RESEARCH REPORT

Industrial digital technologies for UK SME exporting manufacturers.

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August 2023

Abstract:

This research project examines the drivers, barriers, and performance outcomes of adopting industrial digital technologies (IDT) in UK manufacturing firms and develops interventions that facilitate IDT adoption to enhance their performance in international markets. The project collected primary data from focus groups, interviews and a survey of 303 UK export manufacturing SMEs. The outcomes from the primary research were used to develop an IDT adoption toolkit and decision-making model. The toolkit allows UK SME manufacturers to benchmark their level of IDT adoption against the industry standard, to identify which specific IDTs will have the greatest impact on improving their business performance across many indicators, and additionally can direct users to the digital solutions most relevant to their needs, thereby simplifying the process of IDT adoption.

This work was supported by the UKRI Made Smarter Innovation Challenge and the Economic and Social Research Council via InterAct [Grant Reference ES/W007231/1]

To cite this research report: Pham, H, Wong, C.Y ,and Hodgett, R. (2023). Industrial digital technologies for UK SME exporting manufacturers. https://business.leeds.ac.uk/faculty/dir-record/research-projects/2086/industrial-digital-technologies-for-uk-sme-exporting-manufacturers.

Executive summary

This research project examines the drivers, barriers, and performance outcomes of adopting industrial digital technologies (IDT) in UK manufacturing firms and develops interventions that facilitate IDT adoption to enhance their performance in international markets. The project collected primary data from focus groups, interviews and a survey of 303 UK export manufacturing SMEs.

The outcomes of the focus group and interviews are briefed as follows. SMEs see the potential benefits of IDTs, but their perceived risks of investing in IDTs come from the fear of losing investment from a wrong choice of IDTs and being locked into inflexible software that involves regular payment and the lack of control over data and security. SMEs prefer IDTs that are easier to adopt and set up with proven use cases and those that offer opportunities to collaborate, for example, with buyers. While access to knowledge about IDTs was reported as difficult partly due to a lack of collaboration to share guidance or best practices, SMEs are not very keen to use a community of practice with potential competitors. SMEs feel the information provided by IDT suppliers is less reliable. SMEs would like access to impartial advice from honest third parties rather than relying on technology suppliers. SMEs believe the type and scale of government support in IDT adoption is insufficient. They perceive the business support landscape as "fragmented" and confusing. The qualitative research findings were used to develop the survey questionnaire.

The outcomes from the quantitative research show that there are many new IDTs that many UK SMEs have not adopted. Moreover, when adopting IDTs, SMEs aim to achieve responsiveness, in addition to quality, efficiency, flexibility and transparency. The key drivers that promote the adoption of IDTs among SMEs include pressure from business partners, laws/regulations and governmental funding, in addition to access to impartial advice, required data, and human and financial capital. The complexity and maturity of the technologies also play important roles. Survey results also indicate that SMEs need a clear vision of needs and change, not a fixed road map for adoption. More importantly, the quantitative research shows significantly positive impacts of some IDTs on several indicators of operational performance, export performance and financial performance of IDT adopters.

The outcomes from the primary research were used to develop an IDT adoption toolkit and decision-making model. The toolkit allows UK SME manufacturers to benchmark their level of IDT adoption against the industry standard, to identify which specific IDTs will have the greatest impact on improving their business performance across many indicators, and additionally can direct users to the digital solutions most relevant to their needs, thereby simplifying the process of IDT adoption.

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1. Introduction

SMEs are important for the UK economy, accounting for 96.3% of UK businesses in 2019 (ONS, 2020). Although only about 10% of SMEs are exporters, they contribute significantly to the UK's export turnover, accounting for over 50% of UK exports in 2008 and 2009, with the recent decreases possibly due to declining competitiveness in international markets, with the total falling to 32% in 2018 (ONS, 2020). To reverse this decline, and in order to help SMEs sustain and improve export performance, the UK government has launched several support schemes for SMEs (BEIS, 2018), notably, identifying the strategic role of digitalisation in driving the UK's productivity, especially in the manufacturing sector (DCMS, 2022), and commissioning several organisations, including Made Smarter, to lead the UK's plans to grow manufacturing through industrial digital technologies (IDTs).

IDTs including such technologies as the industrial internet of things, robotics, artificial intelligence (AI), augmented and virtual reality (AVR), have the potential to radically transform how firms manufacture and deliver products. These IDTs enable the revolution toward smart manufacturing, which is a fully integrated, collaborative production ecosystem that responds, in real-time, to ever-changing demands (Lu & Weng, 2018). This means the integration of IDTs into every facet of manufacturing is a strategic priority for manufacturers (Ghobakhloo & Ching, 2019).

However, research indicates UK SME manufacturers have not effectively utilised the government's support and IDTs to enhance export performance. Research by Make UK (2020) shows that adoption of IDTs is not high across the board; for example, 45% of manufacturers are aware of the benefits of IDTs but few are adopting them, especially SMEs. This indicates a low level of investment in IDTs by UK SME manufacturers, which can make exporters less competitive. A weak or vague business case for investment in IDTs can weaken SME exporters. Therefore, we need research to support decisions to adopt IDTs for enhancing UK SME manufacturers' export performance.

In responding to this necessity, this research project examines the adoption of IDTs in UK export manufacturing firms and suggests interventions that facilitate the adoption of IDTs in the UK manufacturing small and medium enterprises (SMEs) to enhance performance in international markets. The project fulfils six objectives:

- Investigate how UK SME export manufacturers adopt and utilise IDTs, the needs, risks and challenges facing them when adopting IDTs.
- Identify relevant IDTs that UK SME export manufacturers can adopt to enhance export performance.
- Develop a decision-making model that enables SME export manufacturers to select and utilise relevant IDTs to enhance export performance (named thereafter as the IDT decision-making model).

- Develop a toolkit for adoption and utilisation of IDTs to enhance export performance.
- Promote diffusion of IDTs in the UK manufacturing sector through disseminating research outcomes.

To achieve its objectives, this project undertook mixed-methods research in collaboration with two partners. The research team collaborated with David McKee from Slingshot, a digital solution company and Neil Harriman from Oxford Innovation Company (OIC) which runs the Manufacturing Growth Programme to engage with UK SME export manufacturers.

This project comprises three work packages. ***WP1*** *comprised primary research*, collecting data from firm managers, industry experts, practitioners, policymakers and academics to understand the needs, the risks and challenges facing UK SME export manufacturers when they use IDTs in managing their production and export. It involved both qualitative and quantitative elements. Qualitative research consisted of a focus group conducted in the form of a roundtable workshop on 7th February 2023 (hosted by Clarion Solicitors Ltd in Leeds) and a series of interviews conducted in April 2023. Quantitative research involved a survey of 303 UK export manufacturing SMEs. ***WP2*** *developed the decision-making model*. The findings from WP1 informed the development of the IDT decision-making model. ***WP3*** *disseminated project outcomes through* a dissemination workshop (hosted by Leeds University Business School on 13th July 2023), direct communication about the research outcomes (i.e., the IDT adoption toolkit) to 493 UK manufacturing SMEs, presenting research outcomes at academic conferences, news articles in Business Daily, SME Today, Factory & Handling Solutions, The Manufacturer, Dealer Support, Leeds University's Research News and LinkedIn. The workshop received 88 participants (both in person and online) who were representatives of SME manufacturers, digital solutions providers, and other stakeholders including policymakers from the Department for Business and Trade and SMEs supporting agencies, digital solution firms, researchers and academics interested in the use of IDTs in manufacturing sector and international business.

2. Industrial digital technologies

Digital technology describes technologies that utilise hardware, software, and digital data or binary code to create, process, store, transmit, display, and communicate information (Autio et al., 2021). It encompasses various technologies that have transformed various aspects of the business world.

ICT and the Internet are two original digital technologies that serve as bases for the development and implementation of digital technologies applied in the business world to facilitate the various business functions conducted by firms.

The digital technologies developed to serve a firm's business processes can be categorised based on business process and functions: digital enterprise & resource management, decision support system technologies, digital marketing and sales technologies, smart supply chain management and smart manufacturing technologies. Noteworthily, the smart manufacturing technologies that are also known as IDTs are completely reshaping the business environment, paving the way for the fourth industrial revolution, which has been dubbed Industry 4.0.

Industry 4.0 digital technologies comprise technologies that allow real-time monitoring, remote control of devices, and production machinery through networked infrastructure, eventually realising a more direct integration and synchronisation between the physical and virtual worlds. Given the broad remit of 4.0 technologies, we cover all the current technologies used in industry and name them IDTs. We provide definitions and applications of each specific technology in Table A1 in the appendix.

3. The adoption of industrial digital technologies in UK manufacturing SMEs

3.1. Key findings from the qualitative research conducted through workshop and interviews.

- SMEs do see the potential benefits of IDTs, e.g., to increase efficiency, responsiveness, transparency and customer satisfaction.
- The risk of investing in IDTs comes from the fear of losses stemming from investments (in terms of cost, training and efforts to adapt to a new culture) into a wrong choice of IDTs (that is irreversible) and being locked-in into inflexible software that involves a regular payment and the consequent lack of control over data and security this involves.
- SMEs prefer IDTs that are easier to adopt (lower barriers of entry) and set up with proven use cases and those that offer opportunities to collaborate (especially for building up new relationships or finding buyers).
- While access to knowledge about IDTs was found to be difficult partly due to a lack of collaboration around sharing guidance on best practices, SMEs are not very keen to participate in communities of practice specifically for IDTs (to avoid sharing with competitors).
- SMEs feel information provided by IDT suppliers to be less reliable. SMEs would prefer access to impartial advice from honest brokers rather than relying on technology suppliers (who may offer expensive solutions not necessarily needed by SMEs).
- SMEs believe that the type and scale of government support in IDT adoption is insufficient. The business support landscape is "fragmented," lacking a single source of independent advice, taking long time and confusing.

- Training and cultural change towards digital transformation are quite challenging for SMEs because it is difficult for employees to see why they need to change and the improvements that IDTs can bring.

3.2. Findings from quantitative research

This section presents the results of the IDT4UKSMEs survey. The survey was conducted in May and June 2023 using the online platform powered by Qualtrics. Qualtrics sent invitations to all UK SMEs, calling for participation in the survey. The screening criteria for qualifying to participate in the survey is that potential respondents need to be working, to be in either upper or lower management, and that their firm needs to be an SME (having a total employee number of less than 250), and finally to operate in manufacturing and exports. At each stage, if a respondent did not meet the criteria, they were sent to exit the survey. The survey received 303 valid responses. Data analysis was conducted using SPSS 28. The following subsections present findings from the data analysis. In particular, Section 3.2.1 describes the demographic characteristics of the sample. In section 3.2.2 findings on respondents' current level of adoption of IDTs are presented, following on from which 3.2.3 provides insights into the motivations driving respondent firms' adoption of IDTs. 3.2.4 presents findings on incentives barriers to adoption of IDTs. Finally, section 3.2.5 presents findings on the impact of IDT adoption on UK SMEs, including the extent to which digitalisation projects undertaken by respondents achieved their goals, as well as the impact of adoption on specific performance indicators.

3.2.1 Sample characteristics

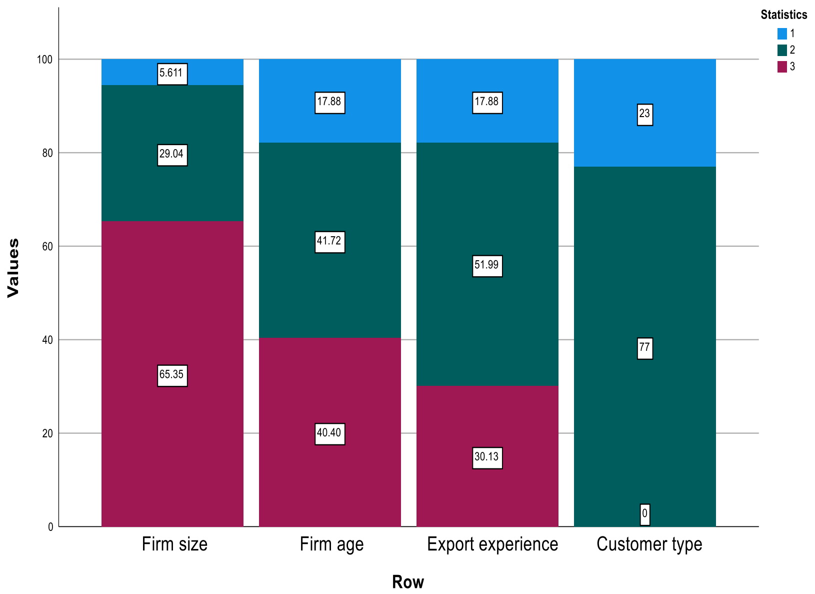
The majority of firms (65.35%) that responded to the survey were of medium size (employing 49-250 people), while 29.04% of firms in the sample can be categorised as small (employing 10-49 people). Finally 5.61% of respondents to the survey were micro-SMEs (employing 1-9 people). The varying ages of firms in the sample was more evenly distributed, with 41.72% of respondent firms being incorporated 5-10 years ago, 40.4% being more than 10 years old, and 17.88% of respondents being relatively new enterprises, incorporated less than 5 years ago.

In terms of types of customers served, 77% of respondents operated on B2C (Business to Consumer) business models, while 23% were B2B (Business to Business). None of the firms responding to the survey operated on a B2G (Business to Government) model. Just over half of respondents (51.99%) were relatively experienced with exporting, possessing 10 years or more of exporting experience, while 30.13% possessed between 5- and 10-years exporting experience, and 17.88% of respondents had less than 5 years of experience with exports.

Figure 1 presents the distribution of firms for the variables described above. For firm size, the number of micro-enterprise are colour coded as light blue, accounting for 5.6%; the number of small firms as dark green, accounting for 29%, and medium size firms are represented by magenta, accounting for 65% . For firm age, new firms are coded light blue and account for

17.88% of the sample, firms that are 10 years or older are coded as dark green, accounting for 41.72% of the sample, and firms that are 5-10 years old are represented by magenta, accounting for 40.4% of the sample. In terms of export experience, firms with less than 5 years of exporting experience are coded light blue and account for 17.88% of the sample, firms with 10 years or more of exporting experience are coded dark green and account for 51.99% of the sample, and firms with 5-10 years of exporting experience are represented by magenta, and account for 30.13% of the sample. For customer type, B2C is colour-coded as dark green and accounts for 77% of the sample, while B2B is represented as light blue, accounting for 23% of the sample.

Figure 1 Distribution of firm size, firm age, export experience and customer type.



3.2.2 The current state of IDT adoption

The first part of the study collected data on respondent firms' adoption of IDTs. These were classified across the following 6 categories:

1. Digital marketing and sales technologies.
2. Enterprise and resource management technologies.
3. Digital supply chain management technologies.
4. Digital decision support technologies.

5. Digital design and visualisation technologies.

6. Smart manufacturing technologies.

Respondents were asked to rate their level of adoption of specific IDTs in each category on a Likert scale with 5 options: Non-use (1), Tested but not used (2), Low use (3), Moderate use (4), and Intensive use (5).

Across all of the above categories of IDTs results for respondents' adoption of IDTs were quite encouraging, with respondents on average being at the low to moderate use level for all IDTs in the survey. For detailed descriptive statistics of IDT adoption levels across all 6 categories, see Table A2 in the Appendix. Specifically, for the category Digital marketing and sales, the IDT with the lowest mean adoption score was AI based marketing, with a mean score of 3.77, and the most adopted technology in this category was CRM (Customer Relationship Management) with a mean score of 4.17. These results align with expectations, since, despite becoming increasingly accessible in recent years with the release of products such as OpenAI's ChatGPT, AI remains a frontier technology and it therefore stands to reason that respondents would be at an earlier stage of adoption in this case. CRM by contrast is currently fairly ubiquitous; thus, it follows that a greater number of respondents would be at a more advanced stage of adoption here. See Figure 2a for the mean scores of the **specific digital marketing and sales tools.**

Figure 2a: Mean scores of adopting specific digital marketing and sales tools.

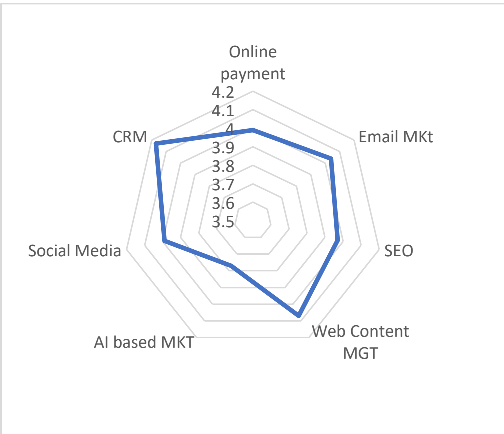
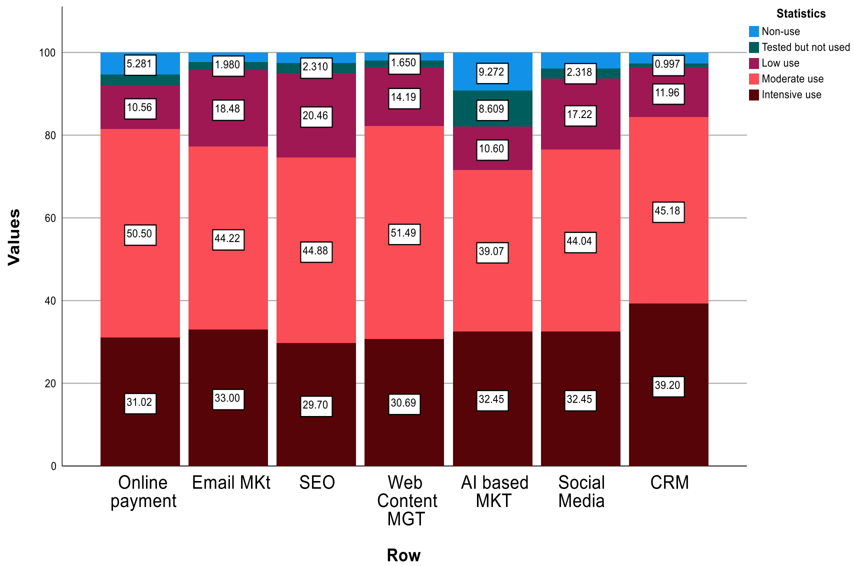


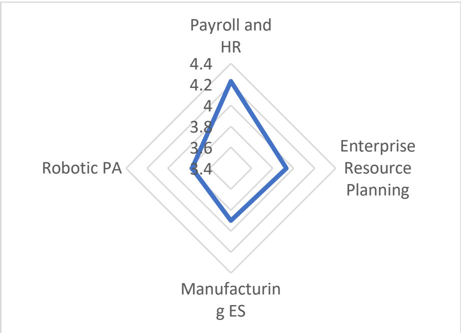
Figure 2b presents the distribution of scores of the adoption of each IDT in this category. In the below, light blue represents non-use, dark green represents that the IDT has been tested but not adopted, magenta represents that IDT is currently little used, orange that the IDT is moderately used, and maroon that the IDT is being used intensively. From the below, it can be seen that in this category the IDT with the highest level of non-use is AI-based marketing (9.272%), and the IDT with the highest level of intensive use is CRM (39.2%).

Figure 2b: Distribution of the adoption of specific digital marketing & sales tools.



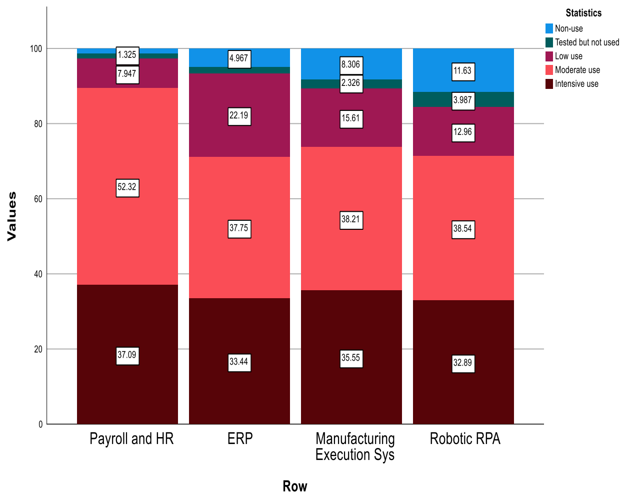
Regarding Enterprise and resource management technologies, Payroll and HR software ranks as the technology with the highest mean score of adoption (4.23), not only in this category but across all six categories in the survey. This result is again in line with expectations, as like CRM technologies, payroll and HR software have become very much ubiquitous in terms of their diffusion throughout the British economy. The relatively high score can also be attributed to payroll and HR software's near- universal applicability, since the criteria for adoption is only that a firm has staff and a reasonable level of IT fluency. The lowest mean score of adoption in this category is Robotic PA (Process Automation), which is in line with expectations, as like AI, robotics is a frontier technology which is only at an early stage of diffusion throughout the UK enterprise ecosystem. Figures 3a presents the mean scores of adoption for IDTs in enterprise and resource management.

Figure 3a: Mean scores of the adoption of specific enterprise and resource management tools.



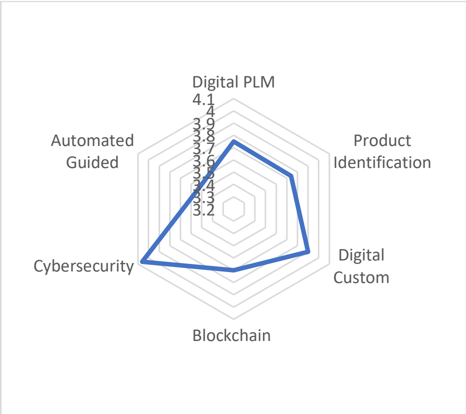
3b presents the distribution of scores of the adoption of each of the IDTs in this category. In the below, light blue represents non-use, dark green represents that the IDT has been tested but not adopted, magenta represents that IDT is currently little used, orange that the IDT is moderately used, and maroon that the IDT is being used intensively. In 3b it can be seen that the IDT with the highest level of non-use is Robotic PA at 11.63%, and the IDT with the highest level of intensive use are Payroll and HR tools with a score of 37.09%.

Figure 3b: Distribution of the adoption scores of specific enterprise and resource management tools.



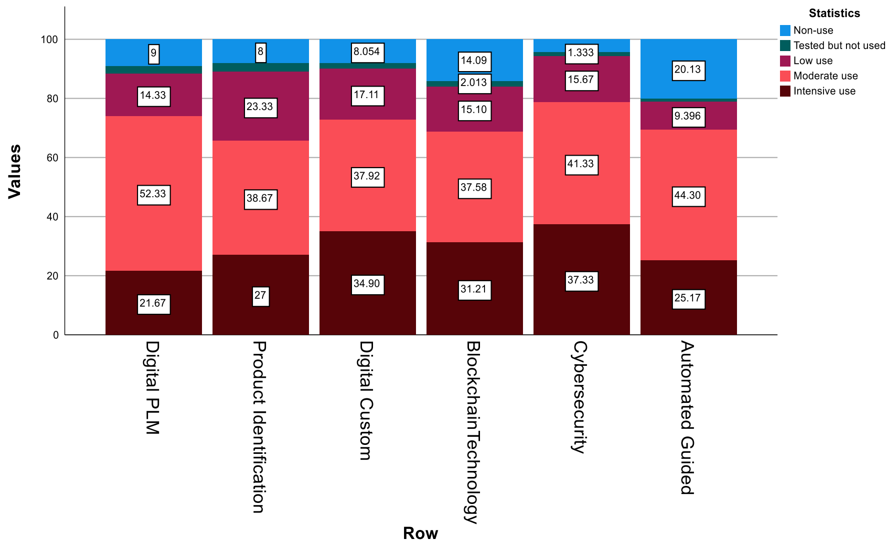
For the category Digital supply chain management, Cybersecurity was the IDT with the highest mean score of adoption, at 4.06. This relatively high score is to be expected, since cybersecurity software is not only relatively easy to implement, but its utility has been underlined in recent years in the public consciousness by numerous reports of cyberattacks on firms and other organisations, including by hostile state actors. The IDT with the lowest mean score in this category is Automated guided vehicles/drones (3.53). Similarly, to robotics, the relatively low mean score for this IDT can perhaps be attributed to its early stage of diffusion, meaning that its use cases are less well-known and the risks of adoption are higher compared to more ubiquitous technologies. Figure 4a presents the mean scores of adoption for IDTs in this category.

Figure 4a: Mean scores of adoption of specific digital supply chain management tools.



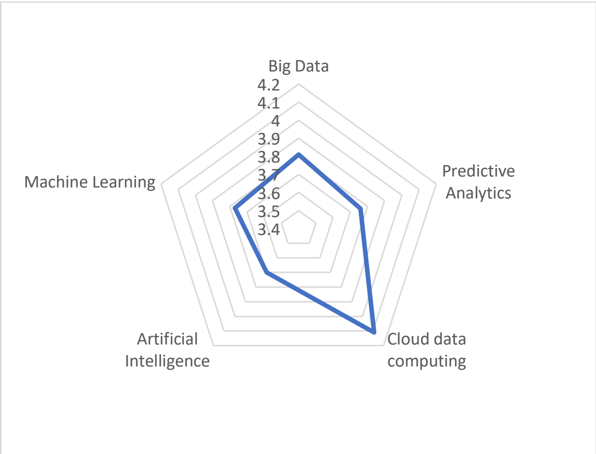
4b presents the distribution of scores of the adoption of each of the IDTs in this category. In the below, light blue represents non-use, dark green represents that the IDT has been tested but not adopted, magenta represents that IDT is currently little used, orange that the IDT is moderately used, and maroon that the IDT is being used intensively. The IDT with the highest score of non-use is Automated guided vehicles/drones (20.13%) while the IDT with the highest score for intensive use was Cybersecurity (37.33%).

Figure 4b: Distribution of the adoption scores of specific digital supply chain management tools.



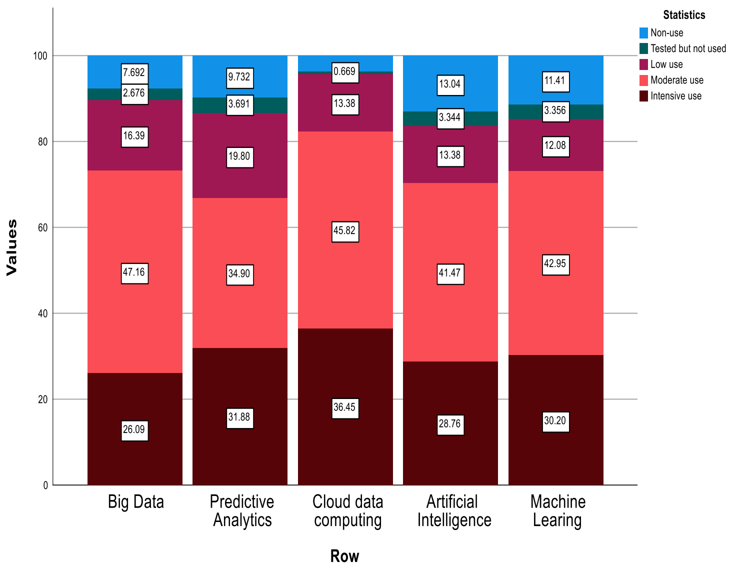
The IDT in the category Digital decision support systems with the highest mean score of adoption is Cloud data computing (4.11). This makes sense due to the relative ease of access and widespread ubiquity of this technology, with most of the major Big Tech firms such as Microsoft, Amazon, and Google offering cloud computing solutions at reasonable prices. As with the category Digital marketing and sales, the IDT with the lowest mean score of adoption in this category is AI (3.7). In addition to the aforementioned factor of AI being a frontier technology at a relatively early stage of diffusion throughout the economy, another possible reason for the low mean score for this IDT in this category is safety concerns, as the fundamental importance of decision support systems to a firm's strategy and sustainability may mean that managers are wary of applying such a new technology in such a crucial business function. Figure 5a presents the mean scores of adoption for IDTs in this category.

Figure 5a: Mean scores of adoption of specific digital decision support systems tools.



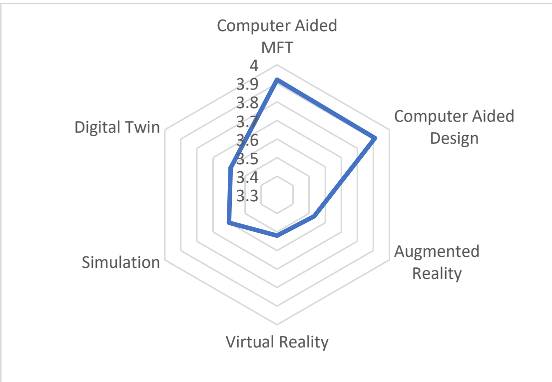
5b presents the distribution of scores of the adoption of each of the IDTs in this category. In the below, light blue represents non-use, dark green represents that the IDT has been tested but not adopted, magenta represents that IDT is currently little used, orange that the IDT is moderately used, and maroon that the IDT is being used intensively. The IDT with the highest level of non-use was AI (13.04%), while the IDT with the highest score of intensive use was Cloud data computing (36.45%).

Figure 5b: Distribution of the adoption scores of specific digital decision support systems tools.



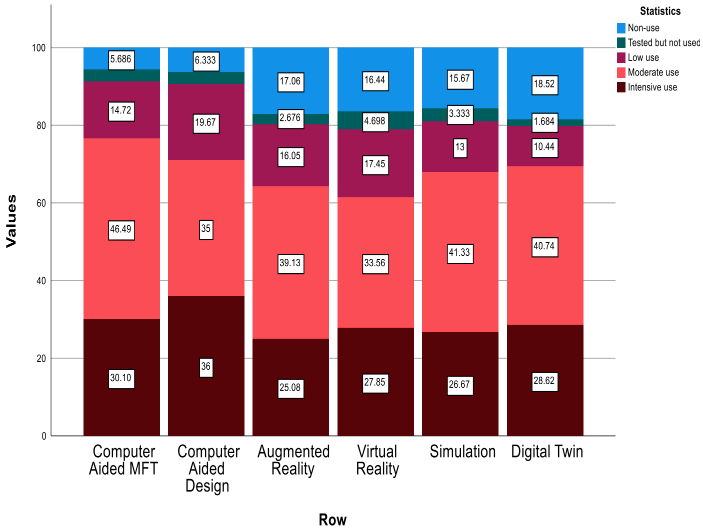
In terms of Digital design and visualisation technologies, mean scores in this category are on the whole lower, with no IDT having a score greater than or equal to 4.0 (moderate use). The IDT with the highest mean score of adoption in this category is Computer aided manufacturing (3.92), followed closely by CAD (Computer Aided Design) (3.91). As before, these IDTs relatively high mean scores of adoption can be attributed to their relatively tried and tested nature and broad use case across manufacturing. By contrast, the IDTs with the lowest mean scores of adoption were Virtual reality (3.52), closely followed by Augmented reality (3.53). Virtual reality in fact has the lowest mean score of adoption across all categories. The lower adoption levels of these IDTs is quite interesting, in that, especially in the case of VR concerted efforts by firms such as Meta have been made to popularise the adoption of these IDTs in business contexts, for instance through extensive advertising campaigns as well as through the development of low-cost VR headsets. The low mean scores for these technologies seems to indicate that these efforts have not yet borne fruit in the form of technological diffusion, at least not yet. Figure 6a presents the mean scores of adoption for IDTs in this category.

Figure 6a: Mean scores of adoption of specific digital design & visualisation tools.



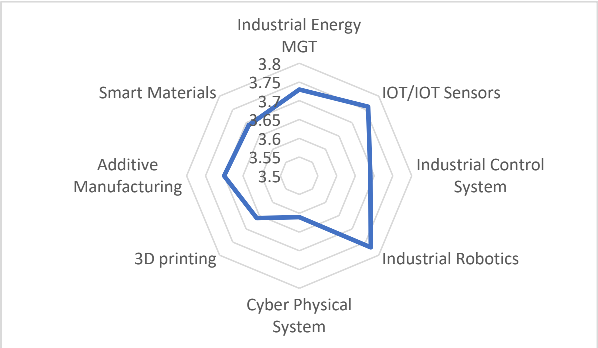
6b presents the distribution of scores of the adoption of each of the IDTs in this category. In the below, light blue represents non-use, dark green represents that the IDT has been tested but not adopted, magenta represents that IDT is currently little used, orange that the IDT is moderately used, and maroon that the IDT is being used intensively. In this category, the IDT with the highest level of non-use is Digital Twins (18.2%), while the IDT with the highest level of intensive use is CAD (36%).

Figure 6b: Distribution of the adoption scores of specific digital design and visualisation tools.



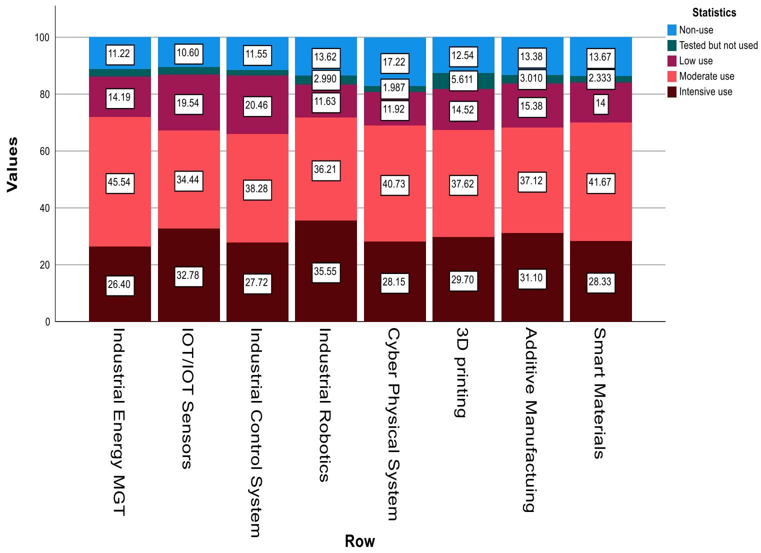
Finally for the Smart factory floor, mean scores of adoption in this category are again lower, with no mean score for any IDT in this category being greater than 3.8. The IDT with the highest mean score of adoption in this category is Industrial robotics (3.77). This score is in line with the reported adoption levels of Robotics in the category Digital enterprise & resource management (also 3.77). The IDT with the lowest mean score of adoption in this category was Cyber physical systems (3.61), perhaps reflecting a relatively lower level of awareness around this technology among respondents. Figure 7a presents the mean scores of adoption for IDTs in this category.

Figure 7a: Mean scores of adoption of specific smart factory floor IDTs.



7b presents the distribution of scores of the adoption of each of the IDTs in this category. In the below, light blue represents non-use, dark green represents that the IDT has been tested but not adopted, magenta represents that IDT is currently little used, orange that the IDT is moderately used, and maroon that the IDT is being used intensively. In this category, the IDT with the highest level of non-use is Cyber physical systems (17.22%), while the IDT with the highest level of intensive use is Industrial robotics (35.55%).

Figure 7b: Distribution of the adoption scores of specific smart factory floor technologies.



3.2. Goals for IDT adoption

Survey respondents were asked to weigh the relative importance of each of the overall goals motivating their adoption of IDTs. These goals were categorised into the following five factors:

1. Responsiveness
2. Quality
3. Efficiency
4. Flexibility
5. Transparency

Respondents were asked to weigh the importance of each factor in turn against all other factors in order to determine which goal was the most significant to their decision making process. The results are presented in Table 1 below.

Table 1: Respondents' goals for IDT adoption.

	Weight of the importance of the goal	Order ranking of the important goal
Responsiveness	0.287843	1st
Quality	0.195046	2nd
Efficiency	0.195046	2nd
Flexibility	0.173413	3rd
Transparency	0.148652	4th

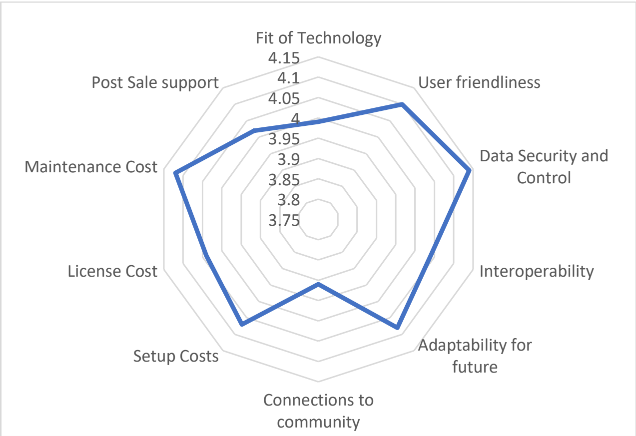
From the above, it can be seen that Responsiveness was found to be the most important goal motivating respondents' decisions to adopt IDTs, while Transparency was considered to be the least significant motivator. Quality and Efficiency were given an equal ranking in terms of importance by respondents.

The results seem to indicate that a key motivator for IDT adoption is increasing the firm in question's responsiveness, for instance by decreasing TTM (Time to Market) to meet customer needs more quickly. This result could indicate that competitive pressures are a key driver of IDT adoption but could also be reflective of the larger weighting of B2C SMEs in our sample. The lower ranking of Transparency seems to indicate that this is considered as much less of a pressing concern driving decision-making as other factors.

Respondents were also asked to indicate what criteria were important in their selection of specific IDTs, doing so by rating the importance of each criterion on a Likert scale from 1-5, with the following values: not important (1), a bit important (2), quite important (3), important (4), extremely important (5). Mean scores in this category tended to cluster around 'important (4)'. The criterion to which the highest mean score was attributed was Data Security and Control (4.14), while the lowest mean score was attributed to Connections to Community (3.91).

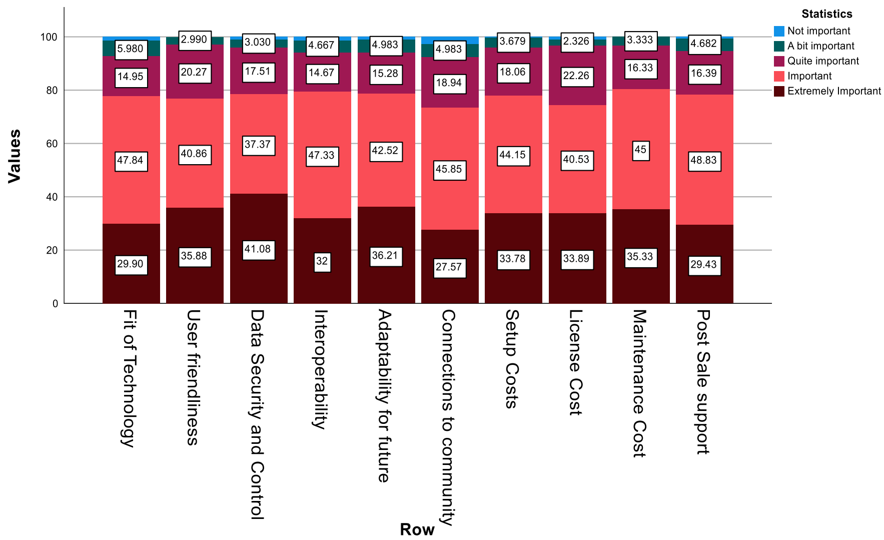
That the lowest mean score of importance was given to Connections to Community is in line with expectations. This is because although collaboration and cooperation between firms (for example through trade associations) is certainly important, nonetheless the fundamental fact that they operate in a market in which they compete with rivals for customers and sales means that community can be of only limited relevance to SMEs. For detailed descriptive statistics for each criterion, see Table A3 in the Appendix. Figure 8a presents data on the mean scores for each of the adoption criteria.

Figure 8a: Mean scores of importance for each of the IDT adoption criteria.



8b presents the distribution of scores of importance of each of the adoption criteria. In the below, light blue represents that the criterion is not important, dark green represents that the criterion is slightly important, magenta represents that the criterion is quite important, orange that the criterion is moderately important, and maroon that the criterion is extremely important. In the below, the criterion with the highest proportion of responses rating it as unimportant was Fit of technology (5.98%), while the criterion with the highest proportion of responses assessing it as extremely important was Data security and control (41.08%).

Figure 8b: Distribution of importance scores for IDT adoption criteria.



3.2.4 Incentives and barriers for IDT adoption

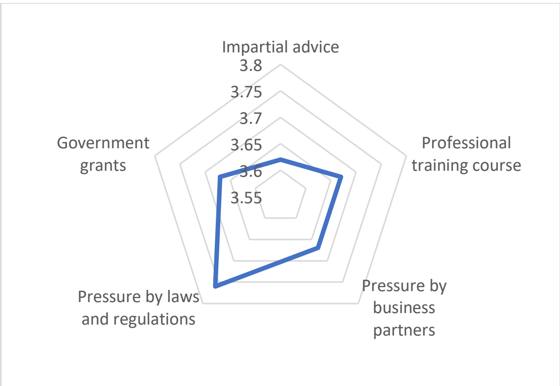
Firms responding to the survey were also asked about factors influencing the adoption of IDTs, including those that incentivise or deter IDT adoption. Respondents were asked to rate the extent to which specific factors influenced their adoption of IDTs using a Likert scale with the following values: no influence (1), little influence (2), moderate influence (3), strong influence (4), and very strong influence (5), as well as not applicable (6).

Mean scores tended to cluster around 'moderate influence (3)', with the highest mean score of influence being given to **Proven use of technology** (3.93). This is in line with the findings described in section 3.3.2, as it was shown that the IDTs with the lowest level of adoption tended to be those IDTs, like AI, for which the use case was still in the process of emergence. The takeaway is that SME manufacturers seem to have a relatively lower appetite for adopting unproven IDTs at the bleeding edge of the technological frontier compared to better established technologies.

A surprising result was that the lowest mean score was given to **Impartial advice** (3.62), as this was a theme that emerged strongly in the interviews as a factor influencing IDT adoption (discussed in section 3.3). One possible explanation for this discrepancy is that while in conducting the research care was taken to solicit interviews from a wide variety of SMEs, it is possible that those firms that were more likely to respond to an interview request were those that were experiencing a lack of impartial advice as a barrier to digitalisation, as these firms would be more likely to be amenable to discussing their issues with outside researchers.

Figures 9a and 9b and 10a and 10b present the mean scores and distribution of scores for factors incentivising and deterring IDT adoption. Table A4 in the appendix presents more detailed data for each factor.

Figure 9a: Mean scores for incentives to IDT adoption.



9b presents the distribution of scores for incentives to IDT adoption. In 9b, light blue represents that the factor is not applicable, dark green represents that the factor is not influential, magenta represents that the factor has little influence, orange that the factor is moderately influential, maroon that the factor is strongly influential, and light green that the factor is very strongly influential. In the below, the factor with the highest proportion of responses assessing it as having no influences was Government grants (3.987%) while the factor with the highest proportion of responses assessing it as very strongly influential was the availability of Professional training courses (26.73%).

Figure 9b: Distribution of scores for incentives to IDT adoption.

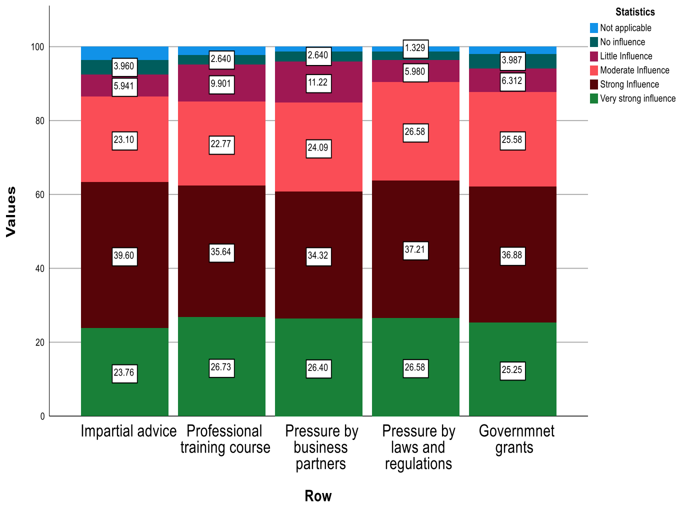
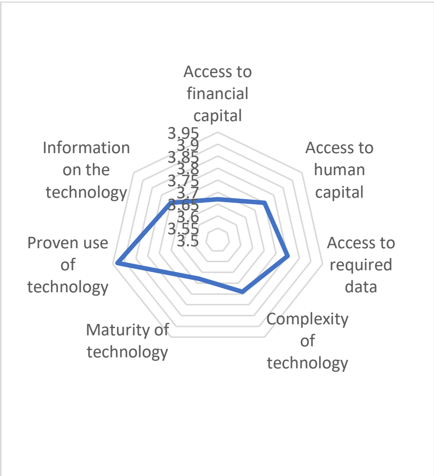


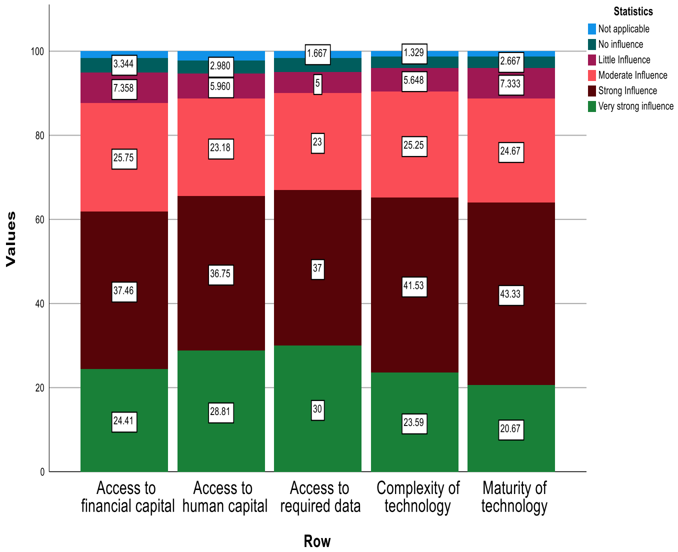
Figure 10a: Mean scores for barriers to IDT adoption.



10b presents the distribution of scores for incentives to IDT adoption. In 10b, light blue represents that the factor is not applicable, dark green represents that the factor is not influential, magenta represents that the factor has little influence, orange that the factor is moderately influential, maroon that the factor is strongly influential, and light green that the factor is very strongly influential. In 10b, the IDT with the highest proportion of responses rating it as having no influence as a barrier to IDT adoption was Access to financial capital (3.344%), while the IDT with the highest proportion of responses rating it as very strongly influential as a barrier to adoption was Access to required data (30%).

Commented [AR1]: Narrative about 10a seems to have slipped out of the latest version

Figure 10b: Distribution of scores for barriers to IDT adoption.



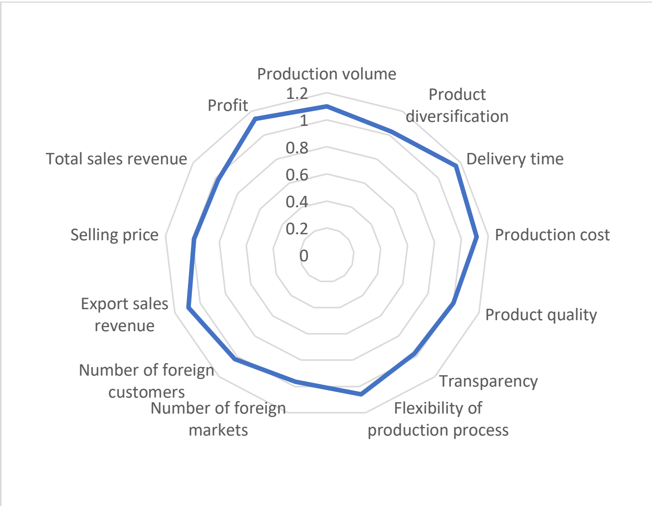
3.2.5 Impact of digital technologies on firm performance

Finally, respondents were asked to estimate the impact of IDT adoption on particular indicators of firm performance. As before, respondent firms were asked to indicate the impact on specific performance indicators using a Likert scale with the following values: decreased considerably (-2), decreased a bit (-1), no change (0), increased a bit (1), increased considerably (2).

The results for this portion of the survey were encouraging, with the mean impact on all performance indicators being positive. The indicator for which the biggest impact was registered was **Delivery time** (1.16). This is in line with the findings described in previous sections, since it was found that on average the most highly valued goal of digitalisation for SMEs was greater responsiveness. The performance indicator for which the smallest mean improvement was found was Number of foreign markets (0.96), although on the other hand for a related indicator, Number of foreign customers, respondents on average reported a small improvement in performance (1.03). One possible interpretation for this is that while digitalisation was relatively less helpful to SMEs in entering new overseas markets, it did help them increase their customer base in markets in which they were already present.

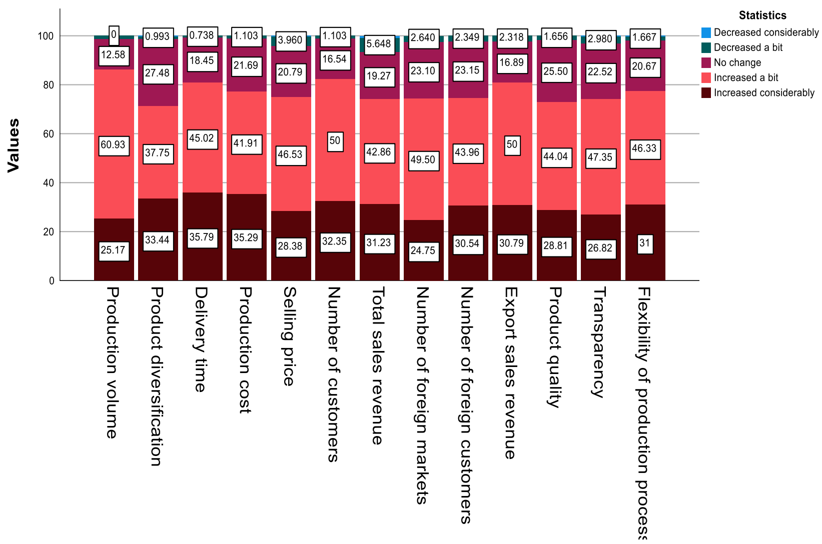
Figures 11a and 11b present the mean scores and distribution of scores for reported changes in performance indicators. Table A5 in the Appendix presents descriptive statistics of the changes in performance reported for each indicator.

Figure 11a: Mean scores of impacts of IDT adoption on performance indicators.



In 11b, light blue represents that the performance indicator has decreased considerably, dark green that the indicator decreased slightly, magenta that the there was no impact on the performance indicator, orange that the performance indicator increased slightly, and maroon that the performance indicator increased considerably. In the below, the performance indicator for which there was the highest proportion of responses reporting a slight decrease was Total sales revenue (5.648%), while the indicator with the highest proportion of responses reporting a considerable increase was Product diversification (33.44%).

Figure 11b: Distribution of scores of impacts of IDT adoption on performance indicators.



Finally, a multi-regression analysis was conducted to test the impact of each of the IDTs for which respondents had indicated their level of adoption in section 3.3.2 on performance indicators across three categories: Operational performance, Export performance and Financial performance. The multi-regression results are presented in the Appendix 4 in Tables A6 and A7. The results indicate that the following IDTs have a significant impact on one or more of the aforementioned performance indicators:

- Email marketing: Operational performance (Transparency, Delivery time), Financial performance (Profit), and Export performance (Export sales revenue).
- Web content management: Operational performance (Transparency), Financial performance (Total sales revenue).
- AI based marketing: Operational performance (Product quality, Transparency), Financial performance (Total sales revenue), Export performance (Number of foreign customers).
- Social Media: Financial performance (Total sales revenue).
- CRM: Financial performance (Total sales revenue), Export performance (Number of foreign markets, Number of foreign customers, Export sales revenue).
- Payroll and HR software: Operational performance (Production volume).
- Manufacturing ES: Financial performance (Total sales revenue), Export performance (Number of foreign markets).
- Robotic PA: Operational performance (Product diversification).
- Digital PLM: Export performance (Export sales revenue).
- Product Identification: Operational performance (Product diversification, Product quality), Export performance (Number of foreign markets, Number of foreign customers).
- Blockchain: Financial performance (Selling price).
- Cybersecurity: Operational performance (Product diversification), Financial performance (Profit).
- Automated Guided Vehicles: Operational performance (Flexibility), Financial performance (Total sales revenue).
- Big data: Financial performance (Profit).
- Predictive Analytics: Operational performance (Delivery time), Export performance (Export sales revenue).
- Cloud Data Computing: Operational performance (Production volume).
- Machine Learning: Operational performance (Transparency), Export performance (Export sales revenue).
- Computer Aided Manufacturing: Operational performance (Production volume), Financial performance (Selling price, Total sales revenue).

- Computer Aided Design: Operational performance (Product diversification, Transparency), Export performance (Export sales revenue).
- Virtual Reality: Operational performance (Product diversification, Transparency, Production Cost), Financial performance (Total sales revenue), Export performance (Number of foreign markets, Export sales revenue).
- Simulation: Financial performance (Selling price).
- Digital Twin: Operational performance (Product diversification, Delivery time), Export performance (Number of foreign customers).
- Industrial Energy Management: Operational performance (Production volume, Transparency), Export performance (Number of foreign customers).
- Industrial Control System: Operational performance (Flexibility, Production cost).
- Additive Manufacturing: Export performance (Number of foreign markets).

3.2.6. Summary of key findings from the survey

1. There are many new IDTs that UK SMEs have not adopted.
2. In adopting IDTs, SMEs aim to achieve responsiveness, in addition to quality, efficiency flexibility and transparency.
3. Key drivers that promote the adoption of IDTs among SMEs include pressure from business partners, laws/regulations and governmental funding, in addition to access to impartial advice, required data, human and financial capital. Complexity and maturity of the technologies also play important roles.
4. What SMEs need is a clear vision on needs and change, not a road map,
5. The adoption of IDTs has the highest impact on delivery time. Production volume and cost have also been improved.

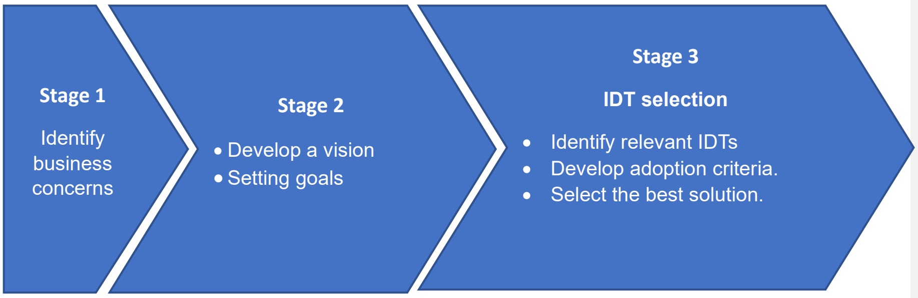
4. IDT adoption toolkit

4.1. The development of the toolkit

The findings from primary research were used to develop the IDT adoption toolkit. In particular, the mean values of the level of adoption of specific IDTs and mean values of performance indicators were used as benchmarks for comparison of the firm interested in IDT adoption with the current practices in the manufacturing sector and providing appropriate solutions for their choice. The results of the impacts of specific IDTs on operational performance, export performance and financial performance were employed as benchmarks for benefits that each IDT have bought to the UK export manufacturing SMEs and provided suggestions of which IDT is relevant to the firm. The results of the pairwise comparison ranking goals for IDT adoptions among the UK SMEs were used to calculate the average ranking of the importance of goals which then were used as benchmarks for comparison of the firm interested in IDT adoption with the current practices in the manufacturing sector. These results were later used to build a decision-making model. The decision-making model is built upon Simulated Uncertainty Range Evaluations (SURE) (Hodgett & Siraj, 2019), a method for decision-making under uncertainty. SURE method utilises simulations based upon triangular distributions to create a plot which visualises the preferences and overlapping uncertainties of decision alternatives. It facilitates decisionmakers to visualise the not-so-obvious uncertainties of decision alternatives (Hodgett & Siraj, 2019).

Building upon SURE method, we develop the IDT adoption decision making model presented in Figure 12. This model consist of three key stages with detail descriptions as follows.

Figure 12: The IDT adoption decision making process model.



Stage (1): Identify business concerns.

In this stage a business needs to identify their main business concern. Are they related to:

- Overall business performance: sales or profit growth?
- Operational performance: product quality (product safety, product defective rates and product reliability), or service quality (on time deliveries, order accuracy and order flexibility) ?
- Environmental performance (e.g., reusable packaging, material efficiency, wastewater reduction, total waste reduction for recycling, overall impacts and energy consumption)?
- Customer related performance: customer satisfaction and customer loyalty?
- Employee-related performance: employee satisfaction, employee commitment and low employee turnover?

Stage (2) Develop a vision and goals to be achieved in digitalisation.

At this stage, a business needs to decide what they want to achieve from IDT adoption?

Stage (3) IDT adoption decision.

At this stage, a business needs to implement three tasks: (i) identify relevant IDTs that will help to achieve these goals, (ii) develop IDT adoption criteria, (iii) select a digital solution vendor.

4.2. The application of the toolkit

The toolkit allows a firm to select IDTs relevant to its needs, size, and current stage of IDT adoption. In particular, the toolkit allows UK SME manufacturers to compare their level of IDT adoption to the industry standard and identify which specific IDTs will have the greatest impact on improving their business performance across a number of indicators. Then, the toolkit allows the firms to determine the best choice among several competing technologies offered by the digital solution providers that they may engage with in their adoption process, based on their specifical goals and selection criteria (e.g., investment cost, sale growth and environmental sustainability performance).

The specific guidance for how to use the toolkit as well as demonstration results of using the toolkit to identify the best choice of technologies for two specific real life case firms can be found in the separated document entitled "Industrial digital technology adoption toolkit for UK SME manufacturers".

Note that in the toolkit we use two different decision-making methods on each case to demonstrate two different methods to model the decision. Specifically, we use SURE for real life case firm A uses and AHP-TOPSIS (AHP for the weights and TOPSIS for the decision calculation) for real life case firm B. We have demonstrated different methods so that users are aware of a wider range of the methods available and can select the method they prefer.

4.3. Limitations

The toolkit has several limitations as below:

- There are several decision-making methods available, with no best method, and method selection depends on how you prefer to provide your preferences and evaluate the outputs. As high amount of uncertainty is present with IDT adoption decisions, SURE was proposed as one of the best approaches.
- The toolkit has only been tested and evaluated with 2 test cases, whereas it would be best to test the toolkit on more real life cases.

- The toolkit has been developed in Excel which is excellent for prototyping, and we know is widely used in industry. However, there may be a better way to disseminate the toolkit which provides a better user experience and allows us to collect data on how it's being used.
- For SURE, only ~5,000 simulations were used to generate the distributions that represent the uncertainty in the outputs. This may not be the optimum number to use. More simulations will provide a better understanding of the uncertainty but will take more computational time.

To overcome the limitations, we suggest future work as below.

- Develop a web-based system for IDT selection that will provide a better user experience over Excel and allow us to test new methods and ways of assisting the decision-maker (with A/B testing for example).
- The toolkit requires users to identify the criteria that is important to them for IDT selection. If data was collected from users, we could eventually provide prompts as to what additional criteria should be considered.
- Work closely with suppliers to identify the data that is relevant for IDT adoption decisions so we could pre-populate some information in the decision table.

Acknowledgement

This document was prepared with the support of Alexander Riley, a PhD researcher in the International Business Department, Leeds University Business School, University of Leeds.

InterAct Network

The investigation forms part of the InterAct Network project that aims to bring together economic and social scientists, UK manufacturers, and digital technology providers to address the human issues resulting from the diffusion of new technologies in industry. Although technology is important in the digitalisation of the UK Manufacturing Industry, the InterAct Network recognises that there are many social and economic factors that will be hugely influential in achieving this aim. The InterAct Network has two primary roles:

- Develop and support the creation of an effective digital innovation ecosystem to accelerate the innovation and diffusion of Industrial Digital Technologies.
- Ensure that the full range and depth of social and economic science insights are accessed across the Made Smarter challenge and wider UK manufacturing sector.

To find out more about the project, access funding and make use of the latest outputs from the ongoing research projects visit https://interact-hub.org.

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Appendix 1- Glossary of Industrial Digital Technologies with Applications.

Table A1: Definitions and applications of specific IDTs

	Application
Digital marketing & sales technologies	**Technologies that assist with the integration and automation of company sales & marketing**
Online payment for e-commerce	Used to make and receive payment via the internet, including debit/credit cards, wire transfers, net banking, and digital wallets.
Email marketing solutions	Used to create, send, and track emails to their list of subscribers. Using software makes it easier to create well-designed emails, and allows users to see key metrics, e.g., open rates and click-through rates.

Search Engine Optimisation (SEO)	Used to optimise a website's technical configuration, content relevance and link popularity so its pages can become easily findable, more relevant and popular towards user search queries, and hence search engines rank them better.
Web Content Management	Used to create, manage, store, and display content on webpages. It is often used to manage the integrity, revisions, and lifecycle of information and the content that is specifically destined for the web.
AI-based marketing content creation tool	Used for various purposes, such as generating ideas, writing copy, editing, and analysing audience engagement.
Social media management tool	Used to enable the users to effectively manage their presence on social media, facilitating more effective marketing and communication with clients.
Customer relationship management (CRM)	Used to manage, track, and store information related to your company's current and potential customers. By keeping this information in a centralised system, business teams have access to the insights they need, the moment they need them.
Enterprise & resource management	**Technologies that assist with the integration and automation of company accounting, payroll, HR, process scheduling**
Payroll & HR software	Used to improve the efficiency of the users' HR processes, enabling cost reductions and freeing up managerial resources.
Enterprise resource planning (ERP)	Used to manage and integrate the essential parts of their businesses in order to increase the efficiency and transparency of their operations.
Manufacturing Execution System (MES)	Used to manage and optimise production processes, raising outputs and increasing efficiency.
Robotic process automation (RPA)	Used to automate various supply chain processes, including data entry, predictive maintenance and after-sales service support.
Digital supply chain management	**Technologies that assist with the integration and automation of information tracking & traceability of raw materials, work in progress, and finished goods**
Digital product lifecycle management (PLM)	Used in manufacturing to manage a product and its associated data through all stages of the product lifecycle.
Product identification (e.g., RFID, RTLS)	Used to enable the automatic identification and tracking of parts and products, allowing operational processes to become more transparent, efficient, and secure.
Digital customs declaration	Used to check if the goods are allowed into the country and to determine the taxes and duties needed to pay.
Blockchain	Used to record transactions and share information in a secure, transparent, and tamper-resistant manner.
Cybersecurity technologies	Designed to combat threats against networked systems and applications, including theft of sensitive data by hostile state and non-state actors.
Digital decision support system	**Technologies that assist with the integration and automation of company data analysis and decision making process**
Big data analytics	Used for planning and forecasting, predictive maintenance and simulation in manufacturing, supply chain management and maintenance. The data can come from IoT systems connected to the productive layer (e.g., with sensors and associated equipment), or the exchange between IT systems for production and warehouse management.
Forecasting/predictive analytics	Used for continuous adjustment of forecasts to help the company identify new opportunities and risks early and grow profitably.
Cloud data and computing	Used to enable ubiquitous, convenient, on-demand internet access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.
Artificial intelligence (AI)	Used to perform functions including, but not limited to, speech recognition, machine vision or machine learning, e.g., speech recognition, machine vision using sensors and software, machine learning which uses statistical software and data to "learn" and make better predictions without reprogramming.
Machine learning	Used in internet search engines, email filters to sort out spam, websites to make personalised recommendations, banking software to detect unusual transactions, and apps on mobile

	phones such as voice recognition. To handle large amounts of data using the same customer segmentation processes for improving marketing.
Digital design & visualisation technologies	**Technologies that assist with the integration and automation of design and new product development practices**
Computer-aided manufacturing (CAM)	Used to enable manufacturers to create better parts with increasingly more control over the entire process.
Computer-aided design (CAD)	Used to create better quality designs and greater efficiency in the design process.
Augmented reality (AR)	Used for various purposes, including gaming, product visualisation, marketing campaigns, architecture and home design, education, and industrial manufacturing. For example, AR can be used to promote products or services, launch novel marketing campaigns, and collect unique user data.
Virtual reality (VR)	Used in entertainment applications such as video games, 3D cinema, amusement park rides and social virtual worlds.
Simulation	Used to tune up performance, optimise a process, improve safety, testing theories, training staff and even for entertainment in video games
Digital twin technology	Used to monitor equipment at all times and analyse performance data that shows how a particular part or the entirety of the plant is functioning.
Smart factory floor	**Technologies that assist with the integration, automation, quality, and safety of manufacturing processes.**
Industrial energy management systems	Used to monitor energy consumption
Internet of Things (IoT/IIoT), sensors	Used in manufacturing applications and many others (housing and construction, automotive sector, environment, smart city, agriculture, health, etc.).
Industrial control systems (PLS, SCADA)	Used to control industrial processes such as manufacturing, product handling, production, and distribution.
Automation and industrial robotics	Used to replace manual labour and increase efficiency, speed, and overall performance.
Cyber-Physical Systems (CPS/CPPS)	Used to develop the processes, networking and technology needed to seamlessly integrate cyber and physical systems.
Additive manufacturing	3D Printing finds application in prototyping (to support the product development process, static simulation and wind tunnels, etc.), manufacturing (direct production of products), maintenance and repair, and modelling phases, e.g., drugs, medicine, dentistry, automotive sector, construction, customised tools and components.
Machine to Machine (M2M) technologies	Used to capture and transmit data according to specific applications through multiple wireless technologies
Automatic guided vehicle (AGV)/Drones	Used in various applications, including manufacturing, warehousing, inspection, exploration, transportation, and military.
Wireless sensor networks (WSNs)	Used to respond and detect some kind of input from both physical and environmental conditions.
Smart materials	Used to create more efficient and responsive sensors, actuators, and similar devices.

Appendix 2- The survey content.

The survey instruments for IDT4UKSMEs were developed from the outcomes of literature review, focus group and interviews. The survey comprises four sections as follows.

General Information: In addition to standard general information on the organisation (i.e., size, age, exporting year, customer types), the survey asked about the managerial role of the respondent.

Digital Technologies: This section asked about specific digital technologies that are categorised in 6 technology groups serving their 6 key business functions in a manufacturing firm (i.e., Digital marketing & sales technologies, Enterprise & resource management, Supply chain management, Decision support system, design and visualisation, and smart factory floor) with regards to the state of adoption, motivations for and barriers to adoption, and their effect on firm performance. This section was adapted from the technology module of the 2019 United States Annual Business Survey (ABS).

The need for adoption of digital technologies: This section asked about the motivations for a firm's adoption of digital technologies.

The antecedents for adoption of digital technologies: This section asked about the factors that incentivises or discourages a firm's adoption of digital technologies.

Firm performance: This section asked about the changes in operational performance, financial performance and export performance of a firm following the adoption of digital technologies.

Appendix 3: Descriptive Statistics

Table A2: Current state of adoption of IDTs.

	Min	Max	Mean	S.D
Digital marketing & sales				
Online payment	1	5	3.99	1.000
Email Marketing	1	5	4.04	.896
SEO	1	5	3.97	.913
Web Content MGT	1	5	4.07	.831
AI based MKT	1	5	3.77	1.249
Social Media	1	5	3.99	.975
CRM	1	5	4.17	.874
Digital enterprise & resource management				
Payroll and HR	1	5	4.23	.757
Enterprise Resource Planning	1	5	3.93	1.034
Manufacturing ES	1	5	3.90	1.161
Robotic PA	1	5	3.77	1.272
Digital supply chain management				
Digital PLM	1	5	3.75	1.104

Product Identification	1	5	3.74	1.131
Digital Custom	1	5	3.90	1.149
Blockchain	1	5	3.70	1.314
Cybersecurity	1	5	4.06	.986
Automated Guided	1	5	3.53	1.410
Digital decision support system				
Big Data	1	5	3.81	1.092
Predictive Analytics	1	5	3.76	1.219
Cloud data computing	1	5	4.11	.921
Artificial Intelligence	1	5	3.70	1.281
Machine Learning	1	5	3.77	1.240
Digital design & visualisation technologies				
Computer Aided MFT	1	5	3.92	1.038
Computer Aided Design	1	5	3.91	1.115
Augmented Reality	1	5	3.53	1.354
Virtual Reality	1	5	3.52	1.376
Simulation	1	5	3.60	1.336
Digital Twin	1	5	3.59	1.402
Smart factory floor				
Industrial Energy MGT	1	5	3.73	1.206
IOT/IOT Sensors	1	5	3.76	1.237
Industrial Control System	1	5	3.69	1.228
Industrial Robotics	1	5	3.77	1.331
Cyber Physical System	1	5	3.61	1.371
3D printing	1	5	3.66	1.299
Additive Manufacturing	1	5	3.70	1.305
Smart Materials	1	5	3.69	1.286

Table A3: IDT adoption criteria.

	Min	Max	Mean	S.D
Fit of Technology	1	5	3.99	.900
User friendliness	2	5	4.10	.821
Data Security and Control	1	5	4.14	.883

Interoperability	1	5	4.04	.880
Adaptability for future	1	5	4.08	.895
Connections to community	1	5	3.91	.948
Setup Costs	1	5	4.07	.832
License Cost	1	5	4.04	.863
Maintenance Cost	2	5	4.12	.798
Post Sale support	1	5	4.02	.841

Table A4: Factors influencing IDT adoption.

	Min	Max	Mean	S.D
Impartial advice	0	5	3.62	1.228
Professional training course	0	5	3.67	1.181
Pressure by business partners	0	5	3.67	1.138
Pressure by laws and regulations	0	5	3.76	1.067
Government grants	0	5	3.67	1.155
Access to financial capital	0	5	3.67	1.123
Access to human capital	0	5	3.75	1.158
Access to required data	0	5	3.80	1.123
Complexity of technology	0	5	3.74	1.049
Maturity of technology	0	5	3.68	1.049
Proven use of technology	0	5	3.93	1.036
Information on the technology	0	5	3.75	1.167

Table A5: Impact of IDT adoption on firm performance.

	Min	Max	Mean	S.D
Production volume	-1.00	2.00	1.0993	.64961
Product diversification	-2.00	2.00	1.0298	.82473
Delivery time	-1.00	2.00	1.1587	.74081
Production cost	-1.00	2.00	1.1140	.77666
Product quality	-1.00	2.00	1.0000	.78185
Transparency	-2.00	2.00	.9735	.80238
Flexibility of production process	-2.00	2.00	1.0600	.78216
Number of foreign markets	-1.00	2.00	.9637	.76470

Number of foreign customers	-1.00	2.00	1.0268	.79516
Export sales revenue	-1.00	2.00	1.0927	.75020
Selling price	-2.00	2.00	.9868	.82580
Total sales revenue	-2.00	2.00	.9767	.90708
Profit	-1.00	2.00	1.1360	.71867

Appendix 4: Multi-regression results

Table A6: The impacts of each IDT on operation performance indicators

	Production Volume		Product range		Delivery time		Production cost		Product quality		Transparent		Flexibility	
	β	P	β	P	β	P	β	P	β	P	β	P	β	P
(Constant)	3.460	<.001	2.970	<.001	3.855	<.001	3.800	<.001	3.619	<.001	3.633	<.001	3.556	<.001
Firm size	.161	.024	.220	.016	.220	.016	.179	.051	-.423	<.001	-.453	<.001	-.359	<.001
Firm age	-.029	.744	-.146	.206	-.037	.741	-.179	.122	.221	.008	.187	.031	.275	.001
Export experience	.015	.872	.186	.130	-.030	.805	.059	.628	.128	.267	.177	.140	.074	.524
Customer type	.122	.221	.232	.069	-.076	.554	.056	.666	.234	.039	.256	.029	.207	.068
(Constant)	1.850	<.001	1.039	.014	1.974	<.001	2.619	<.001	2.388	<.001	2.216	<.001	2.624	<.001
Firm size	.006	.933	-.055	.555	-.058	.569	-.022	.837	-.128	.263	-.095	.408	-.035	.754
Firm age	.123	.197	.139	.235	.163	.187	.149	.247	-.003	.969	-.002	.980	-.063	.483
Export experience	-.091	.332	.024	.833	-.182	.129	-.149	.234	.103	.346	.136	.225	.037	.734
Customer type	.059	.533	.247	.033	-.010	.938	.032	.801	.075	.499	.043	.703	.071	.518
Online payment	.097	.044	.022	.712	.040	.540	-.099	.145	.031	.587	.027	.637	.045	.420
Email MKt	-.001	.984	.103	.092	.172	.008	.040	.552	.105	.072	.157	.009	.016	.784
SEO	-.032	.554	-.118	.078	.075	.302	.065	.387	-.014	.828	-.001	.986	-.011	.866
Web Content MGT	-.038	.491	-.020	.764	-.012	.868	-.130	.089	-.083	.200	-.176	.008	.033	.608
AI based MKT	-.048	.379	.107	.108	.059	.447	-.045	.579	.144	.024	.134	.041	.087	.172
Social Media	.026	.612	.077	.231	-.079	.247	.020	.777	.039	.529	.048	.440	-.071	.243
CRM	.022	.668	-.003	.959	.084	.214	.025	.720	.056	.357	.031	.613	.000	.995
Payroll and HR	.133	.023	.058	.415	.021	.772	.006	.940	-.037	.588	-.036	.610	-.096	.160
ERP	.024	.632	.077	.215	.041	.543	.033	.643	-.035	.564	.020	.747	.038	.525
Manufacturing ES	-.063	.195	-.011	.852	.105	.106	-.016	.815	-.026	.649	-.026	.662	.029	.608
Robotic PA	-.008	.881	-.126	.056	-.038	.585	.006	.936	.052	.411	.093	.147	.057	.362
Digital PLM	-.039	.550	-.008	.924	-.031	.717	.083	.350	-.024	.749	-.015	.848	.066	.381

Product Identification	.013	.785	.142	.017	.006	.920	.102	.121	-.041	.471	.046	.430	-.029	.616
Digital Custom	.036	.464	-.048	.425	.037	.576	-.022	.750	-.072	.215	.073	.219	-.003	.963
Blockchain	.037	.494	.051	.441	-.091	.189	-.044	.540	-.007	.918	.037	.565	.023	.719
Cybersecurity	.027	.586	.092	.134	-.021	.758	.074	.284	.113	.052	.085	.156	.108	.063
Automated Guided	.008	.880	.067	.274	.056	.416	.044	.542	.107	.069	.086	.151	.139	.018
Big Data	-.055	.362	-.105	.160	.019	.807	-.056	.494	.017	.812	-.131	.077	-.122	.090
Predictive Analytics	-.039	.438	.026	.677	-.162	.012	-.069	.296	-.080	.180	-.081	.186	-.028	.642
Cloud data computing	.093	.059	-.075	.214	.039	.550	.018	.785	-.004	.940	-.021	.722	-.049	.388
Artificial Intelligence	.049	.413	.041	.578	-.055	.456	.076	.331	-.083	.239	-.068	.344	-.045	.521
Machine Learning	.043	.460	.015	.834	-.011	.887	-.002	.975	-.033	.630	-.141	.046	-.052	.452
Computer Aided MFT	.163	.002	.030	.633	-.007	.912	.050	.462	.031	.610	-.047	.453	.042	.488
Computer Aided Design	.025	.579	.197	<.001	.050	.383	.001	.984	.048	.362	.114	.036	.021	.697
Augmented Reality	.033	.532	.065	.315	.012	.862	.014	.844	.080	.195	.104	.098	-.017	.776
Virtual Reality	.039	.484	.077	.266	.069	.333	.190	.011	.152	.023	.149	.030	.060	.365
Simulation	.034	.531	-.067	.312	.089	.186	-.037	.593	.112	.077	-.025	.698	.087	.164
Digital Twin	-.064	.252	.001	.994	-.146	.047	.035	.645	-.206	.002	-.050	.451	-.178	.007
Industrial Energy MGT	.127	.032	-.011	.879	.045	.540	-.002	.983	.053	.440	.149	.034	.127	.066
IOT/IOT Sensors	-.045	.368	-.003	.962	.103	.115	-.088	.200	-.018	.765	-.025	.682	-.008	.895
Industrial Control System	-.064	.173	.024	.682	.028	.644	.154	.015	.096	.081	.072	.201	.107	.051
Industrial Robotics	.046	.366	.007	.906	.006	.926	.048	.482	-.066	.272	-.017	.778	.063	.290
Cyber Physical System	-.047	.390	-.022	.740	.061	.403	-.033	.668	.128	.047	-.124	.060	-.095	.134
3D printing	.004	.939	-.021	.717	-.026	.667	.003	.966	.016	.778	.045	.425	-.021	.703
Additive Manufacturing	.032	.572	.021	.765	-.069	.335	-.111	.138	-.084	.205	-.024	.724	.072	.272
Smart Materials	-.067	.212	-.054	.410	.128	.064	.066	.358	-.048	.448	-.026	.686	-.001	.991

Table A7: The impacts of each IDT on export performance and financial performance indicators

	Number of foreign markets		**Number of foreign customers**		**Export sales revenue**		**Sales price**		**Total sales revenue**		**Profit**	
	β	P	β	P	β	P	β	P	β	P	β	P
(Constant)	3.464	<.001	3.478	<.001	3.775	<.001	3.011	<.001	3.824	<.001	3.588	<.001
Firm size	-.430	<.001	-.259	.023	-.294	.004	.290	.002	.127	.194	.256	.002
Firm age	.166	.038	.133	.139	.054	.499	-.346	.003	-.615	<.001	-.287	.006

Export experience	.247	.027	.191	.126	.248	.027	.298	.018	.368	.006	.189	.086
Customer type	.262	.016	.194	.111	.185	.090	.193	.135	.219	.108	.057	.622
(Constant)	1.841	<.001	1.681	<.001	1.983	<.001	1.392	.003	1.912	<.001	1.935	<.001
Firm size	-.227	.037	-.053	.658	-.103	.337	.083	.435	-.021	.838	.055	.559
Firm age	-.079	.362	-.141	.145	-.177	.040	-.118	.369	-.198	.124	-.039	.738
Export experience	.233	.029	.168	.153	.249	.018	.141	.277	.128	.307	.059	.596
Customer type	.219	.041	.068	.564	.032	.758	.142	.272	.228	.071	-.027	.812
Online payment	.012	.830	.023	.698	.034	.522	.039	.558	.073	.258	.053	.386
Email MKt	.047	.406	.115	.070	.111	.048	.059	.394	.003	.960	.122	.040
SEO	-.023	.706	.020	.775	.032	.604	.005	.946	-.030	.686	.006	.928
Web Content MGT	.051	.414	-.007	.915	-.030	.625	-.042	.581	-.197	.010	.034	.611
AI based MKT	.043	.481	.186	.007	-.024	.692	.067	.373	.218	.003	.018	.802
Social Media	-.002	.972	-.011	.864	.048	.414	-.035	.628	.150	.036	-.003	.961
CRM	.174	.003	.138	.034	.193	<.001	.090	.206	.166	.017	-.044	.481
Payroll and HR	.092	.167	.075	.304	-.001	.984	.081	.312	.046	.557	.059	.387
ERP	.043	.458	-.021	.738	-.025	.662	-.025	.717	.111	.106	-.036	.572
Manufacturing ES	-.130	.020	.064	.305	-.060	.273	.078	.249	-.132	.045	.037	.538
Robotic PA	-.048	.426	.017	.795	.000	.997	.001	.986	-.036	.612	.046	.482
Digital PLM	-.059	.425	.033	.686	.194	.008	-.077	.391	-.099	.256	-.001	.993
Product Identification	.154	.006	-.118	.054	.041	.457	-.096	.152	.003	.965	.028	.631
Digital Custom	.009	.875	-.112	.071	.008	.879	.031	.654	.082	.216	-.069	.267
Blockchain	.050	.417	.056	.413	.104	.091	.149	.047	.066	.368	-.012	.855
Cybersecurity	-.099	.079	-.002	.971	.087	.117	.115	.092	.042	.524	.122	.051
Automated Guided	.041	.475	-.022	.722	.037	.514	.052	.455	.189	.006	.067	.298
Big Data	-.032	.645	-.092	.230	-.079	.250	-.112	.182	.027	.739	-.184	.012
Predictive Analytics	.005	.933	.012	.854	-.153	.007	-.095	.175	-.050	.469	-.012	.841
Cloud data computing	.072	.196	.070	.258	.043	.436	-.008	.901	-.102	.123	.013	.829
Artificial Intelligence	.009	.890	.033	.665	-.087	.199	-.012	.883	-.032	.693	.110	.115
Machine Learning	-.033	.626	-.057	.446	-.168	.012	-.129	.114	-.117	.145	.023	.747
Computer Aided MFT	-.093	.112	-.025	.699	-.025	.668	.152	.033	.184	.008	.051	.411
Computer Aided Design	.062	.230	.063	.270	.125	.014	.106	.091	-.076	.210	.035	.512
Augmented Reality	-.030	.617	.101	.132	-.049	.412	.027	.706	.039	.582	-.024	.703
Virtual Reality	.133	.039	.029	.687	.126	.048	.033	.677	.147	.054	.049	.462
Simulation	-.004	.953	.098	.151	.039	.515	-.183	.014	-.060	.406	-.031	.615
Digital Twin	-.002	.969	-.247	<.001	-.062	.323	.106	.168	-.076	.322	.008	.901

Industrial Energy MGT	.056	.403	.221	.003	.086	.188	.022	.790	-.105	.183	.046	.510
IOT/IOT Sensors	-.009	.869	.001	.984	.004	.939	.054	.431	-.053	.435	-.096	.115
Industrial Control System	.024	.648	-.010	.866	-.016	.763	.088	.172	.110	.083	.099	.080
Industrial Robotics	-.065	.261	-.044	.495	.069	.229	-.044	.529	-.092	.183	-.030	.619
Cyber Physical System	-.034	.588	-.011	.872	.030	.618	.089	.240	.043	.568	-8.79	.999
3D printing	-.078	.146	.088	.140	.044	.406	-.034	.600	.074	.247	.052	.360
Additive Manufacturing	.154	.016	-.094	.185	-.072	.263	.075	.335	.024	.753	.027	.685
Smart Materials	.006	.921	.026	.700	-.032	.592	-.105	.158	-.039	.591	-.040	.533