Business Transformation Powered by Knowledge Management in the Context of Corporate Sustainability

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Abstract: The economic objectives in the different stages of the development of industrial era enterprises were operationalised by changing paradigms. After the industrial revolution and mass production stages, the economies of scale paradigm was followed by the waste elimination paradigm initiated by Toyota, based on the assumption that it is possible to reduce the costs of producing a car without employing the economies of scale. Lean companies improved their ability to meet individual customer needs but continued to be equipped with capital-intensive fixed assets with limited flexibility, thus seeking to extend product series and life cycles. The development of technology accompanying the above organisational changes aimed at increasing the agility of enterprises and the concept of KM 4.0 concluded the fourth stage of industrial production development. A new market objectives of enterprises was the customisation of a product to the individual requirements of a specific customer, characteristic of engineering-to-order production, but with the guarantee of low prices and short delivery cycle times typical of mass production. This paper addresses the issue of the relationship between the level of incorporation of KM 4.0 methods and tools allowing for transformation from Mass production to Mass Customization and the possibility of achieving objectives in terms of economic, human resources and environmental aspects. The empirical research covered 150 medium-sized and large enterprises operating in Poland in various industries. In summary, it can be concluded that there is a correlation between the implementation level of chosen KM 4.0 methods and tools supporting product customisation and the level of efficiency in terms of achieving "triple bottom line" goals in the aspect of economics, the aspect of human resources and the aspect of ecological goals. The methods indicated above largely concern operational and production processes and allow flexible delivery of highly customised products at a price comparable to that of mass products. The conditions and developments in the knowledge economy mean that modern organisations need to build an organisational strategy based at an operational level on KM methods and tools.

Keywords: Knowledge Management 4.0, Mass Customisation, Lean Management, Agile Enterprise, Modern Manufacturing Practices, Industry 4.0

1. Introduction

Mass production initiated at Cadillac Motor Car with the implementation of interchangeable parts technology led to significant price reductions through economies of scale, but at the same time reduced the manufacturer's ability to meet individual customer needs. Companies following the lean organisational strategy pioneered by TOYOTA Motor Company (based on the assumption of waste elimination) while managing to increase their ability to meet individual customer needs, continued to be equipped with capital-intensive fixed assets with limited flexibility, thus seeking to extend product series and life cycles (Trzcielinski, 2011), (Trzcielinski, Włodarkiewicz-Klimek, Pawlowski, 2013), (Jasiulewicz-Kaczmarek, Legutko, Kluk, 2020), (Pawlowski, 2020). The waste elimination paradigm proved to be insufficient in view of the increasing volatility and unpredictability of the environment. The ability to succeed in a competitive environment characterised by constant unpredictable changes creating market opportunities became the paradigm of the fourth stage of industrial production development. The development of technology accompanying the organisational changes aimed at increasing the agility of enterprises and the concept of Industry 4.0 concluded the fourth stage of industrial production development. Industry 4.0 has become an accepted reality, which affects the way companies operate (Jasiulewicz-Kaczmarek, Legutko, Kluk, 2020). A new market objectives of enterprises was the customisation of a product to the individual requirements of a specific customer, characteristic of engineering-to-order production, but with the guarantee of low prices and short delivery cycle times typical of mass production.

2. Research Problem, Literature Review

This paper addresses the issue of the relationship between the level of incorporation of Industry 4.0 methods and tools allowing for mass customisation and the possibility of achieving the company's goals in terms of economic, human resources and environmental aspects. The empirical research covered 150 medium-sized and large enterprises operating in Poland in various industries.

The literature on the subject provides numerous typologies of mass customisation forms, where customisation means adapting a product to the individual requirements of a specific customer (Bednarz, 2010), (Gilmore, Pine, 1997). Gillmore, J.H. and Pine B.J. organised this concept and proposed a general typology, distinguishing forms of mass customisation based on changes in the product itself, and changes in the customer's perception of the product. They also introduced the important concept of customer sacrifice, defining it as "the difference between what the customer accepts and what the customer actually needs, even if he or she cannot clearly name it" (Gilmore, Pine, 1997). By addressing the issue of customer sacrifice, the company can decide on the extent of the changes in the functionality of the product or the perception of the product. The aim of using mass customisation is to tailor the product to the individual requirements of a specific customer, characteristic of engineering-to-order production, but with the guarantee of low prices and short delivery cycle times typical of mass production. A narrower definition describes the concept of mass customisation as a system that uses information technology, flexible processes and organisational structures to enable the delivery of a wide range of products that meet specific customer requirements (often by selecting predefined options from a set) at costs comparable to those typical of mass production (Bednarz, 2010). Duray was the first researcher to use the notion of modularity of the product itself as well as the manufacturing process to identify the various forms of mass customisation. In the case of mass customisation, modularity guarantees low costs. The typology put forward by Duray (2002) identifies between two dimensions: the point of customer involvement and the type of modularity employed. However, the developed classifications do not answer the question of what changes are necessary in operational processes to effectively deliver customised products in an efficient manner (Bednarz, 2010), (Duray, 2002). In Industry 4.0, one of the market objectives of companies is to tailor the product to the individual requirements of a specific customer. The literature on the subject does not offer a single widely accepted definition of Industry 4.0. nor principles of adapting companies to its requirements (Herman, Pentek, Otto, 2015), (Mrugalska, Wyrwicka, 2017), (Alcácer, Cruz-Machado, 2019). The main ideas of industry 4.0 were first published in Germany in 2011 (Kagermann, Lukas, Wahlster, 2011), (Kagermann, Wahlster, Helbig, 2013). A broad analysis of the issue was developed by M. Hermann, T. Pentek, B. Otto, who provided an overview of the definitions and key principles of Industry 4.0 (Herman, Pentek, Otto, 2015). The authors defined four core elements of Industry 4.0: Cyber- Physical Systems, Internet of Things, Internet of Services, and Smart Factory. They also developed six principles to support a company's adaptation to the requirements of Industry 4.0. These include: interoperability, virtualization, decentralization, real-time capability, service orientation, and modularity. With regard to the issue of Knowledge Management 4.0, a wide range of possible research topics has been developed by Ribeiro at all (2023). While Ansari (2019) proposed the following definition of KM 4.0 "as a strategic and operational function comprising exploration and exploitation processes. KM 4.0 is responsible to accomplish the following tasks, namely i) continuously support value generation through enhancing and balancing need- or opportunity-driven knowledge generation and knowledge utilisation capacities, and ii) persistently facilitate developing and protecting human-machine collective intelligence across manufacturing enter-prises and in particular smart factories". With regard to the above this paper focuses on two issues:

1. The issue of operationalisation of mass customisation through the application of Industry 4.0 methods and tools. Salvador et al. identified three key areas of mass customisation (Salvador, Holen, Piller, 2009), (Doligalski T. 2009):

- defining the area of customisation **(solution space development)**,
- designing an efficient process **(robust process design)**,
- and customer selection process **(choice navigation).**

To each of these areas they assigned a so-called core competence (fundamental capability) and a set of methods and tools to develop them. And so:

- As a core competence in terms of defining the area of customisation, the authors identified the selection of product elements that can be customised by the customer. The authors assigned to this competence a set of innovation tools, (*innovation tool kits*), such as virtual product tests (*virtual concept testing*) and customer experience monitoring (*customer experience inteligence*). This paper, referring to the methods and tools of Industry 4.0, analyses the aspects of the level of tracking changes by the companies examined in the customer market, in the economic segment, in the socio-demographic segment of the environment, and in the natural environment, as a way of searching for areas of product customisation. Companies must use new product development as a strategy for remaining competitive in the market place in response to changing consumer demands (Miranda at all, 2019).
- The authors identified the use and configuration of the resources of the organisation or its partners in the value chain to meet the diverse needs of a large number of customers as a core competence for designing an efficient process. Among the methods and tools conducive to the development of this

competence such aspects as flexible automation, process modularity and adaptable human capital were identified. With regard to the above competence, the author asks questions about the level of application of the toolkit supporting the process of adaptation to the requirements of Industry 4.0 pointed out, among others, by Herman, Pentek and Otto (2015). The toolkit covered by this study includes:

  - Internet of Things.
  - Artificial Intelligence.
  - Cloud computing.
  - CAD, CAM, CAE.
  - Reverse engineering.
  - 3D printers.
  - Transport robots(Automated Gaided Vehicle).
  - SCADA.
  - MES (Manufacturing Execution System).
  - e-Kanban.

- In terms of the customer selection process, the authors identified support in identifying the customers' needs while reducing the complexity of their choices as a core competence. With regard to this competence, the authors identified three tools: assortment matching trial and error (*fast cycle, trial-and-error learning*) and embedded configuration. With reference to the above, the authors have posed questions about the level of application of such tools as: artificial Intelligence (computer algorithms process large databases and make decisions without human intervention). Cloud computing (computing is carried out by a service provider without the need to install and administer own software).

2. The second issue addressed in the paper is the effectiveness of the applied methods and tools of Industry 4.0 in relation to corporate sustainability goals (Elkington, 1997). The paper asks questions about the trend of the company's development in business terms, and the level of achievement of the objectives in terms of human resources and environmental aspects in relation to the level of applied methods and tools of Industry 4.0 employed for the purpose of product customisation.

3. Objectives

The aim of the paper is to answer the following question: Is there a correlation between the level of application of Industry 4.0 methods and tools for product customisation and the level of achievement of corporate sustainability goals.

4. The Research

4.1 Research Sample

The research sample comprised 150 medium and large industrial companies (including 60 large ones) operating in 19 different industries in Poland. The respondents were persons directly involved in the management of the production and engineering area (president/managing director; technical director; other persons with similar competencies). The surveys and interviews were conducted through an external company on 28 December 20223.

4.2 Scope of Research

The scope of the research included the level of product customisation, the level of application of Industry 4.0 methods and tools, and the effectiveness of achieving the triple bottom line objectives in the economic, human resources aspect and environmental aspect.

4.3 Research Methods

As part of this study, a questionnaire survey was conducted on a sample of 150 medium and large industrial companies in Poland. The survey was conducted in the form of an interview. Respondents answered on a 1–5 (Likert) scale. In addition, data was partially processed using the Spearman's rank correlation test.

4.4 Data Processing Methodology

The following methodology was used to process the collected data:

- Stage 1 – A group of companies offering products with a high degree of customisation was selected from the research sample.
- Stage 2 – From the companies offering highly-customised products, a group of companies A – characterised by high performance in terms of the triple bottom line objectives - and a group of companies B – characterised by low performance in this respect.
- Stage 3 – For the research samples of companies A and B, indicators of the implementation level of Industry 4.0 management methods and tools were determined, analysed and synthesised. In order to calculate the implementation level of each method, fully implemented methods were identified (response scale 3,4,5 – for solution space development; and scale 4,5 – for robust process design, and choice navigation) in each research sample. Then, the number of fully implemented individual methods and tools was divided by the size of the respective sample (A and B). This yielded an indicator of the implementation level of the respective method (but fully implemented) in each group of companies A and B. In addition, as part of the synthesis, the average total indicator of the implementation of the methods was determined according to the areas of mass customisation: solution space development, robust process design, and choice navigation separately for groups A and B.
- Stage 4 – Spearman's rank correlation tests were carried out for some of the features.

4.4.1 Stage 1 – Product Customisation Level

The following question (E1) was asked in order to identify the group of companies offering highly customised products:

Customisation (personalisation) of the product:

1. none (no customisation of the product and no personalised communication with the customer);
2. narrow scope (standard product + additional services selected from catalogue; no personalised customer contact);
3. medium scope (multiple product variants offered + additional services determined through personalised contact with the customer);
4. extensive scope (customer co-creates the product via personalised contact);
5. very extensive scope (customer co-creates the product via an online service).

Responses 3,4,5 on the scale were rated as high levels of product customisation. 69 companies from the entire research sample of N=150 offered highly customised products.

4.4.2 Stage 2 – Level of Achievement of Triple Bottom Line Objectives – Identification of Group A and B Companies

In order to assess the effectiveness in terms of the achievement of the triple bottom line objectives in the economic, human resources and the environmental aspect, the following questions were posed:

- In terms of the economic aspect, question E2.1 was posed about the trend of the company's development in business terms, starting from the pre-pandemic periods.

1. negative (leading to business closure);
2. stagnant (no growth);
3. acceptable but not satisfactory;
4. good – satisfactory;
5. very good.

Responses 4, 5 on the scale were deemed to reflect a high level of efficiency in terms of economic objectives and a basis for classifying a given company to Group A. Responses of 1,2,3 on the scale, in turn, were deemed to reflect low efficiency in that respect and a basis for categorising the company in question to Group B.

- In terms of the human resources aspect, questions were posed about the degree of implementation of the following measures according to the following scale: (1 – not implemented at all; 2 – implemented to a very low degree; 3 – implemented to a moderate degree; 4 – implemented to a high degree; 5 – implemented to a very high degree)

(E2.2) An analysis of risks to human health and life is carried out in the design stage of products or services.

(E2.3) An analysis of risks to human health and life is carried out in the design stage of manufacturing systems/organising services.

Responses 4, 5 on the scale were deemed to reflect a high level of efficiency in terms of human resources objectives and a basis for classifying a given company to Group A. Responses of 1,2,3 on the scale, in turn, were deemed to reflect low efficiency in that respect and a basis for categorising the company in question to Group B.

- In terms of the environmental objectives, questions were posed about the degree of implementation of the following measures according to the following scale: (1 – not implemented at all; 2 – implemented to a very low degree; 3 – implemented to a moderate degree; 4 – implemented to a high degree; 5 – implemented to a very high degree)

(E2.4) Technologies harmful to the environment are replaced with environmentally-friendly alternatives.

(E2.5) Waste is neutralised to render it harmless to the environment.

Responses 4, 5 on the scale were deemed to reflect a high level of efficiency in terms of environmental objectives and a basis for classifying a given company to Group A. Responses of 1,2,3 on the scale, in turn, were deemed to reflect low efficiency in that respect and a basis for categorising the company in question to Group B.

10 companies with a high level of efficiency in terms of the triple bottom line objectives in all three aspects combined were classified as group A companies. On the other hand, group B included 5 companies with a low level of efficiency in terms of the triple bottom line objectives in all three aspects combined.

4.4.3 *Stage 3 – Indicators of the Implementation Level of Industry 4.0 Management Methods and Tools in Groups A and B*

In order to determine the implementation degree of methods and tools supporting processes in the solution space development area, the following question was posed: In order to identify market opportunities, changes are tracked according to the following scale: (not tracked at all; 2 – tracked only to a limited extent; 3 – tracked to a moderate extent; 4 – tracked to a large extent; 5 – tracked to a very large extent)

- (E3.1) In the economic segment of the environment.
- (E3.2) In the socio-demographic segment of the environment.
- (E3.3) In the natural environment.
- (E3.4) In the technological segment of the environment.
- (E3.5) In the customer market.

Responses of 3,4,5 on the scale were considered to reflect a high degree of implementation of methods and tools supporting solution space development. In group A companies, the total indicator of the level of implementation of methods was 46%. The detailed distribution of the levels of implementation is shown in Figure 1.

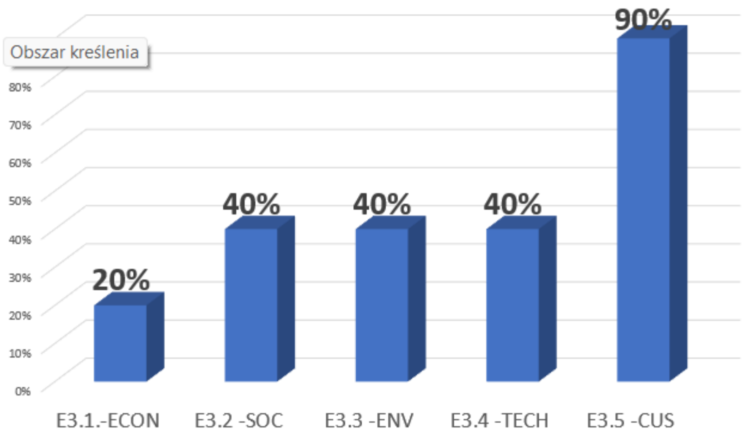

Figure 1: Chart 1. Detailed distribution of the level of implementation of methods supporting solution space development in group A companies.

On the other hand, in group B companies, the total indicator of the level of implementation of the methods was 72%. The detailed distribution of the levels of implementation is presented in Figure 2. These values were not in line with expectations, while the very fact of a considerable use of methods for tracking changes in the environment of group B companies results from high product customisation in the whole segment of enterprises with high customisation level.

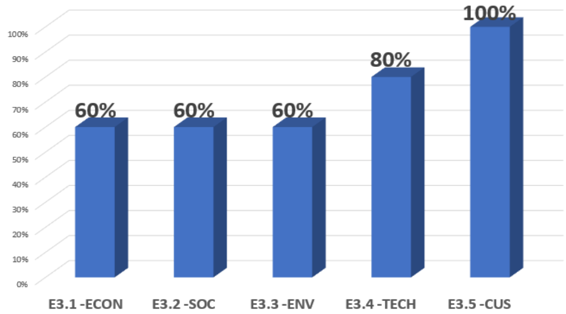

Figure 2: Detailed distribution of the level of implementation of methods supporting solution space development in group B companies.

In order to identify the group of companies supporting robust process design (questions a to j) and choice navigation (questions from b to c), the following questions were posed: The extent of application of the following technologies: (1 – not used, 2 – used to a very small extent; 3 – used to a small extent; 4 – used to a large extent; 5 – used to a very large extent)

- (E3.6) Internet of Things.
- (E3.7) Artificial Intelligence.
- (E3.8) Cloud computing.
- 9E3.9) CAD, CAM, CAE.
- (E3.10) Reverse engineering.
- (E3.11) 3D printers.
- (E3.12) Transport robots (Automated Gaided Vehicle).
- (E3.13) SCADA.
- (E3.14) MES (Manufacturing Execution System).
- (E3.15) e-Kanban.

Responses of 4,5 on the scale were considered to reflect a high degree of implementation of methods and tools supporting robust process design and choice navigation. In group A companies, the total implementation level of methods supporting robust process design was 60%, while the total implementation level of methods supporting choice navigation was 50%. Figure 3 shows a comparison of the implementation levels of methods supporting robust process design (questions from a to j) and choice navigation in groups A and B.

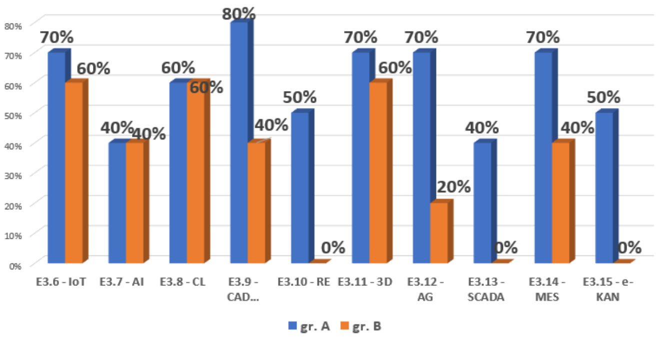

Figure 5: Comparison of implementation levels of methods supporting robust process design (questions from a to j) and choice navigation in groups A and B.

Detailed analysis of the distribution of implementation levels of methods supporting robust process design in group A indicates the highest level of implementation of CAD, CAM, CAE methods, which is most likely due to the wide availability of the above technologies. High implementation level of 70% was also identified for such methods as: a – Internet of Things, f – 3D Printers, g – Automated Gaided Vehicle and – MES. The lowest implementation level for group A companies was identified for such methods as: b – Artificial Intelligence ora h – SCADA. In contrast, in group B companies, the total implementation level of methods supporting robust process design was 32%, while the total implementation level of methods supporting choice navigation was 50%. The detailed analysis of the distribution of the implementation levels of methods supporting robust process design in group B companies shows the highest scores for such methods as IoT, Cloud Computing and 3D printers. In contrast, three groups of methods: Reverse Engineering, SCADA and e-Kanban had zero implementation levels.

4.4.4 Stage 4 – Spearman's Rank Correlation Tests.

In order to verify whether there is a statistical correlation between the implementation level of Industry 4.0 management methods and tools and the performance of enterprises in terms of triple bottom line objectives, a correlation analysis was conducted. Since the variables take values on an ordinal scale, Spearman's rank correlation was used. Statistical analyses were performed using Statistica 13.1 software. Spearman's rank analysis was performed assuming a significance level of $p<0.05000$. The strength of the correlations was assessed based on the classification presented below in Table 1. The interpretation of the correlation coefficient does not provide a clear answer on the causal relationship, but indicates the existence of a certain statistical relationship between the variables examined, which is one of the conditions for the existence of a cause-and-effect relationship (Małkowska-Borowczyk, 2011).

Table 1: The strength of the correlations.

Correlation coefficient value	Interpretation
r ≤0.2	Virtually no relationship
0.2< r ≤0.4	Low but clear linear correlation
0.4< r ≤ 0.7	Moderate correlation
0.7< r ≤0.9	Significant correlation
0.9< r ≤1	Very strong correlation

Elaboration based on Ostasiewicz, Rusnak, Siedlecka, (2000) .

Table 2 presents the results of Spearman's Rang correlation between the implementation level of Industry 4.0 methods and tools supporting the processes of solution space development robust process design and choice navigation and the level of achievement of triple bottom line objectives.

Table 2: Spearman's Rang correlation.

Objectives/Methods		Human Resources aspect		Environmental aspect		Economic aspect
		E.2.2	E.2.3	E2.4	E2.5	E2.1
solution space development	E3.1	0,232510	0,055048	0,026032	0,092053	-0,007062
	E3.2	0,306320	0,067530	0,085222	0,053806	0,001929
	E3.3	0,409306	0,015822	0,073348	0,040235	0,063563
	E3.4	0,177733	0,075493	0,040583	0,058790	0,138388
	E3.5	0,051646	0,151659	0,229805	0,162892	-0,002757
sobust process design and choice navigation	E3.6	0,232510	0,055048	0,118231	0,184938	0,195864
	E3.7	0,306320	0,067530	0,088012	0,128992	0,178924
	E3.8	0,409306	0,015822	0,019361	0,186947	0,246889
	E3.9	0,177733	0,075493	0,068499	0,080334	0,116630
	E3.10	0,051646	0,151659	0,148908	0,096759	0,160551
	E3.11	0,279472	0,046321	0,094857	0,153698	0,160796
	E3.12	0,083694	0,190714	0,135461	0,205505	0,305156
	E3.13	0,131735	0,153927	0,201914	0,190439	0,339416
	E3.14	0,140805	0,128516	0,138452	0,176396	0,320284
	E3.15	0,332559	0,143282	0,209248	0,265239	0,217790

Analysis of Table 2 leads to the following conclusions:

- Figures highlighted indicate all significant correlation coefficients in the ranges between 0.2< r ≤ 0.4 and 0.4< r ≤ 0.7 which indicates a low but clear linear correlation in the first case and a moderate correlation in the second case.
- All significant correlation results are positive, which means that an increase in the implementation level of individual methods and tools supporting the solution space development robust process design and choice navigation processes is accompanied by an increase in the efficiency in terms of achieving triple bottom line objectives.
- The achievement of higher goals in the economic aspect is accompanied by an increase in the level of implementation of methods supporting robust process design, in particular (E3.12) Automated Guided Vehicles, (E3.13) SCADA, (E3.14) MES, (E3.15) e-Kanban, and (E3.8) Cloud computing. These methods and tools are related to the operational manufacturing of products.
- The achievement of more ambitious environmental targets is accompanied by an increase in the implementation level of methods: (E3.5) related to tracking changes in the customer market supporting solution space development processes and (E3.12) Automated Guided Vehicles, (E3.13) SCADA, and (E3.15) e-Kanban, which are conducive to robust process design.
- The achievement of more ambitious human resources objectives is accompanied by an increase in the implementation level of such methods as:(E3.1) tracking changes in the economic segment of the environment, (E3.2) in the socio-demographic segment of the environment, (E3.3) in the natural environment, to support solution space development processes, as well as (E3.13) SCADA, and (E3.15) e-Kanban conducive to robust process design.3. Results
- This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

5. Results and Discussion

The aim of the paper was to explore the question of a potential correlation between the implementation level of KM 4.0 methods and tools supporting product customisation and the level of corporate sustainability goals achieved. Exploring future directions in perspectives for stakeholders the following areas of using KM 4.0 methods and tools could be distinguished:

- Replace human labour with automated work.
- Increase resource flexibility through the use of network solutions.
- Support the identification and outsourcing of processes that do not meet best practice requirements.

Currently, the Polish market (as well as the entire EU market) is facing declining labour resource in all areas of business processes. The application of new emerging technologies not only improves the process of delivering a customized product at mass prices, but in many cases makes it possible to realise the process at all by replacing human labour with automated work. With reference to future directions in group A companies, highly efficient in terms of achieving triple bottom line goals, the implementation level of KM 4.0 methods and tools supporting robust process design and choice navigation was significantly higher compared to group B companies. The methods indicated above largely concern operational and production processes and allow flexible delivery of highly customised products at a price comparable to that of mass products. The result of applying the modern methods of Industry 4.0 in these areas is an increased efficiency in terms of achieving objectives in economics, human resources and environmental aspects. With regard to the implementation level of methods supporting solution space development processes, group B had higher scores than group A. Although the result differs from expectations, this is due to the high product customisation in the entire segment of the companies surveyed.

References

Alcácer, V. and Cruz-Machado, V. (2019) "Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems", Engineering Science and Technology, an International Journal 22, 2019, pp. 899–919.

Ansari, F. (2019) Knowledge Management 4.0: Theoretical and Practical Considerations in Cyber Phisical Production Systems, IFAC PapersOnLine 52-13 (2019) 1597–1602.

Bednarz, L. (2010) Operacjonalizacja strategii masowej kastomizacji w: Konferencja - Innowacje w Zarządzaniu i Inżynierii Produkcji, Zakopane, Polska, pp. 102-111.

Doligalski T. (2009) "Możliwości zastosowania masowej kastomizacji jako usługi internetowej", [w:] Konsument w przestrzeni europejskiej, (red.) Dąbrowska, A. i Ozimek I. , Instytut Badań Rynku, Konsumpcji i Koniunktur, Warszawa.

Duray, R. (2002) "Mass customization origins: mass or custom manufacturing?", International Journal of Operations & Production Management, 2002, nr 3.

Elkington, J. (1997) Cannibals with Forks: The Triple Bottom Line of 21st Century Business, Capstone, Oxford.
Gilmore, J.H. and Pine, II B.J. (1997) "The four faces customization", Harvard Business Review, January-February 1997, pp. 21-30.
Hermann, M., Pentek, T., and Otto, B. (2015) Design Principles for Industrie 4.0 Scenarios: A Literature Review, Working Paper No. 01 /2015, Technische Universität Dortmund Fakultät Maschinenbau Audi Stiftungslehrstuhl Supply Net Order Management www.snom.mb.tu-dortmund.de
Jasiulewicz-Kaczmarek, M., Legutko, S. and Kluk P. (2020) "Maintenance 4.0 Technologies – New opportunities for sustainability-driven maintenance", Management and Production Engineering Review, Volume 11, Number 2, June 2020, pp. 74–87.
Kagermann H., Lukas, W. and Wahlster, W. (2011) Industrie 4.0 – Mitdem Internet er Dinge auf dem Wegzur 4. Industriellen Revolution, Industry 4.0: with the Internet of Things towards 4th industrial revolution, [online] VDI Nachrichte; http://www.vdi nachrichten.com/artikel/Industrie-4-0- Mit-dem-Internet-derDinge-auf-dem-Weg-zur-4-industriellen-Revolution/52570/1.
Kagermann, H., Wahlster, W, and Helbig, J. (2013) Securing the future of German manufacturing industry: recommendations for implementing the strategic initiative INDUSTRIE 4.0. Final report of the Industrie 4.0 working group. Berlin, ForschungsunionimStifterverbandfürdie Deutsche Wirtschafte, Berlin.
Małkowska-Borowczyk, M. (2011) "Otoczenie jako źródło problemów i presji na wybory strategiczne przedsiębiorstw", w: Urbanowska-Sojkin E. (red.). Podstawy wyborów strategicznych w przedsiębiorstwach, PWE, Warszawa.
Miranda, J., Pérez-Rodríguez, R., Borja, V., Wright, P. K. and Molina, A. (2019) "Sensing, smart and sustainable product development (S3 product) reference framework", International Journal of Production Research, 57:14, pp. 4391-4412.
Mrugalska, B. and Wyrwicka, M. (2017) "Towards Lean Production in Industry 4.0.", 7th International Conference on Engineering, Project, and Production Management, Procedia Engineering 182, 2017, pp. 466 – 473.
Ostasiewicz, S., Rusnak, Z. i Siedlecka, U. (2000) Statystyka. Elementy teorii i zadania, Wydawnictwo Naukowe PWN, Warszawa.
Pawlowski, K. (2020) "The State of Adaptation of Enterprises in Poland to the Paradigms of Industrial Production Industry 4.0", In Proceedings of the 36th International Business Information Management Association Conference (IBIMA), Sustainable Economic Development and Advancing Education Excellence in the era of Global Pandemic, ed.: Khalid S. Soliman: International Business Information Management Association, IBIMA, Granada, Spain, pp. 5023-5032.
Ribeiro, V. B., Nakano, D., Muniz Jr., J., and Oliveira, R. B. (2022) Knowledge management and Industry 4.0: a critical analysis and future agenda. Gestão & Produção, 29 e5222,
Salvador, F., De Holen P.B. and Piler F. (2009) "Cracking the Code of Mass Customization", MIT Sloan Management Review, vol. 50, nr 3, 2009.
Trzcieliński, S. (2011) Przedsiębiorstwo zwinne, Wydawnictwo Politechniki Poznańskiej, Poznań, Poland.
Trzcieliński, S., Włodarkiewicz-Klimek, H. and Pawłowski, K. (2013) Współczesne Koncepcje Zarządzania. Wydawnictwo Politechniki Poznańskiej, Poznań, Poland.