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Sustainability and Industry 4.0 in the packaging and printing industry: a diagnostic survey in Poland

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ABSTRACT
Industry 4.0 (I4.0) became an important paradigm to bridge the gap between technologies and humans. The paper aims to diagnose sustainability performance and I4.0 maturity in Poland's printing and packaging sector and identify research areas where further actions for improvements are necessary. This article adopts a mixed-method study combining in-depth interviews of eleven heterogeneous enterprises, supported with a quantitative survey on a representative sample of 301 companies. The findings revealed an insignificant correlation from a statistical point of view (0.44) between the adopted I4.0 technologies currently used and sustainable best practices. Internet of Things technologies are more often adopted in the printing industry (27.2 %) than in the packaging industry (14 %). The study concludes that using I4.0 technologies boosts the execution of sustainable practices and/or realising sustainable development practices requires I4.0 technology adoption. The paper clarifies that more in-depth analyses are needed to help achieve sustainable objectives for printing and packaging companies through digital technologies. The methodology is replicable and might be applied in other economies across separate multinational enterprises to influence sustainable digitalised business strategy.

KEY WORDS
Industry 4.0, packaging, printing, smart manufacturing, survey, sustainability

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Introduction

The printing and packaging industry greatly contributes to European manufacturing, employing more than 600,000 employees and generating an overall turnover of about EUR 80 billion (Grace, 2021). This manufacturing sector has been widely influenced by the overall debate about business and production in the last few decades. In addition, the global financial crisis in 2008–2009 stimulated this debate (Barbier, 2010), and these concerns were translated into a vision of a "green economy" (Hesh-

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mati, 2018). This green economy transition led to reforming traditional economic models to address climate change, biodiversity loss, water scarcity, etc., promoting the challenges of technological change for sustainability (Söderholm, 2020; Szpilko & Ejdys, 2022). The reasons for this perspective change have been discussed in sociology, being referred to as the so-called "macro-trends" or "game-changers" (Avelino et al., 2017), among which the climate change is recognised as a big player, despite being "only the tip of the iceberg", and hiding a "societal transformation towards sustainability" (Campos et al., 2016). As noticed by Worthington and Patton (2005), the manufacturing sector experienced a change in business perspective from a profit-oriented one (Friedman, 1970) to a framework influenced by sustainability sensitivity (Holliday, Schmidheiny & Watts, 2017). Demjanovičová and Varmus (2021) presented a study on companies' attention to shift the perception of business values of environmental sustainability. It was also confirmed that companies that extend their performance through eco-efficiency measures might effectively contribute to sustainability (Heikkurinen, Young & Morgan, 2019). The sustainability concept, being the result of debates, was accelerated by the implementation of the so-called 2030 Agenda for Sustainable Development (SD Agenda 2030) and its 17 Sustainable Development Goals (SDG) (UN, 2022).

For this research, eleven enterprises were examined using descriptive statistics. The pilot study revealed that advanced technology has a positive impact on sustainability. Since the representative sample size was insufficient, the current paper extends previous considerations, enriching them with evidence from primary data collected through a quantitative questionnaire survey. In this context, a representative sample consisted of 301 enterprises from the printing and packaging industry. Based on the collected data, statistical analyses were performed to uncover a correlation between adopting sustainable practices and Industry 4.0 technologies.

Therefore, the paper aims to diagnose sustainability performance and I4.0 maturity in Poland's printing and packaging sector. The diagnosis, in its nature, is meant to constitute a basis for further studies.

The structure of the paper follows the commonly used IMRaD approach. Section 2 includes the objectives and formulated research questions and presents the materials and methods used in the article. Section 3 contains the results of the interviews and surveys conducted. Sections 4 and 5 discuss the results, conclusions and directions for further research.

1. Literature review

A well-known approach has been introduced by the Brundtland Report (World Commission on Environment and Development, 1987), which has brought to the so-called "Triple Bottom Line"(TBL), represented by "Economic", "Social" and "Environmental" perspectives (Elkington, 1994) but other valid interpretations have been given in this regard, such as the 3P (Profit, People, Planet) adopted by Kaptein and Wempe (2002) and extended to CSR (corporate social responsibility) relationship that insist more on an ethics perspective (Kaptein & Wempe, 2002). In this perspective, a work aiming at clarifying and further refining the concepts and definitions of sustainability concerning the company perspective has been published by Van Marrewijk (2003), showing that no universal meaning can be provided to describe this topic. Still, most existing frameworks addressing sustainability can be discussed using the same pillars: environment, economic, and social. Wilson (2015) argued that these three concepts can be seen as mutually complementary and influencing and can assess an entity's sustainability in the three dimensions. Treating any dimension separately is a misleading use of the sustainability approach (2020).

Even if these 3P frameworks can be inflected towards manufacturing practices, their influence in this domain cannot be addressed by neglecting the other trends characterising this sector. In particular, the topic is reflected in the so-called "Industry 4.0" (I4.0), which strongly addresses the digitalisation of manufacturing companies. I4.0 includes renovating companies' machines (with new or revamped ones able to produce structured data, enabling a more profound knowledge of the assets and production statuses) (Nucera et al., 2021). It also considers remodelling the companies' internal organisation towards structures closer to the informative systems implied in the manufacturing management, e.g., referring to the IEC 62264 standard (ISO, 2013), which relies on turning on the Purdue Enterprise Reference Architecture (Bernus, Nemes & Schmidt, 2003).

Today, sustainability and Industry 4.0 are leading concepts in the literature and industrial practice. Several studies have been carried out to demonstrate the benefits of this paradigm adoption in the holistic manufacturing environment (Kiel, Arnold & Voigt, 2017; Dalenogare et al., 2018) and improvement programmes like lean manufacturing (Ejsmont et al., 2020). Few cited publications also addressed different specific areas of the manufacturing environment, such as internal logistics (Quadrini, Negri & Fumagalli, 2020; Fragapane et al., 2022), maintenance and asset management (Cattaneo et al., 2018; Polenghi et al., 2020), supply chain management (Ivanov et al., 2016; Ben-Daya, Hassini & Bahroun, 2019), and decision-making (Negri, Fumagalli & Macchi, 2017; Villalonga et al., 2021).

The importance of sustainability for the industry is also reflected in the United Nations Sustainable Development Goals initiative (UN, 2021) and addressed directly by UN SDG No. 9, i.e., build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation (UN, 2021). Several studies have been published regarding the interactions between Industry 4.0 adoption and sustainable development practices. In particular, a 2017 literature review depicted the adoption of Industry 4.0 as a means towards sustainability (Liao et al., 2017). More precisely, concerning the TBL approach, the first one has been widely studied, at least concerning the productivity and competitiveness-related benefits (Oesterreich & Teuteberg, 2016; Stock & Seliger, 2016; Müller, Buliga & Voigt, 2018). At the same time, several works addressed the environmental dimension, mainly referring to the energy management topic, given the fact that the data produced by the machines usually reflect or directly address the energy consumption of the monitored assets (Shrouf, Ordieres & Miragliotta, 2014; Baccarelli et al., 2017; Ghobakhloo, 2020) or sustainability impacts and assessments of specific technologies (Gladysz et al., 2020; Kluczek, Gladysz & Ejsmont, 2021). Recent literature review showed that relationships between Industry 4.0 and sustainability are bi-directional, i.e., Industry 4.0 impacts sustainability performances (possibly positively and negatively), and sustainability initiatives may impact Industry 4.0 adoption (possibly positively and negatively as well) (Ejsmont, Gladysz & Kluczek, 2020). Resilience is also an increasingly important aspect in terms of how businesses operate in the era of Industry 4.0 and increasing environmental awareness of companies. The COVID-19 pandemic highlighted the importance of resilience and manufacturing companies' continuity (Mubarik et al., 2021).

Some researchers have recently studied the relationship between Industry 4.0 and sustainable development in the printing sector, mainly focusing on the environmental bottom line of sustainability (Gladysz et al., 2021).

2. Research methods

Considering the aforementioned issues, the following research objectives are formulated:

- Enrich the existing literature on packaging and printing manufacturing with specific assessments about its reception of Industry 4.0-related technologies, given the fact that, despite its economic relevance, this sector has fewer materials than other ones, e.g., construction (Ghosh, Edwards & Hosseini, 2020);
- Investigate the evolution of the packaging and printing manufacturing sector towards sustainable development practice, particularly concerning the social dimension of the Triple Bottom Line approach.

To investigate these objectives, the authors answered the following research questions in the design of the work:

- Which Industry 4.0-related technologies are used (or intended to be used) in packaging and printing companies?
- Which sustainability practices are used or in progress in packaging and printing companies?
- Do packaging and printing companies expect any (business) benefit from I4.0 implementation?
- Do packaging and printing companies expect any (business) benefit from sustainability practices?
- Is there any relationship between the size of a company and the I4.0 implementation advancement in packaging and printing companies?
- Is there any relationship between the size of a company and sustainability implementation advancement in packaging and printing companies?
- Is there any perceived or hidden relationship between Industry 4.0 technologies and sustainability practices in packaging and printing companies?

This study collected quantitative data through a survey to provide evidence answers to the listed questions. It identified the current state, and its description will be transformed into a consecutive research plan to address specific areas that emerged from the diagnosis. Due to its diagnostic nature, the presented study does not aim to address particular issues, indicate their potential or actual roots, or propose or verify possible solutions. The idea is to show the present status and suggest areas for further action. Pilot research involved interviews that were aimed at getting qualitative insights into companies to define a questionnaire for the survey. The gathered data were analysed quantitatively using statistical analyses (descriptive statistics) to verify whether correlations between the research questions (4–7) exist.

The reported work presents the results of a study conducted over a specific pool of companies belonging to the Polish printing and packaging sector: a purposive convenience sample numbering 11 companies, reflecting the overall Polish segmentation of this sector, has been considered. The representatives from selected companies were individually interviewed and guided during an online structured in-depth interview questionnaire by filling out a web-hosted form. Two interviewers conducted each so-obtained input to validate the data accuracy. An interviewee always authorised interview results.

Structured in-depth interviews (IDIs) are a qualitative data collection method that allows a lot of information to be gathered on a given topic. Structured IDIs have similarities to a conversation — although it is a conversation with a purpose, i.e., a research topic based on pre-developed questions. The advantage of structured IDIs is that the researcher can gain rich and deep information from the interview process (Jennings, 2005). An interview completed in this form provides reasonably objective information. Answers are likely similar and not intersubjectively variable if another interviewee conducts the study. Structured IDI protects against cognitive errors. IDIs allow for flexibility and discussion of topics that arose during the conversation and were not previously planned. Some degree of flexibility is crucial with the topic of Industry 4.0 and sustainability, where there are so many threads, application examples, and relations that it is impossible to identify them all before launching the study. The interviews were conducted online using Microsoft Forms and Teams (data collection questionnaire and videoconferencing conversation). Easy to use, with small barriers to use (no installation required), and widely used tools were chosen. That way made it convenient for participants, giving more flexibility in terms of time, as the place was not constraining the interview date. Obtained answers to the questions were then carefully analysed, and if there were any doubts, the disputed issues were clarified with the respondent. Respondents authorised final questionnaires. Misunderstanding and incorrect interpretation of answers were avoided.

At first, the sample of interviewed companies has been clustered according to the declared company size. The interviewed companies have been able to assess themselves, according to the number of their employees, as small (employees < 50, annual turnover ≤ EUR 10 m or balance sheet total ≤ EUR 10 m), medium (employees < 250, annual turnover ≤ EUR 50 m or balance sheet total ≤ EUR 43 m), or large (employees ≥ 250, annual turnover > EUR 50 m or balance sheet total > EUR 43 m) enterprises. Hence, the qualitatively interviewed sample was composed of two small enterprises, six medium enterprises, and three large enterprises. The interviewed companies' scope of operations was national (1), European (8), international (1), and global (1). The average duration of the interviews was about 75 minutes. Interviewees were selected from the management/top levels of the company to make sure they have knowledge of business strategies and sustainable development agenda. The interviewed companies are specifically involved in the production of printing products such as self-adhesive labels, wrap-around labels, heat-shrinkable labels, wet-glue labels, and in-mould labels. The sampled companies use technologies like flexographic, offset, and rotogravure and packaging products like bottles, cups, caps, containers, and similar products printed by dry-offset methods. The sample is the same basis as the work reported in the previous efforts by the authors (Gladysz et al., 2021).

After the qualitative research (interviews), quantitative research was conducted among companies registered in Poland using the CATI (computer-assisted telephone interviewing) technique supported by a structured questionnaire survey. The respondents were persons holding the following positions in companies: (i) owner/co-owner or (ii) a representative of the top management (executive), including persons supervising technical divisions or R&D — design and implementation of innovation. The inclusion of respondents in the survey depended on their preferences, decisions, and the completeness of contact details contained in the databases. In total, 301 effective surveys were carried out (i.e., those in which the answers to all questions were obtained) with representatives of companies within two sectors: printing and packaging (Table 1). As part of the study, it was

Tab. 1. Number of companies from selected sectors

Sector	Number of employees		
	1-49	50 and more	Total
Printing	127	24	151
Packaging	120	30	150

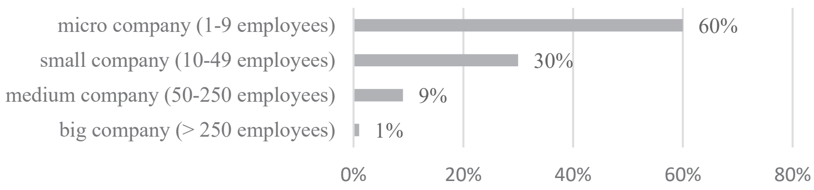

Fig. 1. Company size by the number of employees

used as the basis of the Bisnode (2022) database, which contains a total of data on over 7 million companies, of which 4.6 million are active and whose data is constantly updated (database update in daytime mode). The supplementations were the Eniro (2022) database (over 1 million enterprises) and Directan (2022) database (B2B records). The selection of the sample for the study was quota-losing, where the layers were:

- sector (the overwhelming sector of the company's activities divided into two categories: printing and packaging);
- size of the company calculated in the number of employees (divided into two cohorts: 1–49 employees and above 50 employees).

Detailed data on the selected sample is presented below. The structure of the sample (company size) is consistent with the structure of the population, as found in Statistics Poland (2022).

The survey included companies of different sizes divided by the number of currently employed people in two cohorts. Companies with 1 to 49 employees accounted for 90 % of the respondents, while the remainder were companies with 50 or more employees. The detailed distribution of companies whose representatives participated in the survey is presented in Fig. 1.

The respondent group comprised 24 % of women and 76 % of men. It had 218 owners or co-owners (72 %), while the remaining 28 % (83 persons) were executives, including those who oversee technical or R&D divisions. Surveys were conducted with companies throughout Poland. The territorial division was based on the question of the province in which the company is located. A minimum of 5 % of surveys were completed in each province. Quantitative data were used to check if a statistically important correlation exists between exploitation and plans for sustainability practices and Industry 4.0 technologies. Correlation coefficients were calculated depending on the nature of a variable. Statistically significant and strong correlations were discovered and discussed.

3. Research results

The answers to Industry 4.0-related questions have already been published in a previous work (Gladysz et al., 2021). To track the sustainable development awareness of the companies, the sample has been asked to assess its personnel's perception of SD practices according to the hierarchical levels of the

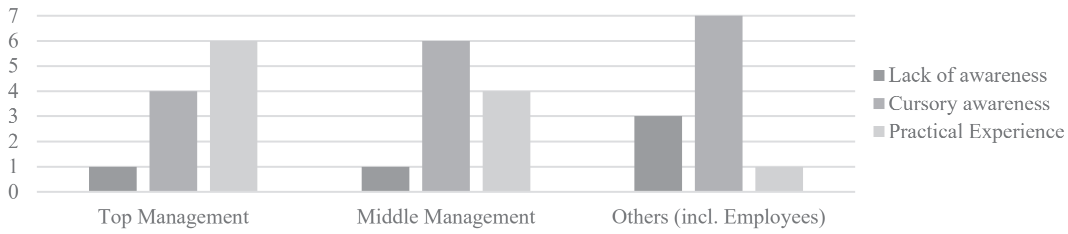

Fig. 2. SD awareness

different companies' employees. The outcome of this question is summarised in Fig. 2.

Interviewees were asked to frame the SD objectives according to the company strategies to estimate the management attitude towards sustainable development practices. To target the social dimension, companies were asked to evaluate their involvement in each sub-thematic area, as depicted in Fig. 3. Interviewees were also asked about the economic dimension to integrate the survey into the SD dimensions (Fig. 4). For the last evaluation area, so-called multi-perspective (DESD, 2014) companies are framed according to Fig. 5. After this area-based assessment, the interviewed companies were asked to assess a stage of the SD practices. Possible options were given as:

- We have not considered this;
- We are planning the pilot implementation;
- We are planning the implementation in selected areas of the company;
- We are planning the implementation in the whole company;
- We are carrying out the pilot implementation;
- We are carrying out the implementation in selected areas of the company;
- We are carrying out the implementation in the whole company;
- We have finished the implementation of the SD concept, and continuous improvement is ongoing.

Fig. 6 shows the answers provided to the aforementioned questions, where, among the eight possible options, companies framed themselves only in four scenarios (nominally, the three ones referring to the most advanced implementations and one expressing a preliminary implementation purpose).

Figs. 7 and 8 show that cybersecurity is the most frequently used I4.0 technology currently by the surveyed printing and packaging companies. Respondents indicated the second most frequently used technology is Additive Manufacturing. Simulation is the third most often used technology. The last of the listed technologies of I4.0 respondents pointed to Autonomous Robots, Big Data and Cloud computing. The results are confirmed by industry articles (white papers) (Młynarczyk, 2022; Poligrafika.pl, 2023) highlighting the growing importance of 3D printing and simulation. The issue of cybersecurity, on the other hand, is crucial, not only for the printing and packaging companies but for all those that use I4.0 technologies that are interconnected (IoT, cloud, etc.). Table 2 presents a two-way table showing the frequencies of observed knowledge of I4.0 technologies and SD practices.

Respondents from the printing and packaging industries answered that they did not know the I4.0 technologies. Only 13 % of respondents from the printing industry and 15 % from the packaging industry answered that they knew of the I4.0 technologies. Only 20 % of surveyed respondents from the printing industry confirmed that they knew about SD practices, and 17 % of respondents from the packaging industry said the same. This demonstrates the still relatively low awareness of I4.0 and sustainability in Poland's printing and packaging sector. However, these are growth areas, as evidenced by the results shown in Figs. 7 and 8. It observed that many I4.0 technologies and SD practices are in the implementation or planned phases. It is also important to note that the respondents' lack of knowledge in these areas does not mean companies are not using I4.0 and/or SD practices.

Spearman's rank order correlation tool was used to analyse the correlation between the number of I4.0 technologies and the number of SD practices on different levels of implementation. The obtained results (Table 3), according to significance level $p<0.05$, show a correlation between the I4.0 technologies and the SD practices currently used at the level of 0.44, which is a medium correlation. A similar correlation was

Tab. 2. Two-way table: frequencies of observed knowledge of I4.0 technologies and SDGs depending on the industry. Red colour if p<0.05

Industry	Knowledge of I4.0 technologies - No	Knowledge of I4.0 technologies - Yes	Record	Knowledge of SDGs - Yes	Knowledge of SDGs - No	Record
Printing	131	20	151	30	121	151
Packaging	127	23	150	25	125	150
Total	258	43	301	55	246	301
Statistics	Chi^2	df	P	Chi^2	df	p
Chi^2 Pearson	0.268	df=1	p=0.605	0.516	df=1	p=0.472
Chi^2 NW	0.268	df=1	p=0.605	0.517	df=1	p=0.472

Fig. 3. Social areas

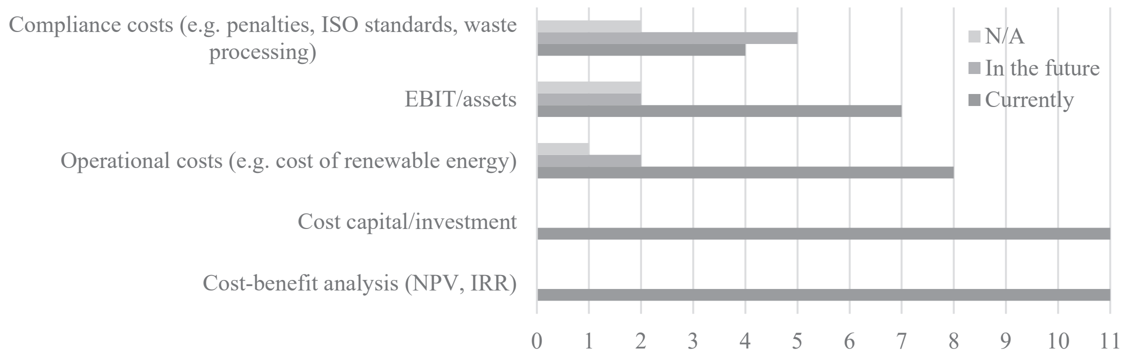

Fig. 4. Economic areas

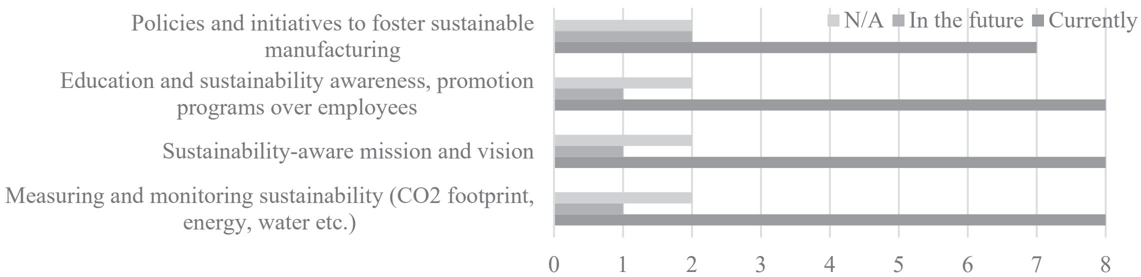

Fig. 5. Multi-perspective areas

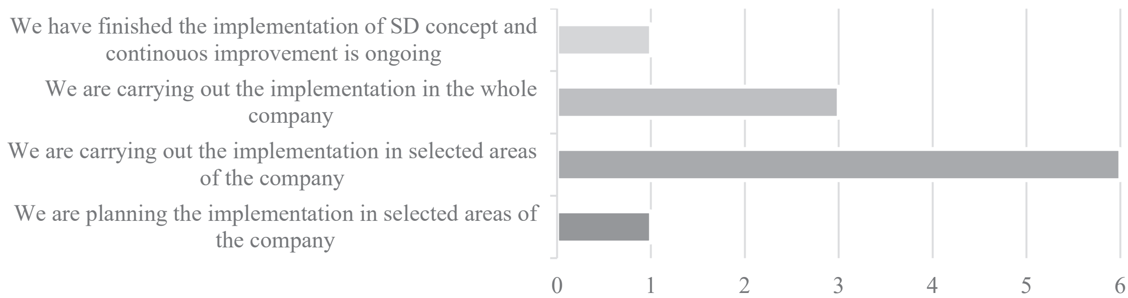

Fig. 6. Stage of SD concept

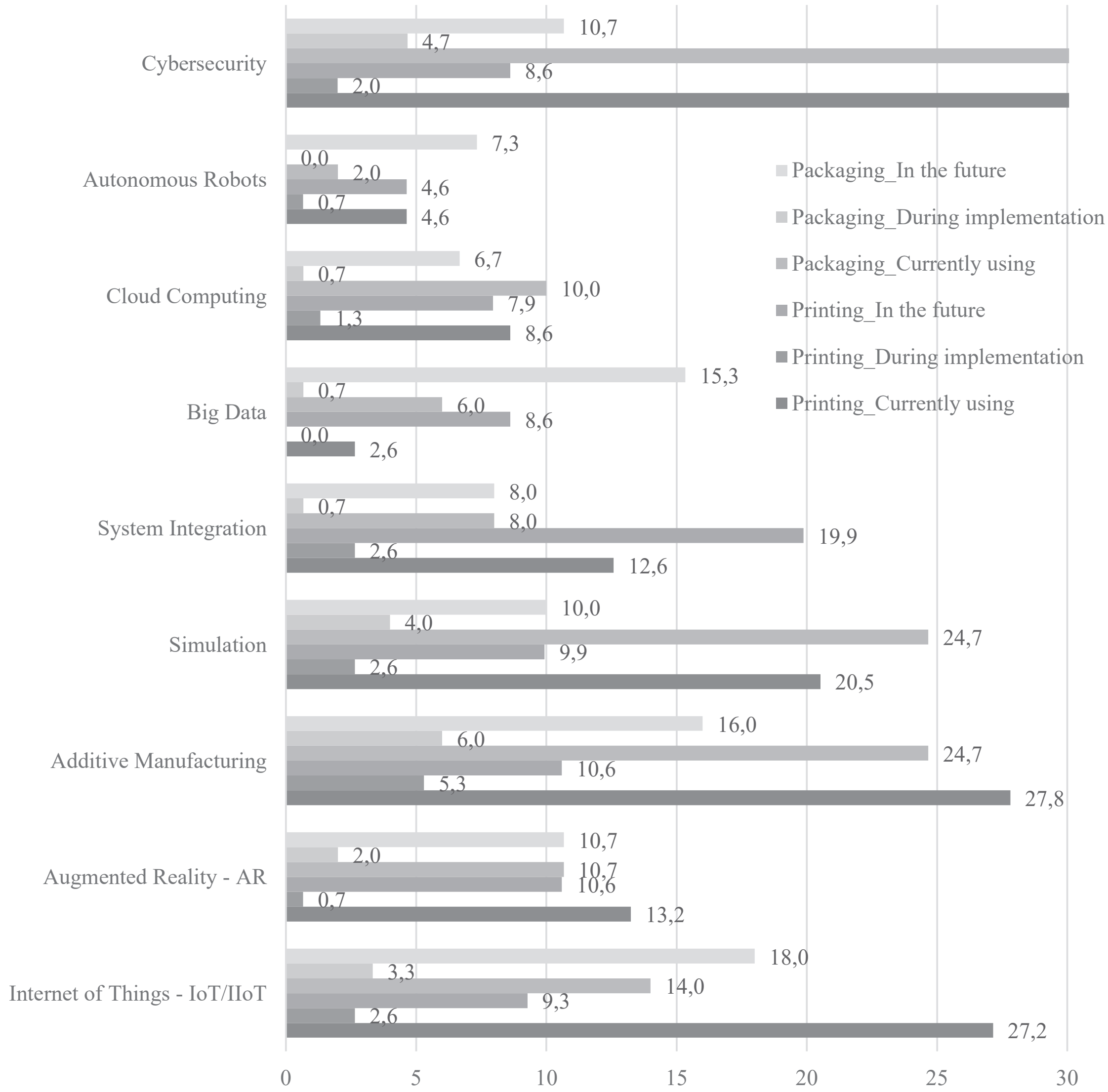

Fig. 7. Percentage of companies interested in the I4.0 technologies

Tab. 3. Spearman's rank order correlation (rho) for I4.0 technologies vs. SD practices on a different level of implementation. Red colour if p<0.05

Variable	SD_Currently using	SD_During implementation	SD_In the future
I4.0_Currently using	0.437	-0.027	-0.149
I4.0_During implementation	0.092	0.113	0.059
I4.0_In the future	0.077	0.098	0.412

achieved by comparing the I4.0 technologies and the SD practices in the future (0.41). Based on the results obtained, companies that use I4.0 technologies are also implementing SD practices. A similar situation applies to the future: companies that intend to use I4.0 technologies are also interested in implementing SD practices. Thus, a hypothesis can be put forward that should be subjected to more in-depth research: the use of I4.0 technologies enables/facilitates the realisation of SD practices and/or the realisation of SD practices requires the use of I4.0 technologies. Table 3 shows the three main reasons to implement I4.0 technologies for printing and packaging companies. Improvement of the quality of products and services was considered the most important, followed by reducing operating costs and opening new business opportunities and areas. Notably, most respondents identified these reasons as either main or

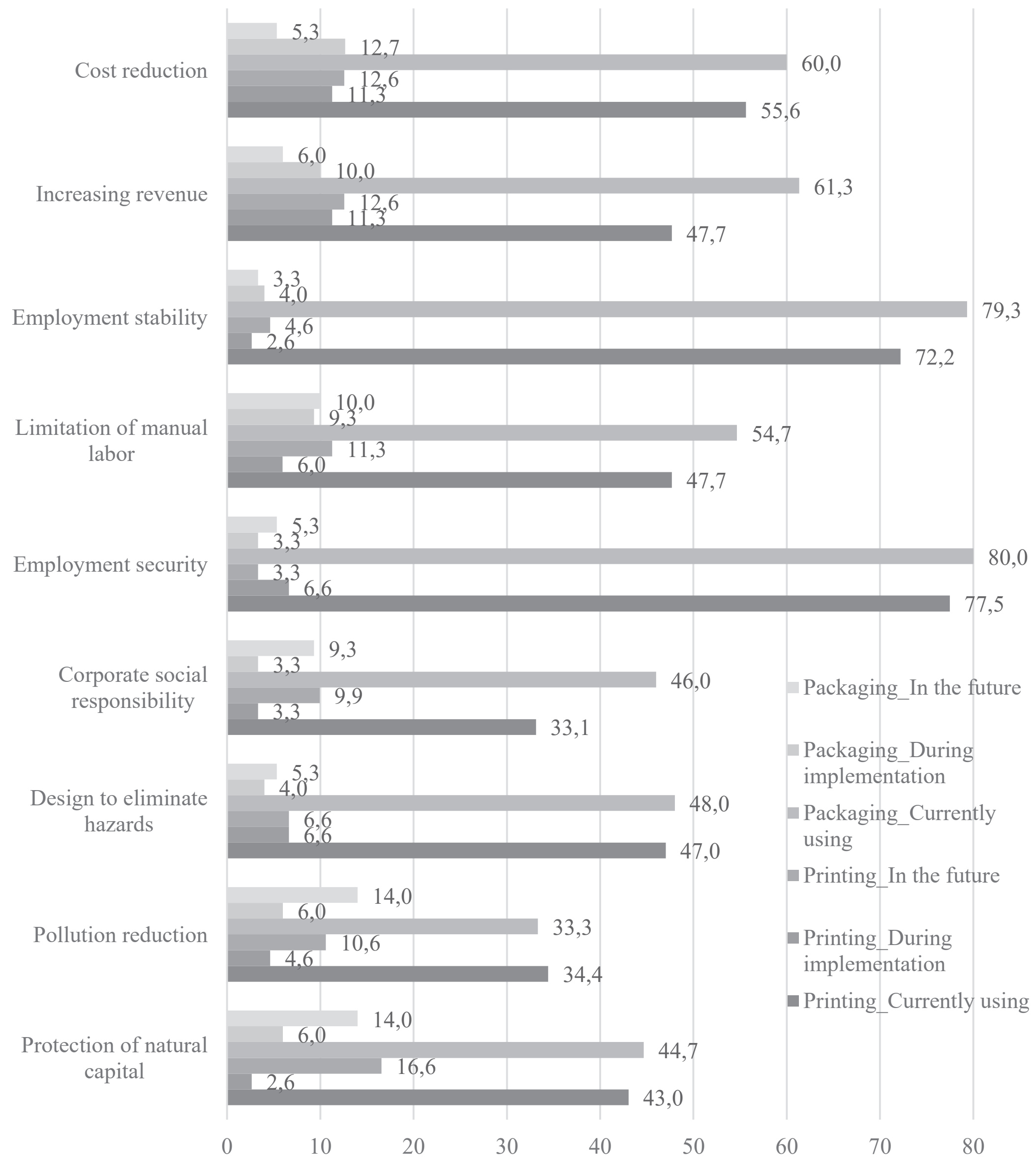

Fig. 8. Percentage of companies interested in the SD practices

additional. The results regarding the percentage distribution of responses are very similar for both industries. However, more respondents indicated the three reasons as the main in the packaging industry and as an additional in the printing industry.

Table 5 provides the reasons for implementing I4.0 technologies versus company size. Only those reasons for implementing the I4.0 technologies, which met the Chi-square test p-value <0.005 requirements and a minimum of four cases in each category, are presented. Concerning the above conditions of conducting chi-square tests, three main reasons for implementing the I4.0 technologies are statistically significant, i.e., (1) gaining a lasting strategic advantage, (2) opening up new opportunities and business areas, and (3) following market trends. Gaining a lasting strategic advantage was the main reason for implementing the I4.0 technologies more for small and medium companies rather than for micro companies. The latter group had no such reason. Nowadays, small (41 % of respondents) and mostly medium (50 % of respondents) printing and packaging companies need to demonstrate and gain strategic advantage by reaching for more advanced methods and techniques like Industry 4.0 technologies.

Looking at the next statistically significant reason for implementing the I4.0 technologies in the print-

Tab. 4. Two-way table: reasons for the implementation of I4.0 technologies depending on industry type. Red colour if p<0.05

	Industry	No reason	Additional reason	Main reason	Total
Reduction of operating costs	Printing	49.35%	61.00%	42.31%	143
	Packaging	50.65%	39.00%	57.69%	138
	Total	77	100	104	281
	Statistics	Chi^2	df	p	
	Chi^2 Pearson	7.228	df=2	p=0.027	
	Chi^2 NW	7.275	df=2	p=0.026	
Opening up new opportunities and business areas	Printing	44.19%	60.55%	44.05%	141
	Packaging	55.81%	39.45%	55.95%	138
	Total	86	109	84	279
	Statistics	Chi^2	df	p	
	Chi^2 Pearson	7.175	df=2	p=0.028	
	Chi^2 NW	7.216	df=2	p=0.027	
Improving the quality of prod-ucts and services	Printing	42.22%	61.47%	45.38%	145
	Packaging	57.78%	38.53%	54.62%	139
	Total	45	109	130	284
	Statistics	Chi^2	df	p	
	Chi^2 Pearson	7.807	df=2	p=0.020	
	Chi^2 NW	7.861	df=2	p=0.020	

Tab. 5. Two-way table of main reasons for implementing I4.0 technologies vs. company size. Red colour if p<0.05

	Company size	No reason	Additional reason	Main reason	Total
I4.0 Gaining a lasting strategic ad-vantage	Micro	52.69%	21.56%	25.75%	167
	Small	25.00%	33.75%	41.25%	80
	Medium	23.08%	26.92%	50.00%	26
	Total	114	70	89	273
		Chi^2	df	p	
	Chi^2 Pearson	22.14643	df=4	p=0.00019	
	Chi^2 NW	22.69090	df=4	p=0.00015	
I4.0 Opening up new opportunities and business areas	Micro	33.73%	38.55%	27.71%	166
	Small	29.76%	44.05%	26.19%	84
	Medium	20.00%	20.00%	60.00%	25
	Total	86	106	83	275
		Chi^2	df	p	
	Chi^2 Pearson	12.43334	df=4	p=0.01440	
	Chi^2 NW	11.39806	df=4	p=0.02244	
I4.0 Following market trends	Micro	39.88%	30.64%	29.48%	173
	Small	23.81%	45.24%	30.95%	84
	Medium	30.77%	23.08%	46.15%	26
	Total	97	97	89	283
		Chi^2	df	p	
	Chi^2 Pearson	10.93832	df=4	p=0.02727	
	Chi^2 NW	10.84133	df=4	p=0.02841	

Tab. 6. Two-way table of main reasons for implementing SD practices vs. company size. Red colour if p<0.05

	Company size	No reason	Additional reason	Main reason	Total
SD Gaining a lasting strategic advantage	Micro	47.88%	31.52%	20.61%	165
	Small	24.05%	35.44%	40.51%	79
	Medium	30.77%	26.92%	42.31%	26
	Total	106	87	77	270
		Chi^2	df	p	
	Chi^2 Pearson	18.09749	df=4	p=0.00118	
	Chi^2 NW	18.39029	df=4	p=0.00104	
SD Employment reduction	Micro	75.63%	18.13%	6.25%	160
	Small	57.14%	25.97%	16.88%	77
	Medium	50.00%	23.08%	26.92%	26
	Total	178	55	30	263
		Chi^2	df	p	
	Chi^2 Pearson	16.79438	df=4	p=0.00212	
	Chi^2 NW	15.83228	df=4	p=0.00325	
SD Quick improvements	Micro	38.65%	42.94%	18.40%	163
	Small	27.27%	41.56%	31.17%	77
	Medium	24.00%	28.00%	48.00%	25
	Total	90	109	66	265
		Chi^2	df	p	
	Chi^2 Pearson	13.31397	df=4	p=0.00984	
	Chi^2 NW	12.59180	df=4	p=0.01345	
SD Following market trends	Micro	37.95%	38.55%	23.49%	166
	Small	30.38%	37.97%	31.65%	79
	Medium	20.00%	20.00%	60.00%	25
	Total	92	99	79	270
		Chi^2	df	p	
	Chi^2 Pearson	14.70820	df=4	p=0.00535	
	Chi^2 NW	13.55807	df=4	p=0.00885	

ing and packaging industry, which is opening new opportunities and business areas, it is clear that it was the main reason for medium enterprises (60 % of respondents). For small companies, it was only an additional reason (44 % of respondents), as well as for micro companies (39 % of respondents). Following market trends was also the main reason for the medium enterprises (46 % of respondents) to implement the I4.0 technologies, rather than for the other companies, where again it was an additional reason for small companies (45 % of respondents), and it was no reason for micro companies (40 % of respondents).

Table 6 consists of four main statistically significant reasons for implementing the SD practices versus company size by the assumption: (1) the same conditions of chi-square tests as above and (2) listed four main reasons for implementing the SD practices, i.e., (1) gaining a lasting strategic advantage, (2) employment reduction, (3) quick improvements, and (4) following market trends. Gaining a lasting strategic advantage was the main reason for small (41 % of respondents) and medium companies (42 % of respondents), and it was no reason for micro companies (48 % of respondents). These results correlate with the same main reasons for the I4.0 technologies because micro-enterprises are not as interested in implementing I4.0 technologies and SD practices to achieve a strategic advantage. Employment reduction is statistically significantly important for implementing SD practices. Still, it confirmed that the respondents of each company size answered that employment reduction is not the main reason for implementing the SD practices. Respondents who mostly claimed that it was no reason were from micro-enterprises (76

%), small companies (57 % of respondents), and medium companies (50 % of respondents). Quick improvements were the main reason for medium companies' respondents (48 %). For micro and small companies, this was an additional reason for implementing the SD practices, respectively, 43 % and 42 % of respondents. Following market trends was the main reason for implementing the SD practices for medium printing and packaging companies, i.e., 60 % of respondents. This was only an additional reason in micro and small companies, respectively, 39 % and 38 % of all respondents.

4. Discussion of the results

This study aimed to diagnose the level of the use of I4.0 technologies and the best practices for SD. The research sample mainly included SMEs. While responses were obtained from four large enterprises, they were not considered for further analysis due to the sample size. Thus, surveys covered SMEs only. The level of awareness both in I4.0 and SD was higher in medium-sized enterprises than in small-sized ones. The research showed that advanced companies using I4.0 technologies also apply SD practices. This correlation is especially strong for medium-sized enterprises. Another important observation is that among enterprises interested in I4.0 and SD solutions, the largest percentage comprised those already using or intending to use them in the future. At the same time, the smallest number represented enterprises in the implementation process. These may prove to be relatively simple solutions that individual companies are interested in (i.e., short implementation time).

The research results indicate that for both I4.0 and SD, most surveyed enterprises are currently not interested in using I4.0 technologies and SD practices in their operations. However, the study does not show any significant (from a statistical point of view) correlation between the implemented I4.0 technologies and the implemented SD best practices.

In addition, the research shows that printing and packaging companies are more advanced in using SD best practices than in using I4.0 technologies. The authors believe this is mainly due to the requirements for products/services set by the surveyed enterprises for their customers. Due to growing environmental concerns about packaging and printing, environmental legislation and final consumer demands for sustainable packaging have increased, encouraging businesses to consider greener materials and cleaner manufacturing processes (Nguyen et al., 2020). In addition, businesses can utilise SD practices to attract investors by providing positive signals to the product and financial markets (Zhang, Wang & Dong, 2023). Typical technical considerations towards sustainable packaging include reducing raw materials, using single- and non-toxic materials, increasing recycled contents, optimising packaging size and volume, seeking reusable options, and providing clear labels to deliver correct recycling information.

Entrepreneurs lack conviction and understanding of how I4.0 technologies can generate added value for their business. For this reason, suppliers of solutions and/or technologies and business environment units should devote more effort towards promoting the I4.0 concept and SD best practices and propagating specific applications in business practice to build sustainable business performance. Companies in the packaging industry are more experienced in the use of I4.0 technologies than companies in the printing industry. Field research has shown differences between the technologies used in the printing and packaging industries. In the authors' opinion, this differentiation should be further examined, as there are no obvious reasons. In contrast, printing and packaging companies often exchange large files with customers (e.g., 2D/3D files with patented structural design in packaging), which requires a high level of cybersecurity in both industries.

The responded enterprises from the packaging and printing sectors reported that cybersecurity is the most frequently adopted I4.0 technology. Most industry sectors, including the packaging and printing sectors, are very active in having safer and more efficient cybersecurity systems as they are highly dependent on information technology infrastructure for the overall workflow (e.g., R&D, finance, manufacturing, and quality assurance)(Ani, He & Tiwari, 2017). Approximately a quarter of the studied companies in the packaging and printing sectors reported using additive manufacturing technology. In the packaging and printing industries, additive manufacturing technology, such as 3D printing, is typically applied to prototype physical mock-ups and fabricate packaging parts. More than 20 per cent of the companies that responded from both the packaging and printing industries also reported using simulation technologies. In the packaging industry, diverse simulation technologies are used to predict mechanical properties and interactions of packaging components (e.g., finite element analysis), calculate the best packaging size and combination for optimised storage and shipping (e.g., packaging/pallet configuration analysis), and quantify the environmental footprint of packaging (e.g., life cycle analysis). Print simulation software that virtually reproduces various printing conditions in the printing industry is often used for training, performance enhancement, process analysis, and skills assessment. The results showed that Internet of Things (IoT) technologies are more often adopted in the printing industry (27.2 %) than in the packaging industry (14 %). This result implies that the digitalisation and automation levels of the surveyed printing industry are higher than those of the surveyed packaging industry. Manual operations may be involved in the surveyed packaging industry.

Enterprises perceive technologies as investments, particularly I4.0 ones. For this reason, the economic calculation related to implementing a given solution is crucial to them. It is worth noting that the smaller the enterprise, the shorter its planning horizon. This must also be considered when promoting I4.0 and SD solutions among enterprises. Other important reasons for implementing the I4.0 technologies are the reduction of employment and quick improvements, which may indicate the willingness of enterprises to improve operational efficiency. As costs are determined to be the biggest obstacle when implementing I4.0 technologies, as shown by the authors' of the other research (Gladysz et al., 2021), it is not surprising that micro-enterprises are not as interested in the implementation of these technologies to achieve a strategic advantage as small and medium companies, i.e., 53 % of respondents answered that there was no reason.

The quantitative research produced more results, but it is challenging to draw inferences. Initially, a correlation matrix of I4.0 technologies (Table A1) and SD practices (Table A2) was made, which allowed for the comprehension of the correlation between the relevant I4.0 technologies and SD practices. A dependency matrix was also created between I4.0 technologies and SD practices (Table A3), allowing a preliminary assessment of how individual I4.0 technologies are linked to SD practices. However, these results require more in-depth research because little can be deduced from the statistical analyses.

Integrating the use of I4.0 technologies and SD practices to influence business strategy is a future research direction. Additional research may be focused on the application of individual solutions in an individual (multinational) enterprise, i.e., technology and/or good practices, in terms of the separate SDGs to build sustainable business strategies. The authors believe this requires additional studies among enterprises with experience in I4.0 technologies and SD best practices. Wider research might include examining the "supply part", i.e., enterprises offering, integrating, and implementing I4.0 technologies and the SD best practices for other entities. Despite the insignificant correlation (0.44) between the adopted I4.0 technologies and SD practices, finding synergies and trade-offs is still a long way to go. It indicates that the topic needs to be more widely discussed across multinational enterprises, and their experiences need to be disseminated and compared to boost enterprises' awareness of sustainable implications through digitalisation. On the other hand, "awareness is crucial for inclusive actions" (Gupta & Rhyner, 2022), accelerating entrepreneurs to make more sustainable decisions through rational investments in technology 4.0. Moreover, other research in the field may lead to different findings and conclusions.

Conclusions

The interviews that formed the basis for the quantitative research allowed for the conclusion that printing and packaging companies have a good or cursory awareness of the implementation of SD objectives at all three levels of management. This was also confirmed by responses regarding SD activities: various initiatives are implemented in each TBL area in line with SD policies and objectives. The picture becomes complete with the finding that SD implementation is, for most companies interviewed, at the implementation stage in selected areas or the whole company.

This allowed the authors to conclude that companies in the printing and packaging sector are quite advanced in achieving sustainability. It was also found during the interviews that some I4.0 technologies are being used in the printing and packaging sector, although the degree of progress in implementing/using I4.0 was not as high as for SD. Therefore, it was decided to investigate the degree of implementation of I4.0 and SD practices in printing and packaging companies with a representative sample and to see if and to what extent I4.0 technologies support the implementation of SD. This, in turn, allowed verifying (survey) the qualitative results (interviews) quantitatively and disclosing a complete view of the advanced level of companies in the areas of I4.0 technology and SD practices.

The authors' investigations state that adopting I4.0 technologies and sustainability practices must establish a "mechanism" of decision-making and actions that profile integrated thinking influenced by sustainability practices. In this way, these enterprises reinforced by sustainable initiatives may contribute to achieving sustainable development objectives through leveraging digital technologies. The implications for decision-makers underlie the understanding and adoption of sustainable best practices and digital transformation requirements. It helps boost and create value with implications for sustainable business models (George & Schillebeeckx, 2022).

The study is limited due to the considered sampling and implementation of selected statistical analyses. The study is focused on selected SD and I4.0 relationships. Those limitations, however, are due to the diagnostic nature of the study and, at an early stage of research, seem unavoidable. The purpose of the study was to initially identify the existing relationships between SD and I4.0 in the selected sector, which will allow for more in-depth analysis and research in the future, e.g., more companies will be examined, the geographical coverage will increase, statistical analyses will be extended, the relationships identified within this paper will be examined.

The study was conducted in the Polish economy, where the studied sectors (printing and packaging) play important roles. Therefore, findings are limited to the Polish economy and SMEs and are mostly of a diagnostic nature. Broader generalisation would require deepening and widening the scope of the study. A plan of multiple case studies will achieve this research direction. Multiple case studies would deepen the study's scope and enable more detailed explanations of phenomena lying behind diagnosed state-of-art. In parallel, the study is currently widened by introducing it to the setting of another economy. For this purpose, the Canadian printed packaging sector was chosen, and the study was already triggered.

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Appendices

Tab. A1. Spearman's order correlation (rho) matrix of I4.0 technologies. Relevant variables in red colour (p<0.05)

Variable	Internet of Things - IoT/IIoT	Augmented Reality - AR	Additive Manufacturing	Simulation	System Integration	Big Data	Cloud Computing	Autonomous Robots	Cybersecurity
Internet of Things – IoT/IIoT	1.000	0.424	**0.428**	0.409	0.161	0.281	0.357	0.294	0.315
Augmented Reality – AR	0.424	1.000	0.378	0.418	0.214	0.245	0.378	0.289	0.256
Additive Manufacturing	**0.428**	0.378	1.000	0.408	0.205	0.357	0.310	0.177	0.393
Simulation	0.409	0.418	0.408	1.000	0.297	0.270	0.379	0.297	0.266
System Integration	0.161	0.214	0.205	0.297	1.000	0.216	0.176	0.291	0.197
Big Data	0.281	0.245	0.357	0.270	0.216	1.000	0.279	0.291	0.158
Cloud Computing	0.357	0.378	0.310	0.379	0.176	0.279	1.000	0.425	0.281
Autonomous Robots	0.294	0.289	0.177	0.297	0.291	0.291	0.425	1.000	0.225
Cybersecurity	0.315	0.256	0.393	0.266	0.197	0.158	0.281	0.225	1.000

Tab. A2. Spearman's order correlation (rho) matrix of SD practices. Relevant variables in red colour (p<0.05)

Variable	Protection of natural capital	Pollution reduction	Design to eliminate hazards	Corporate social responsibility	Employment security	Limitation of manual labour	Employment stability	Increasing revenue	Cost reduction
Protection of natural capital	1.000	0.470	0.276	0.432	0.275	0.253	0.219	0.274	0.373
Pollution reduction	0.470	1.000	0.384	0.453	0.227	0.177	0.188	0.313	0.248
Design to eliminate hazards	0.276	0.384	1.000	0.377	0.247	0.175	0.092	0.241	0.293
Corporate social responsibility	0.432	0.453	0.377	1.000	0.398	0.370	0.231	0.380	0.347
Employment security	0.275	0.227	0.247	0.398	1.000	0.281	0.323	0.302	0.272
Limitation of manual labour	0.253	0.177	0.175	0.370	0.281	1.000	0.204	0.222	0.178
Employment stability	0.219	0.188	0.092	0.231	0.323	0.204	1.000	0.346	0.299
Increasing revenue	0.274	0.313	0.241	0.380	0.302	0.222	0.346	1.000	**0.559**
Cost reduction	0.373	0.248	0.293	0.347	0.272	0.178	0.299	**0.559**	1.000

Tab. A3. Spearman's order correlation (rho) matrix of I4.0 technologies vs. SD practices. Relevant variables in red colour (p<0.05)

Variable	Protection of natural capital	Pollution reduction	Design to eliminate hazards	Corporate social responsibility	Employment security	Limitation of manual labour	Employment stability	Increasing revenue	Cost reduction
Internet of Things – IoT/IIoT	0.337	0.311	0.185	0.405	0.128	0.268	0.148	0.194	0.153
Augmented Reality – AR	0.268	0.249	0.178	0.304	0.170	0.226	0.089	0.161	0.192
Additive Manufacturing	0.401	0.361	0.223	0.343	0.194	0.325	0.173	0.170	0.189
Simulation	0.312	0.301	0.157	0.316	0.150	0.152	0.069	0.085	0.102
System Integration	0.191	0.218	0.186	0.212	0.198	0.230	0.188	0.175	0.160
Big Data	0.233	0.185	0.103	0.190	0.086	0.258	0.046	0.084	0.046
Cloud Computing	0.230	0.251	0.178	0.259	0.125	0.157	0.141	0.122	0.140
Autonomous Robots	0.130	0.190	0.127	0.172	0.051	0.139	0.161	0.082	0.101
Cybersecurity	0.302	0.351	0.177	0.382	0.189	0.186	0.181	0.182	0.257

Research, *35*(1), 219-239. doi: 10.1057/s41287-021-00499-6