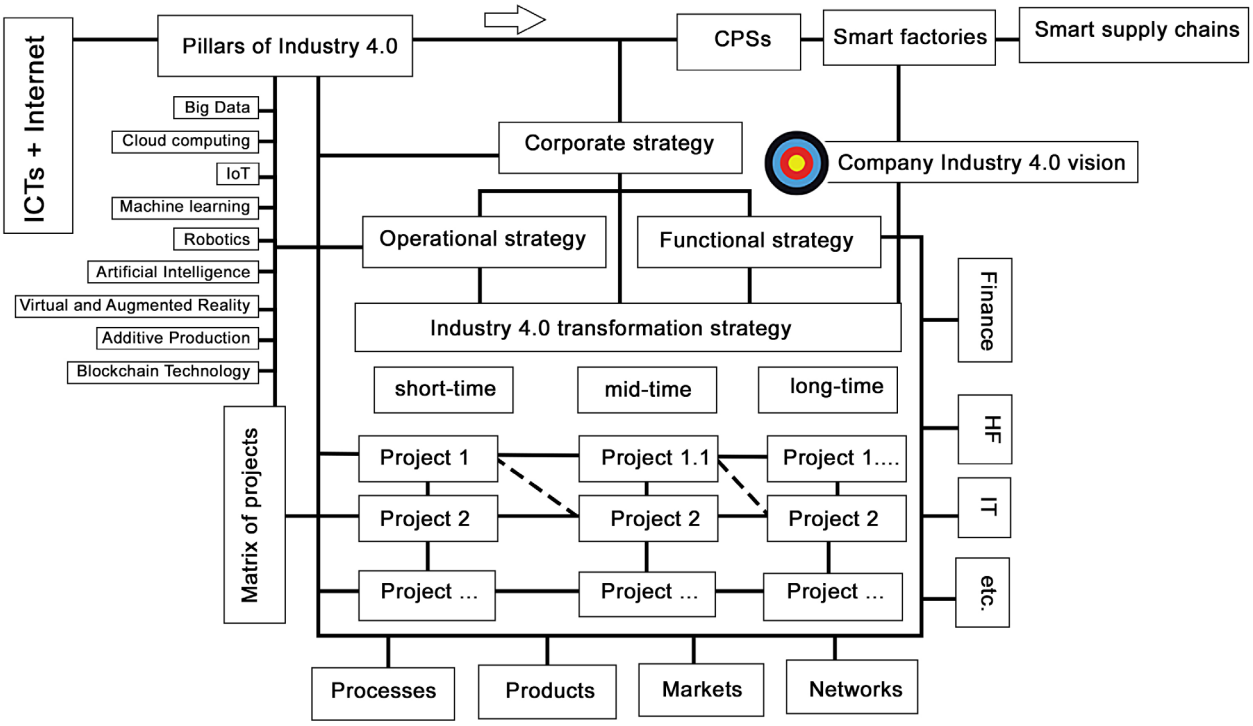

Figure 1. The place of strategies in cyber-physical transformation of manufacturing companies [45].

https://doi.org/10.61577/ibsm.2023.100003

Conclusions

Strategy is the most important business development document. In the transformation taking place, factories should already be writing directions for change into their strategies. The development strategy being developed in light of the Industry 4.0 concept should include objectives for systems integration and global networking based on optimizing the company's business processes and the capabilities of Fourth Industrial Revolution technology. Strategic planning, in particular, enables the creation of a strategic roadmap that can serve as a plan on how to successfully implement Industry 4.0 in organizations. In conclusion, strategic planning is changing with the development of companies and the dynamics of their environment. Strategic management in the new conditions of Industry 4.0 must be more agile than before and more open to the environment. The next solutions to smart innovations enter production technologies, market expansion, supply chain, product lifecycle, workplaces, etc. The developed implementation plan should include guidelines for key changes in the factory to be carried out in order to achieve rapid development effects in Industry 4.0. The strategy begins the changes towards CPSs in manufacturing companies. Without the prominence of Industry 4.0 technologies in company strategies, it is more difficult for these companies to realize change. This paper shows the importance of strategy in building CPSs in industrial markets.

Disclosure statement

No potential conflict of interest was reported by the author.

References

1. German high-tech strategy. https://stip-pp.oecd.org/moip/case-studies/1?answerId=A2-1
2. Schwab K. The Fourth Industrial Revolution. Cologny: World Economic Forum, Switzerland 2016.
3. Kagermann H, Wahlster W, Helbig J. (Eds.) Recommendations for implementing the strategic initiative Industrie 4.0: final report of the Industrie 4.0 working group. In Industrie 4.0: Mit Dem Internet Der Dinge Auf Dem Weg Zur 4 Industriellen Revolution; VDI-Nachrichten: Germany, Frankfurt; 2011.
4. Hermann M, Pentek T, Otto B. Design principles for Industrie 4.0 scenarios: a literature review, working paper no. 01/2015; Technische Universität Dortmund, 2015.
5. Lasi H, Fettke P, Kemper HG, Feld T, Hoffmann M. Industry 4.0. Bus Inf Syst Eng. 2014;6(4):239-242.
6. Lee J, Bagheri B, Kao HA. A cyber-physical systems architecture for industry 4.0-based manufacturing systems. Manuf Lett. 2015;3:18-23.
7. McKinsey I. 4.0 How to navigate digitization of the manufacturing sector. Detroit, Michigan, USA. 2015.
8. Burrell D. Principles of Industry 4.0 and the 9 Pillars. Available online: https://www.plextek.com/industry-4-0-and-the-9-pillars/
9. Liu Y, Peng Y, Wang B, Yao S, Liu Z. Review on cyber-physical systems. IEEE CAA J Autom Sin. 2017;4(1):27-40.
10. Kagermann H. Change through digitization—value creation in the age of Industry 4.0. In: Albach H, Meffert H, Pinkwart A, Reichwald R (Eds.). Management of Permanent Change, Springer, Heidelberg, 2015, 23-45.
11. Erboz G. How to define industry 4.0: main pillars of industry 4.0. Managerial trends in the development of enterprises in globalization era. 2017;761:761-767.
12. Senn C. The nine pillars of Industry 4.0, online: https://www.idashboards.com/blog/2019/07/31/the-pillars-of-industry-4-0/ (7th February, 2019).
13. Sniderman B, Mahto M, Cotteleer MJ. Industry 4.0 and manufacturing ecosystems Exploring the world of connected enterprises. Deloitte Consulting. 2016;1:3-14. https://www2.deloitte.com/content/dam/insights/us/articles/manufacturing-ecosystems-exploring-world-connected-enterprises/DUP_2898_Industry4.0ManufacturingEcosystems.pdf
14. Rüßmann M, Lorenz M, Gerbert P, Waldner M, Justus J, Engel P, et al. Industry 4.0: the future of productivity and growth in manufacturing industries. Boston Consulting Group. 2015;9(1):54-89.
15. Machado CG, Winroth MP, Ribeiro da Silva EH. Sustainable manufacturing in Industry 4.0: an emerging research agenda. Int J Prod Res. 2020;58(5):1462-1484.
16. Othman F, Bahrin MA, Azli N. Industry 4.0: a review on industrial automation and robotic. J Teknol. 2016;78(6-13):137-143.
17. Groumpos PP. A critical historical and scientific overview of all industrial revolutions. IFAC-PapersOnLine. 2021;54(13):464-471.
18. Peters H. Application of Industry 4.0 concepts at steel production from an applied research perspective, presentation at 17th IFAC Symposium on control, optimization, and automation in mining. Miner Metall Process. 2016;53.
19. Matt C, Hess T, Benlian A. Digital transformation strategies. Bus Inf Syst Eng. 2015;57:339-343.
20. Ghobakhloo M. The future of manufacturing industry: a strategic roadmap toward Industry 4.0. J Manuf Technol Manag. 2018;29(6):910-936.
21. Schuh G, Anderl R, Gausemeier J, Ten Hompel M, Wahlster W, editors. Industry 4.0 maturity index: shaping the digital transformation of companies. Herbert Utz Publishing; 2017.
22. Agca O, Gibson J, Godsell J, Ignatius J, Davies CW, Xu O. An Industry 4 readiness assessment tool; WMG-The University of Warwick: Coventry, UK, 2017. https://warwick.ac.uk/fac/sci/wmg/research/scip/reports/final_version_of_i4_report_for_use_on_websites.pdf
23. Castelo-Branco I, Cruz-Jesus F, Oliveira T. Assessing Industry 4.0 readiness in manufacturing: evidence for the European Union. Comput Ind. 2019;107:22-32.
24. Rauch E, Unterhofer M, Rojas RA, Gualtieri L, Woschank M, Matt DT. A maturity level-based assessment tool to enhance the implementation of industry 4.0 in small and medium-sized enterprises. Sustainability. 2020;12(9):3559.
25. Trotta D, Garengo P. Assessing industry 4.0 maturity: an essential scale for SMEs. In proceedings of the 2019 8th International Conference on Industrial Technology and Management (ICITM). 2019;pp.69-74.
26. Lin TC, Wang KJ, Sheng ML. To assess smart manufacturing readiness by maturity model: a case study on Taiwan enterprises. Int J Comput Integr Manuf. 2020;33(1):102-115.
27. Mittal S, Khan MA, Purohit JK, Menon K, Romero D, Wuest T. A smart manufacturing adoption framework for SMEs. Int J Prod Res. 2019;58(5):1555-1573.
28. Gajdzik B. Frameworks of the maturity model for industry 4.0 with assessment of maturity levels on the example of the segment of steel enterprises in Poland. J Open Innov Technol Mark Complex. 2022;8(22):77.
29. Schumacher A, Erol S, Sihn W. A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. Procedia Cirp. 2016;52:161-166.
30. Gajdzik B. Monograph 945. (The title in Polish) Diagnoza kierunków transformacji przemysłu stalowego w Przemyśle 4.0. Silesian University of Technology. Title in English: Diagnosis of the steel Industry transformation direction in the Industry 4.0. ISBN 978-83-7880-850-3. Silesian University of Technology, Gliwice. 2022:pp.468.
31. Gajdzik B, Grabowska S, Saniuk S. A theoretical framework for industry 4.0 and its implementation with selected practical schedules. Energies. 2021;14(4):940.
32. Dai J. Three essays on audit technology: audit 4.0, blockchain, and

https://doi.org/10.61577/ibsm.2023.100003

audit app. Newark, New Jersey, 2017. Available online: https://rucore.libraries.rutgers.edu/rutgers-lib/55154/PDF/1/play/
33. Garcia ML. Fundamentals of Technology Roadmapping, Sandia National Laboratories, 1998.
34. Phaal R, Farrukh CJP, Probert DR. Developing a technology roadmapping system. In A Unifying Discipline for Melting the Boundaries Technology Management. 2005;pp.99-111.
35. Moehrle MG. TRIZ-Based Technology Roadmapping, In: Moehrle M, Isenmann R, Phaal R. (Eds.). Technology Roadmapping for Strategy and Innovation. Springer, Berlin, Heidelberg. 2013;137-150.
36. Santos C, Mehrsai A, Barros AC, Araújo M, Ares E. Towards Industry 4.0: an overview of European strategic roadmaps. Procedia Manuf. 2017;13(1):972-979.
37. Kang HS, Lee JY, Choi S, Kim H, Park JH, Son JY, et al. Smart manufacturing: past research, present findings, and future directions. Int J of Precis Eng and Manuf-Green Tech. 2016;3(1):111-128.
38. Gajdzik B, Wolniak R. Influence of Industry 4.0 projects on business operations: literature and empirical pilot studies based on case studies in Poland. J Open Innov Technol Mark Complex. 2022;8(1):44.
39. Gajdzik B, Wolniak R. Smart production workers in terms of creativity and innovation: the implication for open innovation. J Open Innov Technol Mark Complex. 2022;8(2):68.
40. Erol S, Schumacher S, Sihn W. Strategic guidance towards Industry 4.0 – a three-stage process model. International conference on competitive manufacturing. 2016;9(1):pp.495-501.
41. Industry 5.0 Towards a sustainable, human centric and resilient European industry. European Commission, Brussels, Manuscript completed in January 2021, from https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/industry-50_en#documents (Document in Eng. 12 Nov., 2020).
42. Annanperä E, Jurmu M, Kaivo-oja J, Kettunen P, Knudsen M, Lauraéus T, et al. From Industry X to Industry 6.0 antifragile manufacturing for people, planet, and profit with passion. White Paper 5/2021. Business Finland Oy, Helsinki, Finland, from https://www.alliedict.fi/wp-content/uploads/2021/08/Industry-X-White-Paper-3.5.2021_Final.pdf
43. Chourasia S, Tyagi A, Pandey SM, Walia RS, Murtaza Q. Sustainability of Industry 6.0 in global perspective: benefits and challenges. Mapan. 2022;37(2):443-452.
44. Bonilla SH, Silva HR, Terra da Silva M, Franco Gonçalves R, Sacomano JB. Industry 4.0 and sustainability implications: a scenario-based analysis of the impacts and challenges. Sustainability. 2018;10(10):3740.
45. Gajdzik B, Štverková H. Frameworks of strategic management in Industry 4.0. In proceedings of the 15th International conference on strategic management and its support by information systems 2023, May 22-24, 2023, Ostrava, Czech Republic / Němec Radek , Chytilová Lucie (ed.), 2023, Ostrava, VŠB– Technical University of Ostrava, 72-85, ISBN 978-80-248-4687-3. https://dokumenty.vsb.cz/docs/files/cs/e1c37442-9c5c-460d-b296-cefb7ecce285

https://doi.org/10.61577/ibsm.2023.100003