Ministry of Foreign Affairs

Sector Study on Digitalization of the Manufacturing Industry in Turkey

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Digital Market Study v10

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1. Introduction

The Fourth Industrial Revolution, also known as Industry 4.0, is transforming all industries, including manufacturing. Industry 4.0 implies the use of advanced digital technologies such as automation, artificial intelligence (AI), the internet of things (IoT), cloud computing, and robotics to improve efficiency and increase productivity and introduce improved products to the market. It has the potential to initiate a transformation throughout all industries and sectors[1]. One of the sectors that is being changed by the advancements in Industry 4.0 is the manufacturing sector. Türkiye has a large manufacturing sector, which implies that the country stands to benefit greatly from the adoption of Industry 4.0.

Manufacturing accounts for a significant proportion of Turkey's economy, with a highly diversified range of industries, products, and services provided by this sector. The manufacturing industry in Turkey has a very broad range of industries, including textiles, automotive, machinery, chemicals, and plastics. The adoption of Industry 4.0 has great potential to improve the Turkish manufacturing sector by increasing productivity and improving efficiency. Increased productivity and efficiency have the potential to foster the growth of the manufacturing sector even further.

Türkiye stands out with its export sectors, and the European Union (EU) is the country's main trading partner. Exports of manufactured goods account for a significant share of Turkey's total exports, and the EU is the destination for a large proportion of these exports. The adoption of Industry 4.0 technologies and practices in Turkey's manufacturing sector could help to improve the competitiveness of Turkish exports and to strengthen the country's trade relations with the EU.

Türkiye stands out with its export sectors, and the European Union (EU) is the country's main trading partner. Exports of manufactured goods account for a significant share of Turkey's total exports, and the EU is the destination for a large proportion of these exports. The adoption of Industry 4.0 technologies and practices in Turkey's manufacturing sector could help to improve the competitiveness of Turkish exports and to strengthen the country's trade relations with the EU.

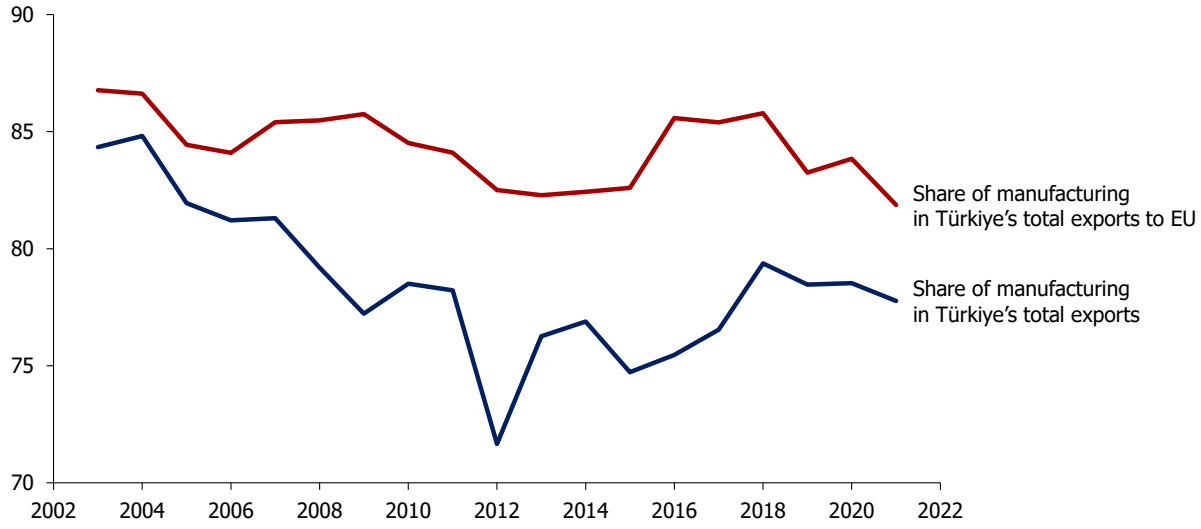
The adoption of Industry 4.0 technologies and practices in the manufacturing sector is likely to create a demand for digitalization expertise and services. This presents an opportunity for businesses and organizations, on both the Turkish and EU sides, to develop new products and services to meet this demand. By investigating the potential of Industry 4.0, it is possible to identify areas of strength and potential for collaboration and to create new opportunities for growth and development in the manufacturing sector.

The manufacturing industry is a key contributor to Turkey's exports. The share of the manufacturing industry in Turkey's exports to the EU is even higher. The share of manufacturing in total exports amounted to 77.8 percent in 2021, whereas the share of manufacturing in total exports to the EU was 81.9 percent in 2021 (*Figure 1*). Türkiye has a

[1] John Hagel III, John Seely Brown, Duleesha Kulasooriya, Craig Giffi, and Mengmeng Chen, The future of manufacturing: Making things in a changing world, Deloitte University Press, March 31, 2015.

long history of trade relations with the EU, and the role of manufacturing has historically been considerable. Türkiye has a Customs Union Agreement with the EU, which has contributed to trade relations between the two regions and aided the growth of exports in the manufacturing industry. Customs Union greatly lowers the trade barrier and led to a fourfold increase in bilateral trade between the EU and Turkey, also allowing Türkiye to integrate into the European production networks[2].

Figure 1. Share of manufacturing exports, %, 2003-2021



Source: TURKSTAT, TEPAV calculations

The recent state of Türkiye – EU relations comprises challenges and opportunities for both parties. For instance, the European Green Deal and trade policies aimed at protecting European producers pose new challenges for exporters from Türkiye. At the same time, they offer opportunities to Turkish exporters. Taking advantage of the EU's focus on green transformation and sustainability, Turkish exporters have the ability to become Europe's main source of green products. The digitalization agenda cannot be thought of separately from the Green Deal. The use of digital technologies will allow manufacturers to improve their products and production processes to comply with new rules and regulations.

The demand for digital technologies is increasing throughout all sectors of manufacturing in Türkiye. In Türkiye, the manufacturing industry is undergoing a major shift in terms of digital transformation. The use of digital technologies, such as artificial intelligence, big data analysis, and cloud computing, is at an all-time high, with prospects of increasing in the near future. In the EU, the manufacturing sector is also going through a digitalization process. Adaptations to Industry 4.0 are increasing manufacturers' abilities throughout the production process and improving the quality of the products.

The digitalization process is creating increasing demand for digitalization tools. For these reasons, Industry 4.0 is an important field that should be thoroughly investigated. By exploring

[2] *EU trade relations with Türkiye*. (2022, July 25). Trade. https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/countries-and-regions/turkiye_en

this area, within the context of Dutch-Turkish relations, the goal is to identify areas of strength and potential opportunities for collaboration.

2. Current trends in digital transformation

2.1. General description of the manufacturing industry in Turkey

The manufacturing industry utilizes a variety of technologies and applications to optimize its processes. These include automation, robotics, big data, cloud computing, the Internet of Things (IoT), 3D printing, computer-aided design, and virtual/artificial reality[3]. Automation and robotics are used to improve efficiency and productivity by automating tasks previously done by humans. 3D printing is a popular advanced manufacturing technique that enables firms to quickly and efficiently create custom-made models and prototypes, reducing costs. IoT technologies allow devices to communicate and share data with one another, enabling better monitoring and evaluation of the production process. These technologies are widely used in Türkiye's manufacturing industry, with varying levels of adoption across different sub-sectors.

Türkiye's government is also supporting efforts to digitize manufacturing in order to modernize production and increase the value-added of products. In 2018, the share of medium-high and high-tech products in manufacturing industry exports was 36.4% and 3.2%, respectively, and the goal is to increase these rates to 44.2% and 5.8% by 2023[4].

Surveys and microdata sets, including the "Survey on Information and Communication Technology (ICT) Micro Data Set (2021)" by TURKSTAT and the "Digital Scorecard Survey for SMEs in Turkey (2021)" by TEPAV, were used to gather information about the use of technologies such as IoT, artificial intelligence, and big data in different sub-sectors of Türkiye's manufacturing industry. These analyses aim to understand the sector as a whole and how digital transformation is affecting firms of different sizes and sub-sectors.

Digital Scorecard Survey for SMEs in Turkey (2021)

Digital Scorecard Survey for SMEs is a survey that was carried out by TEPAV in early 2021. The questionnaire was applied to 2,600 SMEs of different sizes operating in 13 different sectors in 12 pilot provinces (Ankara, Antalya, Balıkesir, Bursa, Erzurum, Gaziantep, Istanbul, İzmir, Kayseri, Malatya, Samsun, and Trabzon) to determine the development areas in the digital transformation of SMEs[5].

According to the E-Scorecard survey, most manufacturing SMEs in Turkey are micro-sized. 59.1 percent of the SMEs in the manufacturing sector employ 1-9 people, whereas 25 percent employ 10-49 and 15.8 percent employ 50-249 people.

The majority of the manufacturing SMEs are located in Istanbul, according to the Digital Scorecard Survey for SMEs held by TEPAV. 35.8 percent of the firms are located in Istanbul, 22.4 percent are located in Izmir, 11.7 percent are located in Ankara, and the rest are spread

[3]Mittal S, Khan MA, Romero D, Wuest T. Smart manufacturing: Characteristics, technologies and enabling factors. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture. 2019;233(5):1342-1361. doi:10.1177/0954405417736547

[4] The Ministry of Industry and Technology, "2023 Sanayi ve Teknoloji Stratejisi" (2019), https://www.sanayi.gov.tr/assets/pdf/SanayiStratejiBelgesi2023.pdf

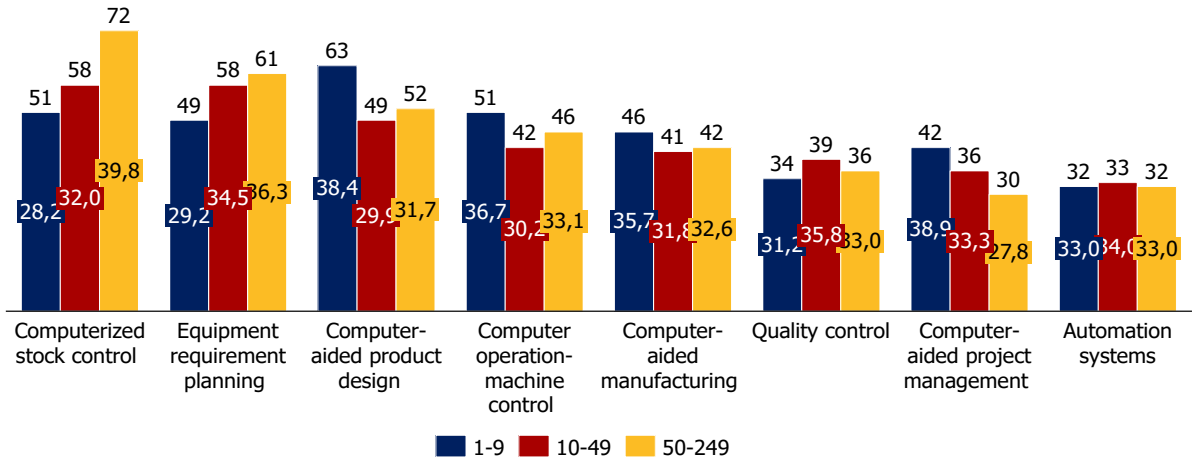
[5] Selin Selimoglu. (2022, July 26). *Mastercard ve TEPAV KOBİ'lerin Dijital Dönüşümü İçin El Ele Verdi*. Mastercard.com. https://www.mastercard.com/news/eemea/tr-tr/haber-merkezi/basin-bultenleri/tr-tr/2022/mastercard-ve-tepav-kob%C4%B1-lerin-dijital-donusumu-%C4%B1cin-el-ele-verdi/

throughout the rest of Turkey. Firms located in Istanbul use digital solutions more commonly than in the rest of the cities in Turkey. In Istanbul, the most commonly used solutions are computer-aided manufacturing and computer-aided project management. In Izmir, the most commonly used solutions are computerized stock control and ERP solutions. In Ankara, even though at lower levels, the most commonly used solutions are automation systems and computer-aided manufacturing.

The most commonly used digital solutions are computerized stock control, equipment requirement planning solutions, and computer-aided product design. Computer operation-machine control, computer-aided manufacturing, and quality control are other common use cases. 34.1 percent of the firms use computerized stock control, whereas 31.6 percent are using ERP solutions.

Use levels for each respective technology are generally higher for bigger firms. The most commonly used technology, computerized stock control, is used by 28.2 percent of the firms that have 1-9 employees and 39.8 percent of the firms that have 50-249 employees. A similar outlook is observed throughout all technologies (*Figure 2*).

Figure 2. Use levels of digital technologies according to firm size, %, 2021



Source: "Digital Scorecard Study for SMEs in Turkey" Survey (2021), TEPAV calculations

Manufacturing firms are planning to use stock/warehouse management, CRM, and production management solutions in the future. When asked about the future prospects of which tools they intend to focus on digitalizing in the upcoming period, 33.3 percent of the manufacturing SMEs stated that they are planning to digitalize stock/warehouse management. 29.2 percent of the firms are planning to digitalize customer-relations management in the upcoming period. Plans to adopt a digitalized stock/warehouse management solution increase with the firm size. Firms located in Istanbul exhibit more inclination towards adopting any of the digital solutions.

Survey on Information and Communication Technology (ICT) Micro Data Set (2021)

A survey on Information and Communication Technology (ICT) usage in enterprises has been conducted by TurkStat on a regular basis since 2005. The objective of the survey is to understand the information society, as well as to identify the use cases and obstacles to the usage of information technologies.

According to TurkStat's survey, the use of ERP software becomes increasingly common as the firm size increases. In general, the basic metals sector has the highest percentage of ERP software usage, followed by the motor vehicles and pharmaceuticals sectors. The overall average usage level is 57.9 percent, while the usage levels reach 100 percent for sectors that commonly use ERP software, with firms that employ 250 or more people.

The use of data from smart sensors is more common for medium-to-high technology sectors; however, the overall usage level is only at 8 percent. The highest usage level for data from smart sensors is in the motor vehicles sector, with 14.2 percent. Confirming that bigger firms employ digital technologies more than smaller ones, 29.4 percent of firms with 250 or more employees in the motor vehicles sector use data from smart sensors.

Geolocation data is not commonly used for big data analysis, except for firms in the petroleum products sector with 250 or more employees. The average usage level for the manufacturing sector overall is 5.5 percent, with the non-metallic mineral products sector having the highest percentage of users at 10.4 percent. The use of geolocation data is common for sectors where raw material is dependent on location.

48.8 percent of firms in the manufacturing sector are using machine learning as a big data analysis method. Even in smaller firms, the use of machine learning is common. The most common users are the plastic products, fabricated metal products, and chemicals sectors, respectively, with usage rates of 64.5 percent, 64.1 percent, and 60 percent.

The use of enterprises' own 3D printers is highest in the computer electronics and motor vehicles sectors. Firms that operate in medium-to-high technology sectors and are of bigger size are more likely to use their own 3D printers. The average for all manufacturing is 10.7 percent. The use of 3D printing services provided by other enterprises is high in medium-to-high technology sectors, but the change with firm size is not as apparent.

The use of industrial robots becomes more common as the firm size gets bigger, and the production process gets longer and more complex. Overall, 53.1 percent of firms in the motor vehicles sector use industrial robots, and 84.4 percent use them if the firm employs more than 250 people. The machinery and equipment (35.9 percent), basic metals (34.4 percent), and fabricated metal products (32.9 percent) sectors are others that have above-average usage levels for industrial robots.

The use of service robots is not common, except for the repair and installation and motor vehicles sectors. The average usage level of service robots is very low, at 1.2 percent; however, 14.3 percent of repair and installation firms with 250 or more employees use this technology. Combined with industrial robots, service robots are used in sectors where the production line is long and complex. The importance of robots in these sectors comes from the need to avoid any unplanned interruptions to the production line and navigate around large factories.

IoT technologies are mostly used for security and energy consumption management purposes. Overall use levels are the highest in the basic metals (36.8 percent), fabricated metal products (36.7 percent), and motor vehicles (36.0 percent) sectors. In each of these sectors, the highest percentage of firms report that they use IoT technologies for premises security. The second most common use is for energy consumption management. For the use of IoT for

production processes, the motor vehicle sector is the most common user at 52.7 percent, followed by plastics at 51.8 percent. Condition-based maintenance is highest for the motor vehicles sector (36.3 percent). This confirms the focus group findings, where the automotive firms expressed that they focus on processing the high volume of data (which is high due to the nature of the production in this sector), in order to use that in a more proactive manner, especially for predictive maintenance.

The use of AI technologies is most common in the motor vehicles sector, even though the overall use levels are at the lower end. The most common uses for AI are robotic process automation and image recognition, at 3.2 percent and 3.9 percent, respectively. Motor vehicles and computer & electronics sectors are the most common users for both technologies. For the automotive sector, AI is used for reasons such as machine vision combined with cobots for the installation of car tops and windshields, as well as predictive maintenance, combined with the data collected from the IoT devices. AI software is again most commonly used in motor vehicles and computer & electronics sectors, for production processes and ICT security reasons.

Focus group findings on the Turkish side

Focus group meetings were held with a number of firms and research institutions that are stakeholders in the digital transformation ecosystem in Türkiye. The aim of those focus group meetings was to identify how those technologies are used in the companies, how they are adapted, and to see what the potentials of those technologies are[6].

All the participating firms and institutions in the focus groups expressed that they adopt or have the willingness to adopt digital transformation strategies to some extent. All of the firms are aware of technologies such as the Internet of Things (IoT) and artificial intelligence (AI), even if they are not actively using them.

Many sectors have internalized and are actively using some digital technologies that are rather old, such as ERP or stock management. Integration of internal processes, such as the standardization of inventory management, purchasing, or warehousing; or integration with customers/suppliers, are common uses for digital technologies.

Making the production process more traceable and improving the ability to collect data from production processes is one of the main purposes of adopting digital transformation strategies for firms. Tracking the production process is important for firms, since the higher volumes of data from the production process are decreasing the barrier to entry for using tools that utilize data.

Production lines that are more complex create a need for data collection since the cost of unplanned cuts in production is very high, especially for the automotive industry. The data collected and processed in novel ways can be used to improve workplace safety, improve and ensure a standardized quality of the products, anticipate the needs for specific parts of the production line, and provide the basis for predictive maintenance.

One of the main determinants in the use of digital technologies such as AI or ML is whether the production process can be standardized or not. If a firm's end product is meant

[6] See Appendix I for a list of focus group participants.

to be sold to another firm, it is less likely to be standardized, hence less likely to be fully digitalized. If a firm's end product is meant for customers, it is more likely to be a fully digitalized production line, since the product is standardized. For instance, machinery and equipment producers have production lines that create a lot of data but do not commonly use AI, since they produce according to the demands of each individual customer, rather than a serially produced, standardized product. However, for sectors such as motor vehicles, the product is standardized and meant for the end user, allowing for an easier digitalization process.

The main motivation for digitalization in firms that are not engaged in serial production is to monitor and optimize production and ensure that they are sticking to the production plan. The production process is less frequently digitalized in non-serial producers, but can be partially so to meet customer demands.

Due to the higher volumes of collectible data from the production process, the demand for new and improved tools for data collection, processing, and security is becoming higher as well. An increasing number of firms from all sectors are demanding sensors for tracking production. ICT security is becoming increasingly important as well. A higher amount of data requires more extensive security measures.

To address these digital transformation needs, most firms outsource the necessary tools while keeping an in-house team for digital transformation needs as well. Outsourcing decisions are mainly based on the market popularity and the expertise of the service provider. The scale of the firm itself is also a determinant. For instance, one focus group participant stated that when there is a need for a certain technology, they look at the technology providers in that technology area. If there are a large number of service providers with affordable prices, they outsource this digital transformation need. The participant stated that in larger companies, an in-house team is always formed for developing these technologies internally, even if it is currently being outsourced. In this case, larger firms are harder to target as a market for technologies, since they are already producing it. However, at the SME level, it might be meaningful to introduce these technologies, since the smaller scale of these firms means that they are more likely to outsource this need.

Digital transformation needs can also be met through collaborations with universities (although this is not as common as in the Netherlands), start-ups, and government agencies. For instance, in the automotive sector, the need for AI for predictive maintenance was met through a collaboration with Boğaziçi University. They collaborated with the university to develop the correct algorithms. A collaboration with IBM on vehicle tracking systems using blockchain technologies was also formed. The firm also intends to finance an innovation laboratory in a university to better meet its digital transformation and innovation needs.

Due to the availability of international trade and existing relationships, both firms and digital service providers in Türkiye choose to outsource their needs from suppliers in the EU to ensure better compliance with existing and potential partners. Needs such as software and hardware are currently in demand from European countries, as well as some raw materials. For instance, the machinery and equipment industry, especially when producing machinery for exporters, has to comply with EU guidelines.

An analysis of the digital transformation ecosystem in Turkey shows that the ecosystem has an extensive web of collaborators, including but not limited to firms, knowledge institutions, and private and public sector actors. Still, there are areas for improvement, with the opportunity to create a deeper network both within and outside of Turkey. This means that there are areas suitable for forming relationships and creating an outlet for Turkish firms to outsource their digital transformation needs from the Dutch side.

Universities are the most common collaborators, with collaborations being more common for bigger firms with access to wider networks and resources. Proximity to a techno park type of structure may affect the ability to form collaborations with other institutions.

Firms are willing to introduce collaborations to their work, but there is ambiguity about how to form these relationships, especially if they are to be newly formed. Firms and individuals working on potentially complementary subjects do not have adequate opportunities to be exposed to one another. Interaction opportunities with the whole ecosystem should be developed. One focus group participant specifically pointed out Digital Innovation Hubs in Europe, where there is an open science policy and data-sharing, which provides firms with leverage on the know-how.

Barriers to the adoption of digital technologies can be attributed to several factors, including language barriers, lack of awareness (especially among SMEs), lack of education, and lack of access to skilled labor. These act as barriers for firms.

ISO500 List, common technology areas

Technologies

The ISO500 list, short for Turkey's Top 500 Industrial Enterprises, is a yearly study initiated by the Istanbul Chamber of Industry. The study aims to reveal the big companies in the industry and is the longest-running and most comprehensive study for the industrial sectors in Turkey[7]. Companies in this list are sorted according to the net production-to-sales criteria. Within the scope of this study, a detailed breakdown of the ISO500 list was done in order to reveal the technologies used by the top 500 companies, intended purposes for the technologies, and any collaborations they might have. Technologies being used are tagged and sorted according to the keywords found in the firm's website, news about the firm, mission and vision statements, or strategy documents of the firm, and as such. Sub-sectors are sorted according to their 2-digit NACE codes.

Virtual reality and simulation technologies are most commonly used by the motor vehicle sector, followed by the wood sector. Other sectors that use VR and simulation technologies are in basic metals and chemicals sectors, however, it is not as common. These technologies are common in sectors where visualization is important in the production process.

Automation and robotic process automation technologies are most commonly used in the motor vehicles sector. Food production and fabricated metal products sectors also have a high

[7] *Tarihçe ve Metodoloji*. (2021). Iso500.org.tr. https://www.iso500.org.tr/tarihce-ve-metodoloji

number of users following the motor vehicles sector. High usage levels in the motor vehicles sector confirm the trends seen in the survey and the focus group meetings.

The number of cloud computing and data warehouse users is highest among basic metals and non-metallic minerals sector. Food products and fabricated metal products sectors also have firms that use cloud computing technologies.

ERP, namely SAP software, is most common in the basic metals sector, followed by food production firms. From the surveys, ERP/SAP is common throughout all sectors since it is an older technology compared to the others. However, the basic metals sector is newly adopting a comprehensive version of SAP for digital transformation of the iron & steel sector in Turkey, which in turn is recently on the focus of those companies.

IoT is used by a higher number of firms and in a wider variety of sectors than the other technologies. Motor vehicles and food products sectors are the most common users, with varying use purposes. For instance, the food products sector uses IoT devices for purposes of monitoring the agricultural products to increase productivity and the quality of the raw material. In the motor vehicles sector, IoT technologies are used for monitoring the production process itself and gathering data from production and maintenance systems.

The use of physical robots is common in food products and motor vehicles sectors, followed by chemicals. Physical robots are common in sectors where the production process takes place in a long and complex production/assembly line, since the use of robots decreases the transaction costs of tasks that would otherwise be performed by humans, as well as decreasing the losses in productivity caused by human error.

Even though it is a newer technology, AI adoption is as high as other older technologies in some sectors. For instance, the motor vehicles sector has the highest number of firms stating the use of AI technologies. AI is used for purposes such as automating in-house operational work, improving dealer processes, reducing CO2 emissions and waste, improving part quality, reducing costs, better connectivity to customers, vehicles, and the entire production process. Food products and chemicals sectors have a higher number of firms using AI as well, following motor vehicles.

Big data and data analysis are common in sectors where the production process creates higher volumes of data, such as basic metals and chemicals sectors. Motor vehicles are again a common user of big data and data analysis technologies in their work. A common theme that emerges in all of these sectors is that the use purpose of big data is creating a more efficient production process while decreasing the margin of error and preventing anything unpredictable in the process.

Machine learning is most commonly used in the chemical sector. The purposes of its use include real-time monitoring of the production process and energy consumption, improving the speed of production, and decreasing occupational health and safety hazards. Basic metals and motor vehicles sectors are the other sectors with common use of ML.

The prevalence rate of any technology is highest in Istanbul for all technology types. Most of the firms on the ISO 500 list are located in Istanbul, which means there is a higher variety of technologies there. This also creates a higher level of exposure for firms to new technologies in

Istanbul. Other cities with higher numbers of firms for each technology are Ankara, Izmir, and Kocaeli. Kocaeli is also located in the Marmara region, and the geographical proximity may be allowing those companies to have better exposure to digital technologies as well.

Collaborations

ISO 500 companies are the giants of the industry in Turkey, and they have a wide reach in terms of collaborations. Their collaborators include universities, private sector companies, and public sector institutions, depending on the type of need.

University collaborations are common in high-technology sectors such as motor vehicles and chemicals. Universities also contain institutions such as technology transfer offices and/or technoparks, which allows companies a wider variety of collaboration opportunities. Reasons for university collaborations in these sectors include providing a competitive advantage, developing a culture of innovation to increase the innovation capacity of firms, and carrying out research for improving production processes.

The geographical proximity of the firms to the university does not seem to be the determining factor or a limiting one. For instance, a company operating in Istanbul can be forming a partnership with a university in Ankara and vice versa.

A common reason for university collaborations is outsourcing the development of technology. Instead of keeping an in-house team for developing a certain technology, let it be software or hardware, the companies prefer to direct their resources to a university with the necessary research capacity and human resources and keep an in-house team for the day-to-day operations of the said technology.

Collaborations with the Scientific and Technological Research Council of Turkey (TÜBİTAK) are prevalent in the food products and basic metals sectors. TÜBİTAK has a subordinate research center, the Marmara Research Center (MAM), which has a food institute specifically. This may have been a contributing factor to the higher prevalence of the food products sector in collaborations. Some collaborators of TÜBİTAK are at the very top of the ISO 500 list, including TOFAŞ and Ereğli Demir Çelik.

National strategy documents

Digital transformation of the manufacturing industry, especially through technologies such as the Internet of Things, artificial intelligence, big data, cloud computing, augmented reality, cybersecurity, sensor technologies, and robotics, is highly promoted in Türkiye's national strategy documents. These documents mainly focus on increasing the utilization of these technologies, causing productivity growth in the sectors and supporting domestic suppliers to develop them. These strategies are mainly stated in the 11th National Development Plan.

In the National Industry and Technology Strategy for 2023, defense industry, aerospace technologies, unmanned and autonomous systems, and smart weapon systems are the areas that are expected to be developed with the help of sensors, the Internet of Things, artificial intelligence, robotics, and cloud computing. One of the objectives of this strategy is to produce at least 23 smart products with a world-leading market share or brand value in at

least one of the disruptive technology fields. Additionally, "**AI and machine learning"** and "**big data and data analytics**" were prioritized within 27 technology areas under the scope of "Identification of Priority Technology Areas to Focus on within the Scope of Groundbreaking Strategic Approach" carried out by the **Presidential Science, Technology and Innovation Policy Board**, and they were determined as the areas with the highest impact and feasibility in terms of economic impact, social benefit, and national security.

Cloud computing is an area that is expected to grow with countries with which Turkey has intensive trade relations. This area is unique since there is a prioritization of the countries with which Turkey will have a close collaboration. According to the 11th National Development Plan, "A regulatory framework and incentive mechanisms will be established to develop the data center sector, and cooperation initiatives will be taken for the provision of cloud services with countries having intensive trade relations with Turkey." Furthermore, the National Industry and Technology Strategy for 2023 states that "To scale the investments, collaborations will be made to provide cloud services located in Turkey to countries where Turkey's trade is high." According to recent data, the Netherlands is Turkey's 10th biggest trade partner. Another point about cloud computing is that an **industrial cloud platform** is currently being planned, in which the relevant professional organizations and the state participate. Third-party service providers can develop applications and reach users, and digital infrastructure and services will be provided centrally to companies. This platform will be established for the **automotive industry** in the first place.

There are different new interfaces to accelerate the digital transformation of Turkish businesses. The most popular interface is developed by **the Model Factory (SME Competency Center) Consultancy Support Program**, which has been implemented by the Ministry of Industry and Technology and UNDP. Under this program, 8 centers have been established in Turkey's leading industrial cities (Ankara, Konya, Kayseri, Bursa, Gaziantep, Mersin, Adana, and İzmir) to increase productivity in the manufacturing industry and accelerate digital transformation processes since 2019. With the training and consultancy services it provides, the centers aim to change the existing mentality of enterprises on continuous improvement, lean production, and digital transformation.

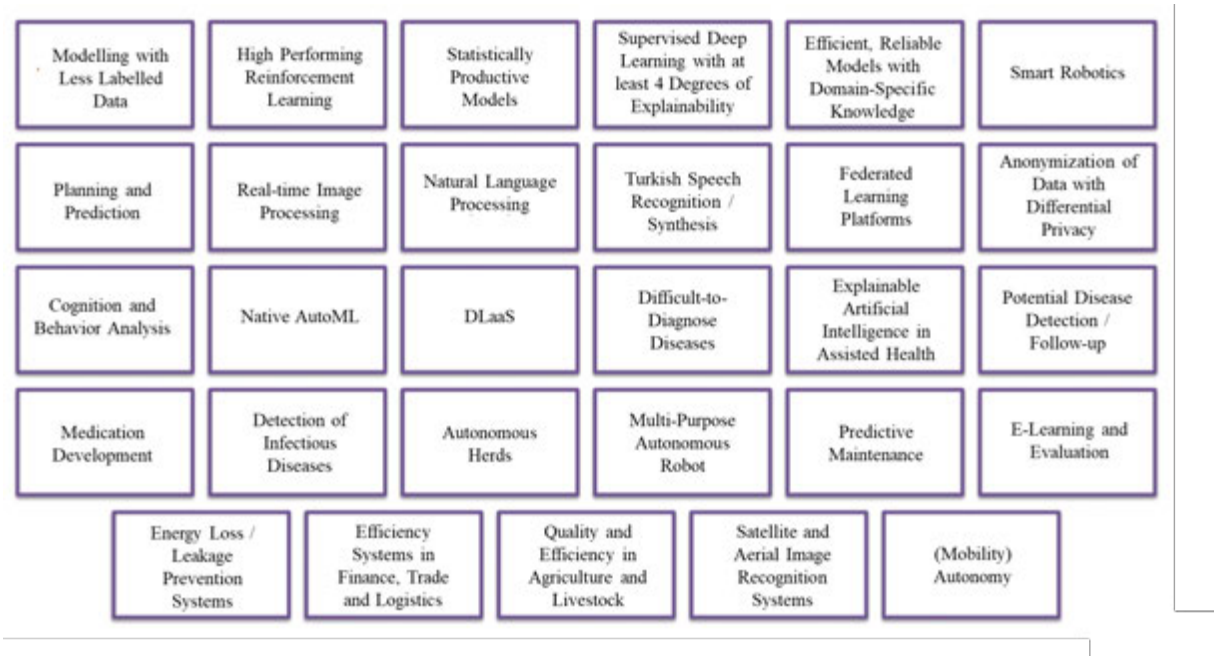
TUBITAK has three key priority areas related to the digital transformation of Turkish businesses for R&D and innovation activities in 2022 and 2023: artificial intelligence, big data and cloud computing, and cybersecurity. The other (non-digital) priority areas are biotechnological medicine, motor, advanced materials, microelectromechanical systems (MEMS)/nanoelectromechanical systems (NEMS), semiconductor technologies, advanced photonics, and quantum technologies. This means support programs and other activities performed by TUBITAK will focus on developing these three areas (i.e. artificial intelligence, big data and cloud computing, and cybersecurity). Consequently, in the focus group meetings, Turkish stakeholders stated that those areas, especially big data and artificial intelligence, will be used more widely in Turkey than today. Furthermore, they expect that the increasing data volume due to big data use will cause an increase in demand for cybersecurity solutions.

Figure 3. TÜBİTAK Priority R&D and Innovation Areas, 2022-2023

Source: TÜBİTAK 2022-2023 Ar-Ge ve Yenilik Konu Başlıkları, November 2022

Under the artificial intelligence area, the most of technologies prioritized are related to health industry in general, whereas robotics draws attention in the manufacturing industry. Diseases that are difficult to diagnose, explainable artificial intelligence in assisted health, potential disease identification/monitoring, pharmaceutical development, and infectious disease detection are related to health industry. The reason behind this, Turkey (especially Istanbul) is an important hub for medical services for Europe and MENA regions and medical tourism is highly promoted by the government. For the manufacturing side **smart robotics, real time image processing, multipurpose autonomous robots** and **predictive maintenance** are the technology areas which are prioritized by TUBITAK. Those areas are compatible with the current use stated by the participants of Turkish focus group meetings. They have stated that they use smart robots for productivity and safety purposes, and **predictive maintenance** is getting increase its importance. Another important point is **artificial intelligence based energy loss/leakage prevention systems** is one prioritized topic in which has an huge potential in Turkey (according to market potential analysis) and the Netherlands has high use level (according to the focus group meetings with the Netherlands side). Therefore, the knowledge institutions from two countries could collaborate in R&D activities under this topic.

Figure 4. Priority R&D and Innovation Areas in AI Technologies, 2022-2023



Source: TÜBİTAK 2022-2023 Ar-Ge ve Yenilik Konu Başlıkları, November 2022

Big data and cloud computing solutions are mainly focuses on manufacturing industry and the main purposes are

- **establishing large data libraries that will enable the processing and analysis of data from production, energy and IoT sensors on the basis of each machine and/or line in factories to be used for purposes such as predictive maintenance, flexible production, unmanned breakdown and stock management, machine assistance, flexible productivity management**
- **developing solutions that can provide real-time monitoring and feedback**

For those purposes, the technologies to be prioritized by TUBITAK are **industrial cloud services, big data-based solutions** in the manufacturing industry, **virtual data spaces** in industry and manufacturing, **digital twin solutions** in the manufacturing sector, **knowledge-based production solutions, large-scale test and experiment centers,** and **edge computing** solutions.

Figure 5. Priority R&D and Innovation Areas in Big Data and Cloud Computing Technologies, 2022-2023

Source: TÜBİTAK 2022-2023 Ar-Ge ve Yenilik Konu Başlıkları, November 2022

Under cybersecurity, there are different IoT-related technologies for R&D and innovation priorities of TUBITAK. These technologies include application layer supported Web/VoIP/**IoT**/Database, technologies that can monitor and manage traffic in networks with OT, **IoT devices** (firewall, access control, etc.), and prevent cyber-attacks. Other prioritized technologies include domestic cybersecurity technologies and products for 5G and beyond, **IoT** and base stations (including SDN/NFV-based security applications and SDN/NFV security), and technologies that will provide secure communication for smart production systems. Reputation systems, access control and authorization systems, prevention of data leakage from products such as RFID, **IoT**, Pick-to-Light, detection, and prevention of cyber-attacks are also among the top priorities.

Figure 6. Priority R&D and Innovation Areas in Cyber Security Technologies, 2022-2023

Source: TÜBİTAK 2022-2023 Ar-Ge ve Yenilik Konu Başlıkları, November 2022

TUBITAK's priority areas about big data and cloud computing are very similar to the technological objectives and prioritized sectoral applications stated by the Big Data and Cloud Computing Technology Roadmap prepared by the Presidential Science, Technology, and Innovation Policy Board. In this roadmap, there are seven technological objectives and six prioritized sectoral applications, listed below:

Technological Objectives:

- **Real-Time Big Data Processing Technologies** - Development of big data technologies needed for near real-time and real-time processing and analysis of data, analysis and mining applications for the solution of artificial intelligence problems. This includes:
    - Real-Time Infrastructure for Decision and Integration Layers
    - Reliability Solutions in Artificial Intelligence
    - Real-Time Infrastructure for Data Analytics
    - Real-Time Infrastructure in Edge/Fog Computing

  - Infrastructure for the Prevention of Data Rate Losses
- **SaaS for Converged Big Data** - Development of SaaS solutions to create and process integrated (all-process) big data by protecting the privacy of data of different content or structure obtained from different sources. This includes:
  - SaaS for Converged Big Data
- **Cloud Technologies Providing Virtualization Solution Suitable for Microservice Architecture** - Development of cloud technologies suitable for microservice architecture, providing platform-independent and container virtualization solutions. This includes:
  - Microservice Architecture and Virtualization in the Cloud
- **Distributed Registry (DLT/Blockchain) Based Encryption Infrastructure -** Development of distributed ledger (DLT/blockchain)-based encryption infrastructure, smart contract, and token technologies (NFT) in accordance with Big Data Architecture structures for the creation of systems that can be harmonized with international regulations and standards and resistant to cyber-attacks in order to ensure the confidentiality and security of cloud-based big data. This includes:
  - Blockchain Based Big Data
  - Blockchain Based Digital Identity
- **Hybrid Cloud Technologies -** Development of hybrid cloud technologies that are flexible, scalable, adaptable with open interfaces, fast working, suitable for 5G and beyond advanced communication technologies, and have high-security features for the data of different institutions/organizations/users. This includes:
  - Hybrid Cloud Technologies
- **Cloud Computing Infrastructure Services (IaaS) -** Development of cloud computing infrastructure services (IaaS) over data centers that will be geographically located in different regions of Turkey, where high-speed network access will be provided, high-availability, scalable, and physical/logical/cybersecurity will be meticulously constructed. This includes:
  - Cloud Computing Infrastructure Services (IaaS)
  - Cloud Based GPU Service
  - Cloud Based FPGA Service
  - Cloud Based Quantum Computing Service
- **Development of Big Data Pre- and Post-Processing Tools -** Development of data visualization tools and attribute engineering tools that can be used in big data display. This includes:
  - Data Visualization Tools
  - Big Data Attribute Engineering Tools

Prioritized Sectoral Applications:

- **Real Time Mission Support Mechanism -** development of real-time decision support mechanisms using cloud computing and big data technologies for use in the defense industry. This includes:
  - Real Time Mission Support Systems
  - Cloud Based Defense Analysis and Simulation Systems

  - Homomorphic Cryptographic Technologies
- **Industrial Cloud Services -** development of technologies and applications for the delivery of industrial cloud services to SMEs (WEF, MEXT cloud service project to SMEs, industrial IOT; World Bank and MOIT Industrial Cloud Project). This includes:
  - Industrial Cloud Services
- **Personalized Medicine/ Big Data Libraries and Cloud-Based Big Data Analytics -** building big data libraries and developing cloud-based big data analytics solutions to combine data collected from medical records and patients using smart devices to assist personalized healthcare applications, disease prediction, and prevention activities. This includes:
  - Personalized Healthcare Applications
  - Common Model and Tools for Big Data Libraries
  - Ontology and Services for Big Health Data
- **Big Data Library for Machine-Line Based Data -** creation of big data libraries collecting, processing, and analyzing data from production, energy, and IoT sensors on the basis of each machine and/or line in factories. This is to be used for purposes such as predictive maintenance, flexible production, unmanned breakdown and stock management, machine assistance, flexible productivity management, and development of solutions that can provide real-time monitoring and feedback. This includes:
  - Big Data Based Solutions in the Manufacturing Industry
  - Large-Scale Test and Experiment Centers
  - Edge Machining Solutions
  - Virtual Data Spaces in Industry and Manufacturing
- **Cloud Storage of Machine-Line Based Data -** creation of big data libraries collecting, processing, and analyzing data from production, energy, and IoT sensors on the basis of each machine and/or line in factories. This is to be used for purposes such as predictive maintenance, flexible production, unmanned breakdown and stock management, machine assistance, flexible productivity management, and development of solutions that can provide real-time monitoring and feedback. This includes:
  - Digital Twin Solutions in the Manufacturing Industry
  - Knowledge Based Manufacturing Solutions
  - Cloud Based Digital Twin Solutions (SaaS)
- **Financial Applications with Cloud Computing Methods (DLT/Blockchain, Smart Contracts, Token etc.) -** distributed ledger (DLT/blockchain), smart contracts, to enable financial services industry products to serve multiple users simultaneously, globally, decentralized and development of fast, reliable, and easily accessible financial applications using cloud computing methods of technologies such as tokens. This includes:
  - Blockchain and Cloud Computing in Finance
  - Cloud Based Blockchain Solutions (BaaS)
  - National Blockchain Platform
  - National Open Data Catalog System
- **Telecommunications, Communications/Cloud Computing and Big Data Solutions -** developing with cloud computing and big data solutions that can meet the real-time

data needs for distributed, high-bandwidth, logged, special use cases (disaster and emergency, etc.) for the realization of network virtualization functions in the core network in 5G and beyond communication systems as an edge cloud. This includes:

- Cloud Computing and Big Data Solutions in Communication

Knowledge institutions and collaborations

In order to understand the current performance and potential collaboration of Dutch and Turkish knowledge institutions, we have used restricted data derived from the InCites database of Clarivate[8]. In this database, we have collected and analyzed three main indicators, listed below, for both countries in different research areas:

- ***International Collaborations:*** the number of publications that have been found with at least two different countries among the affiliations of the co-authors.
- ***Industry Collaborations:*** the number of publications that contain two or more organizations with at least one organization listing its organization type as corporate or global corporate.
- ***h-index:*** a metric to obtain an understanding of the performance of research output by using a combination of productivity (number of documents) and impact (number of citations) in one index.

The research areas that we look for are also listed below:

- Computer Sciences (Hardware & Architecture)
- Information Systems
- Artificial Intelligence
- Automation & Control Systems
- Robotics
- Remote Sensing
- Cybernetics

Figure *7* shows a detailed assessment research performance of knowledge institutions and their collaboration with international institutions and the industry. The main findings from this assessment, are as follows:

1. **Dutch research institutions are much well-versed in than the Turkish ones in terms of collaborations with international institutions and industry.** Red lines on the graphs show the average values, which are almost tenfold higher in the knowledge institutions of Netherlands than the ones in Türkiye, in terms of both international collaborations and industry collaborations.
2. **Academic organizations are more likely to engage in international collaborations, more than the corporate organizations.** There are certain companies seen in the upper left part of the graphs, i.e. they have higher industry collaborations, despite their low international collaborations. Those companies are Aselsan, Havelsan, Ford[9] and TAI (mainly the big players from defense and aerospace industries) for Turkey, and Philips,

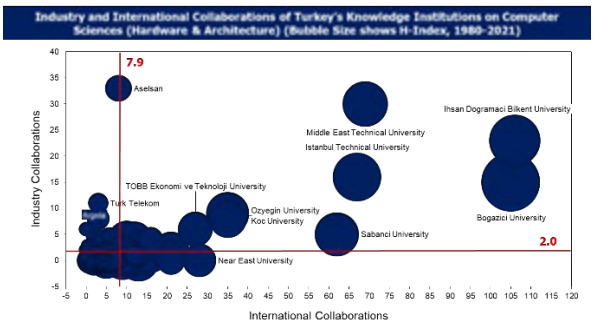
[8] *Clarivate*. (2022). Clarivate.com.https://incites.clarivate.com/#/landing
[9] It is a company from automotive industry, indeed, but they are owned by Koç Holding (with the partnership of Ford Motor Company) which operates defence industry activities under the company named 'Otokar'.

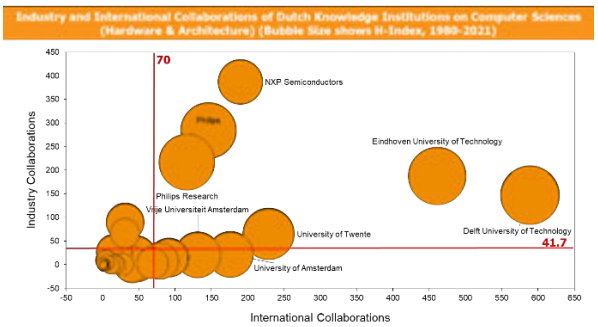
Philips Research, Philips Healthcare, NXP Semiconductors (subsidiary company of Philips), Airbus, ASML Holding, Royal Dutch Shell (electronics, health, oil and aerospace industries). Since, the sectoral composition of those companies are different in those countries and they are mostly collaborating with domestic partners, it is better to focus on the collaboration of academic organizations between the Netherlands and Türkiye.

3. **Although they vary depending on research area, there are certain number of Dutch and Turkish academic knowledge institutions can collaborate in those areas. Further, some universities from Istanbul province mostly focus on non-industrial collaborations with international organizations** (i.e. they are positioned on the right lower sides of the graphs). **Bilkent, Middle East Technical University** (in Ankara province), **Bogazici, Istanbul Technical University, Koc, Sabanci** (in Istanbul province) are knowledge institutions shown in the right upper part of the graphs for almost all of relevant research areas. (i.e. they are well performed in terms of both industry and international collaborations. Apart from them, **TOBB ETU** (for computer sciences – hardware and architecture and artificial intelligence), **Hacettepe** (for artificial intelligence and remote sensing), **Gazi** (for artificial intelligence and automation and control systems) universities in Ankara, and **Dogus** (for automation and control systems), **Ozyegin** (for computer sciences – hardware and architecture, information systems, robotics and cyberetics), **Yıldız Technical University** (for automation and control systems and remote sensing) in Istanbul have also good performances. In the Dutch side, **Delft University of Technology, Eindhoven University of Technology, University of Amsterdam, University of Twente, Vrije Universiteit Amsterdam** and **Wageningen University & Research** could be good players for the possible collaboration with Turkey's knowledge institutions on manufacturing industries.

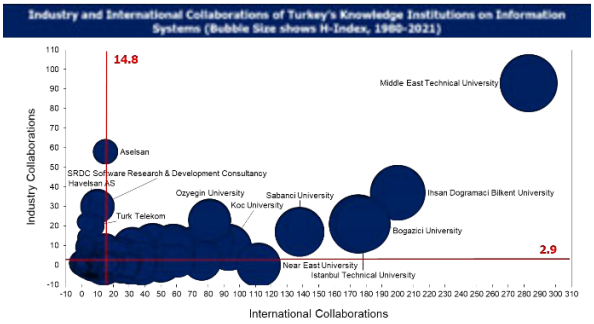
Figure 7. Assessment of the Dutch and Turkish Knowledge Institutions

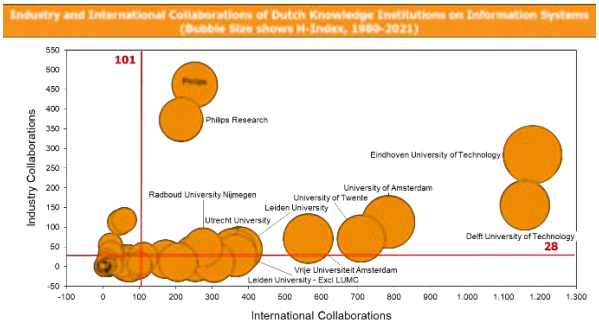
Computer Sciences (Hardware & Architecture)



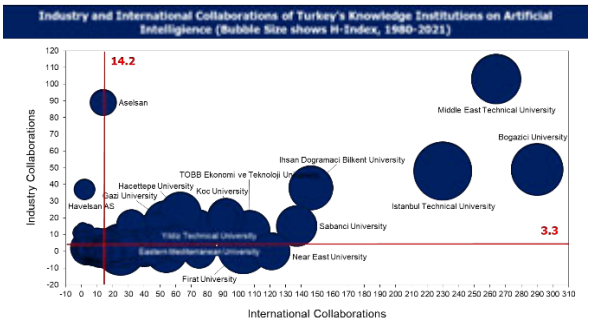


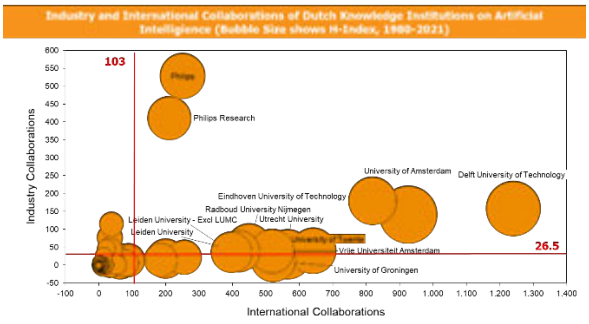
Information Systems



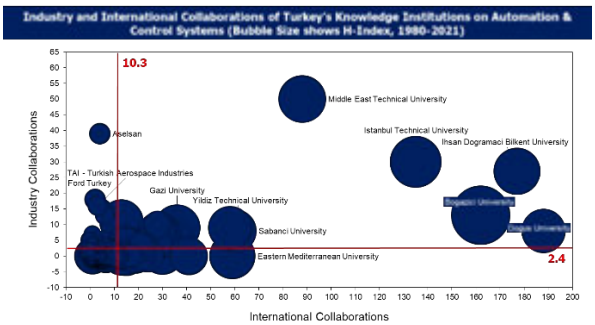


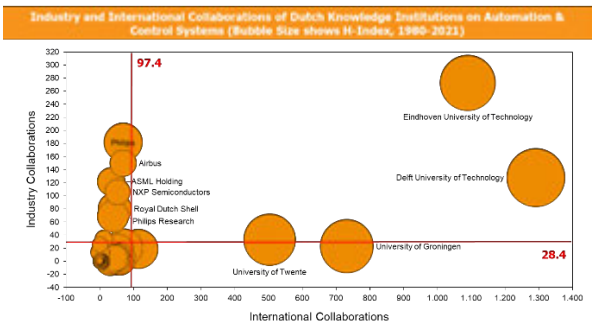
Artificial Intelligience



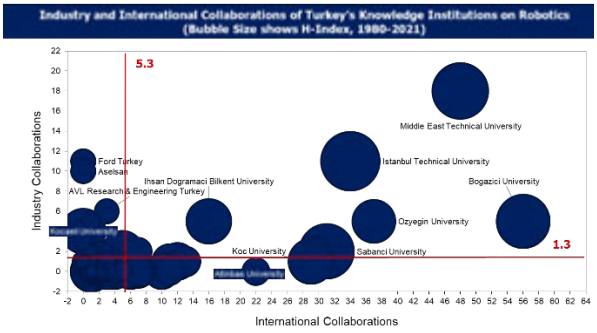


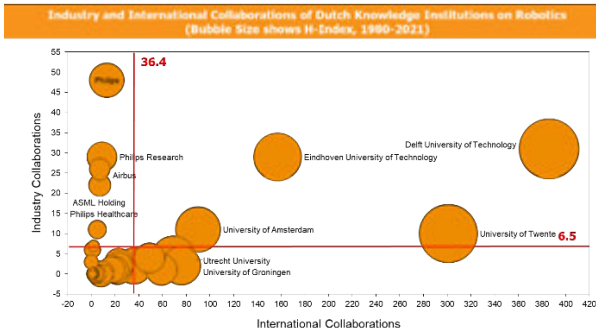
Automation & Control Systems



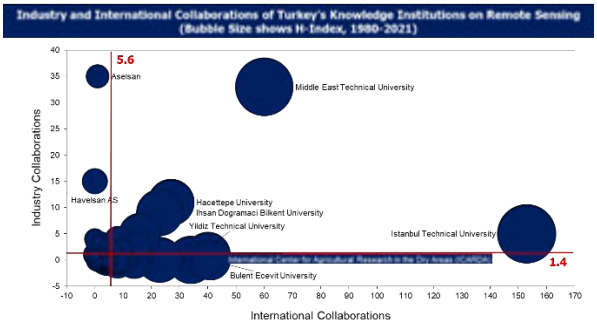


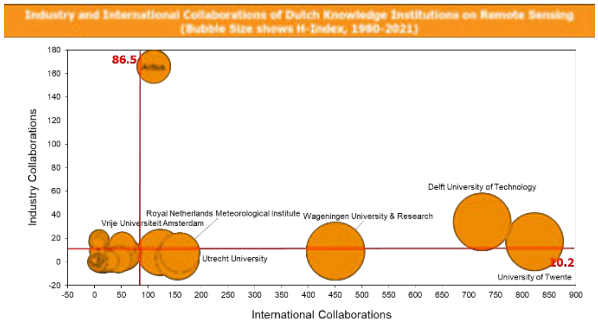
Robotics



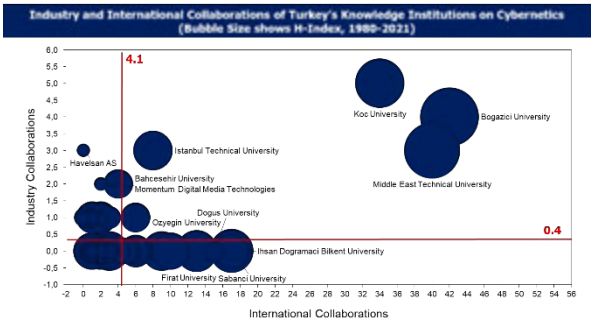


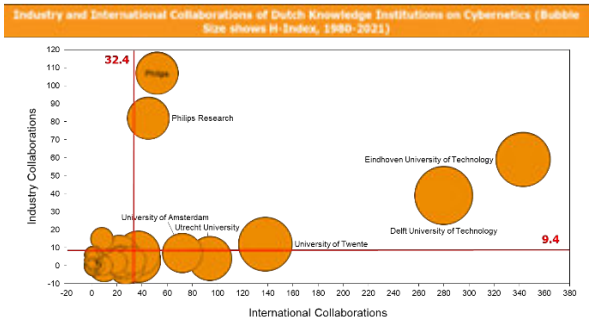
Remote Sensing





Cybernetics





Current and potential demand for digitalization in Türkiye's manufacturing sector in comparison with the EU

With the increasing demand for digitalization and the complex nature of Turkish manufacturing as a whole, there is a need to understand each technology area, coupled with the relevant sector.

To assess the current and potential market of certain technologies for the manufacturing sub-sectors in Turkey, we used three main indicators:

(1) Current use level of each technology in Turkey ('**TR Current'** variable)– Eurostat E-business statistics[10]
(2) Current use level of each technology in the EU ('**EU Potential'** variable)– Eurostat E-business statistics
(3) Number of SMEs which have 10 or more employers ('**Size'** variable) – TURKSTAT Business Database

Those indicators are used in two equations listed below.

- Current market size for technology i in sector j = TR Current(i, j) * Size(j)
- Potential market size for technology i in sector j = EU Current(i, j) * Size(j) - TR Current(i, j) * Size(j)

Notice that the current and potential market size shows the expected number of enterprises that have 10 or more employees using the technology currently or despite not using it currently, potential to use in the future, given that the subsector will achieve the EU use level for each technology.

It should also be noted that if Türkiye's use level is higher than the EU (although it is very rare), the potential market size is taken as zero. In other words, the market has reached its potential with the current use level for that technology in the relevant subsector.

Enterprises that send e-invoices have already reached EU levels of use, which is a general trend in technologies that provide integration with customers/suppliers. Supply chain management technologies have a lower chance of growth, since they are already commonly digital. Regarding supply chain management, enterprises whose business processes are automatically linked to their suppliers and other customers are at half of their potential, compared to EU use levels. This potential is especially high for resource-based traditional export sectors of Turkey, such as textiles, chemicals, and basic metals.

Firms in sectors with complex processes have already adopted ERP software for several purposes, such as sharing information between different functional areas. Therefore, ERP software usage does not have a lot of room for growth compared to EU use levels. Customer relations management (CRM) tools are also commonly used, and the potential is already exhausted to some extent. Textile and machinery have a higher potential compared to other manufacturing sectors.

Cloud computing is a newer technology area for Turkish firms that has higher potential. Uses such as database hosting have potential in sectors with more complicated production

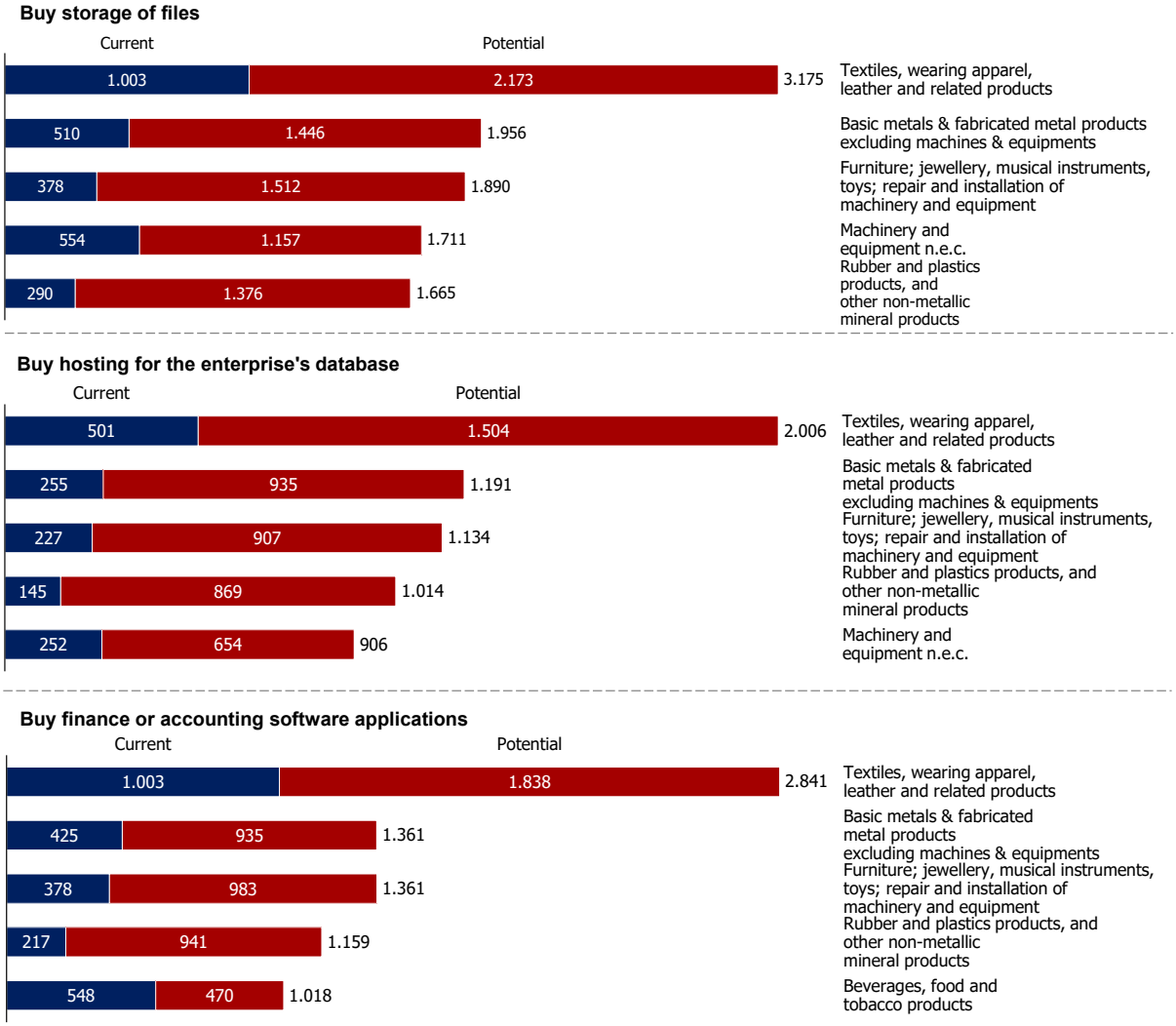
[10] *E-business integration - Statistics Explained*. (2021). Europa.eu. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=E-business_integration

processes and resource-based production. Complex production processes and resource-based production increase the need for production planning, as well as increasing the amount of data generated by the production process, hence the higher demand and potential for cloud computing. Cloud computing is a newer area that has yet to reach its potential and is open to development and improvement[11]. Global trends are increasing the demand for cloud computing technologies as well. Turkey, in general, has a lot of potential regarding cloud computing, and interest has been increasing over the past few years[12].

Eurostat data shows that textiles, basic metals, furniture, rubber, and machinery are sectors that have already adopted cloud computing services to some extent. However, they still have potential left in this technology compared to EU. Cloud computing services are used for purposes such as storage of files, hosting enterprise databases, and finance and accounting software applications. What these sectors have in common is that they are already established sectors in Turkey and operate on a larger scale with more complex production lines, which, in turn, increases the need for cloud services. Cloud computing provides these companies with better in-firm integration (Figure 8).

[11] Bilgi ve İletişim Teknolojileri Sektörü. (June 2022). Retrieved December 12, 2022, from https://www.tubisad.org.tr/tr/images/pdf/tubisad-bit-2021-tr-20220526.pdf
[12] For more details, please refer to: https://www.tepav.org.tr/tr/haberler/s/3851

Figure 8. Use of cloud computing services, number of firms, 2021



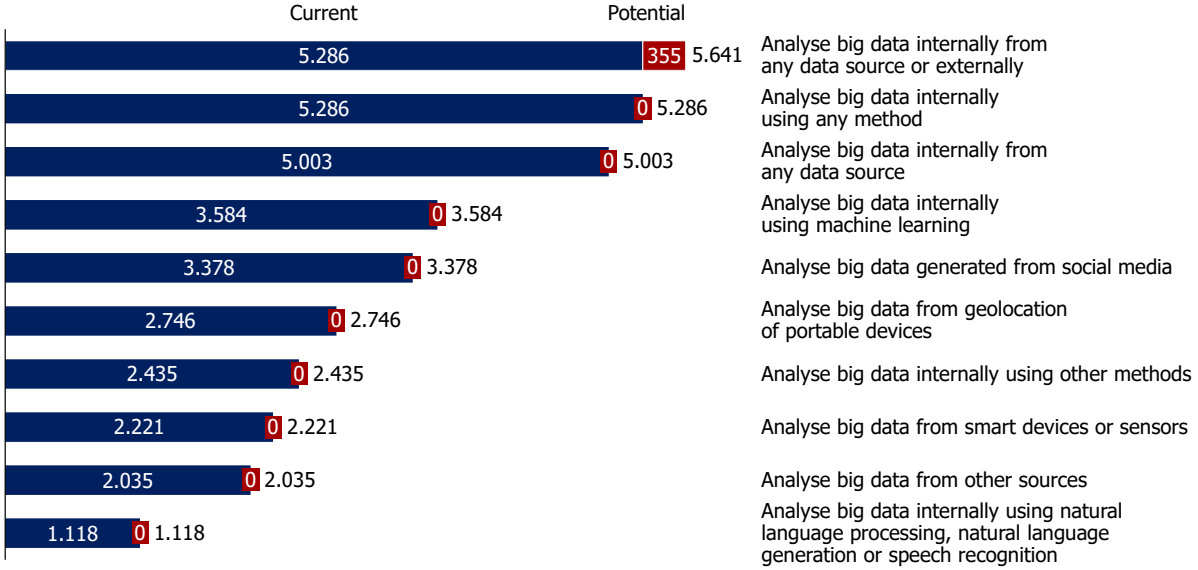
Source: Eurostat, TEPAV calculations

Customer relationship management (CRM) solutions are commonly used cloud computing services. Sectors that use CRM solutions have also commonly adopted other cloud computing solutions such as ERP. CRM is an older, more commonly used technology than other use areas, meaning that using CRM solutions might have led to a higher potential for using other newer cloud computing services. A similar situation is presented with enterprise resource planning (ERP) software applications. ERP is a well-established technology commonly used and closer to its potential. So, we can say that the know-how created by cloud computing services and technologies such as CRM and ERP translates into a higher propensity to use other cloud computing services in different areas of operation.

The higher use levels of cloud computing operations create a need for security applications. Traditional export sectors of Türkiye, such as textiles, basic metals, and plastics, have adopted cloud computing solutions to some extent, creating a need for security software applications of cloud computing services. The unused potential is higher in this aspect of digital transformation since this is a newer area fed by the other adoptions of digital transformation.

Almost all sectors in Türkiye are below the EU average in buying cloud computing services and using them for IoT purposes. The use of cloud computing services increases the potential for the use of IoT technologies since the data is readily stored and available. Sectors with long and complicated processes create more data during production, which can increase the demand for cloud computing services for storage and IoT technologies to benefit from the data. The manufacture of basic metals, plastics, and food are the sectors with the highest potential for buying cloud computing services and using IoT.

Figure 9. Big data technologies according to use purposes, 2021, number of firms

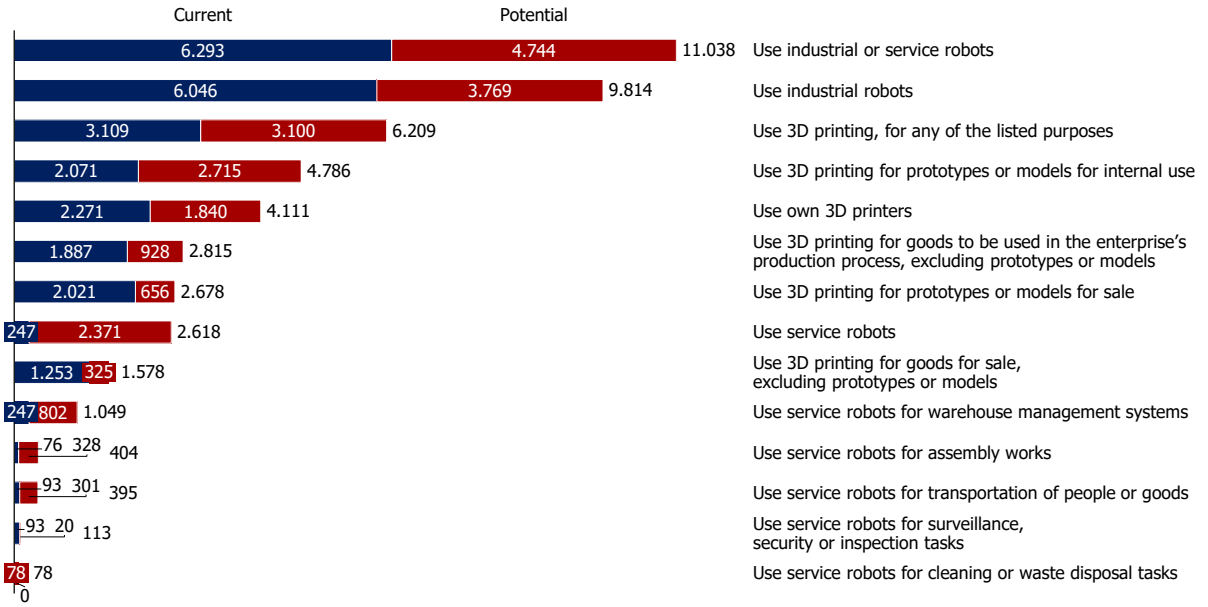


Source: EUROSTAT, TURKSTAT, TEPAV calculations

Big data analysis is an already established technology in Türkiye, with a few sub-sectors where the potential is yet to be reached. More complex and longer production lines create a more extensive array of data that can be used for big data analysis. Big data analysis is most common in the chemicals sector, which also has the highest potential. The electrical equipment, textile, food and beverage, and basic metals sectors also employ big data analysis in their operations. However, the potential is limited, as most sectors have already adopted this technology up to EU levels (Figure 9). Big data analyses from smart devices and sensors, as well as geolocation of portable devices, are also widely adopted, with minimal potential left to reach EU levels of use. Turkish firms have already adopted big data analysis for different purposes within their operations. In the focus groups, the uses for big data were listed as including but not limited to quality control, automation of production processes, optimization of production processes, increasing efficiency, and decreasing downtime. It can be concluded that the reason why there is still unused potential in the chemicals sector can be attributed to the nature of production. Big data analysis using natural language processing or natural language generation is commonly used in many sectors; however, the potential is mostly reached. The potential left is limited to motor vehicles.

3D printing and robotics are newer areas, and each use purpose for the technology is yet to reach its potential. The use of industrial or service robots is the most common use case in the EU (Figure 10). In Turkey, some firms have started using industrial or service robots, as well as 3D printing, but it is still behind the use levels in the EU.

Figure 10. 3D Printing and Robotics according to use purposes, 2021, number of firms



Source: EUROSTAT, TURKSTAT, TEPAV calculations

3D printing and robotics are used in sectors where production is based on the processing of raw materials, and where design is an important aspect. Sectors such as furniture, jewelry, and textiles still hold potential in 3D printing for prototypes or models for sale, whereas the potential is reached in sectors such as machinery and electrical equipment. 3D printing is more often used for sales purposes instead of internal use purposes, leading to the conclusion that the sectors where design is important may be using 3D prototypes for marketing purposes.

Robotic 3D measurement devices are used for quality control in the production processes of the motor vehicle sector. However, 3D printing and robotics have not yet reached EU levels of use in the motor vehicle sector. The sector is currently adopting these technologies to prevent unplanned interruptions in production due to quality issues.

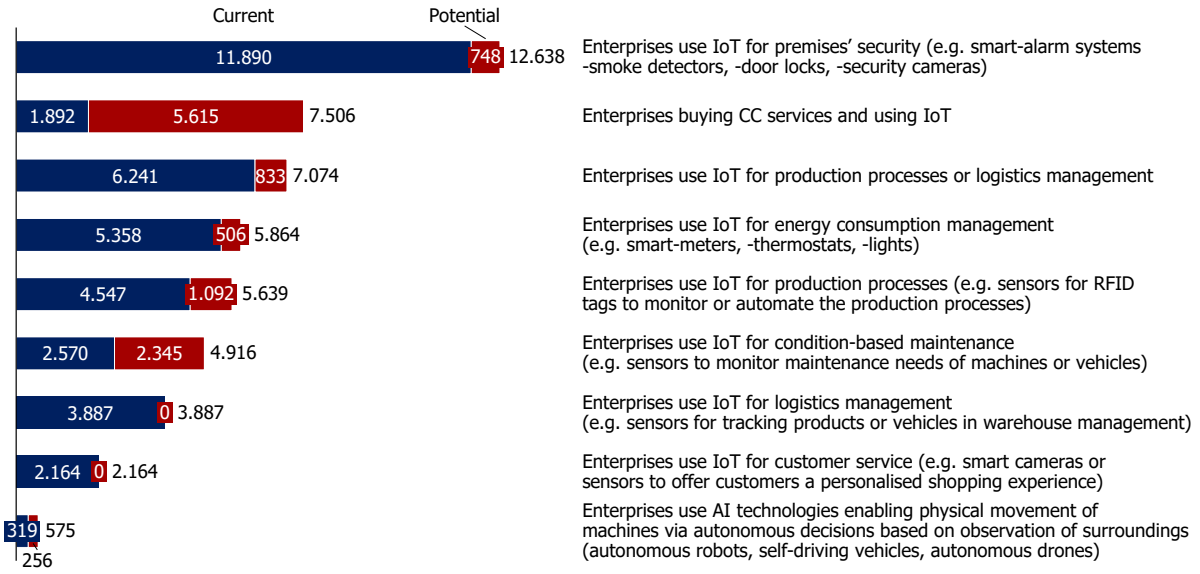
The use of industrial robots has higher potential in traditional export sectors such as chemicals and plastics. Basic metals, electrical equipment, and textiles are also among the sectors that have adopted the use of industrial robots. These sectors are likely early adopters due to the nature of their production processes. Additionally, the number of enterprises that own their own 3D printers is higher in these sectors, which again reflects the nature of their production processes. These sectors are also larger in scale, allowing them to adopt and internalize digital technologies more quickly.

For sectors that have a higher variety of products or longer production lines, the use of 3D printing and robotics for warehouse management systems is more common. More complex production lines can require more service robots. The data suggests that sectors such as chemicals, textiles, and electrical equipment still have potential in this technology area. The focus groups also highlighted that service robots are commonly used for transportation of people or goods and workplace safety measures. For instance, Renault factories use service robots to carry various parts within the factory, increasing productivity by decreasing the time used for part transportation. This also increases workplace safety by decreasing the likelihood

of human error and occupational health hazards. The data also suggests that the chemicals, plastics, and electrical equipment sectors also have potential for the use of service robots for transportation. The number of raw materials along the production line is the determining factor, as service robots lead to increased productivity when used for transportation purposes.

The use of internet of things (IoT) technologies is most commonly adopted for security purposes, complementing cloud computing services, and production processes or logistics management. Turkish firms have commonly adopted IoT technologies, but some certain use purposes are still yet to reach their potential (Figure 11). For instance, the textile sector has highly internalized the use of IoT technologies and is at the same use level as the European average for purposes such as energy consumption management, automation of production processes, logistics management, and customer service.

Figure 11. Internet of Things usage according to purposes, 2021, number of firms



Source: EUROSTAT, TURKSTAT, TEPAV calculations

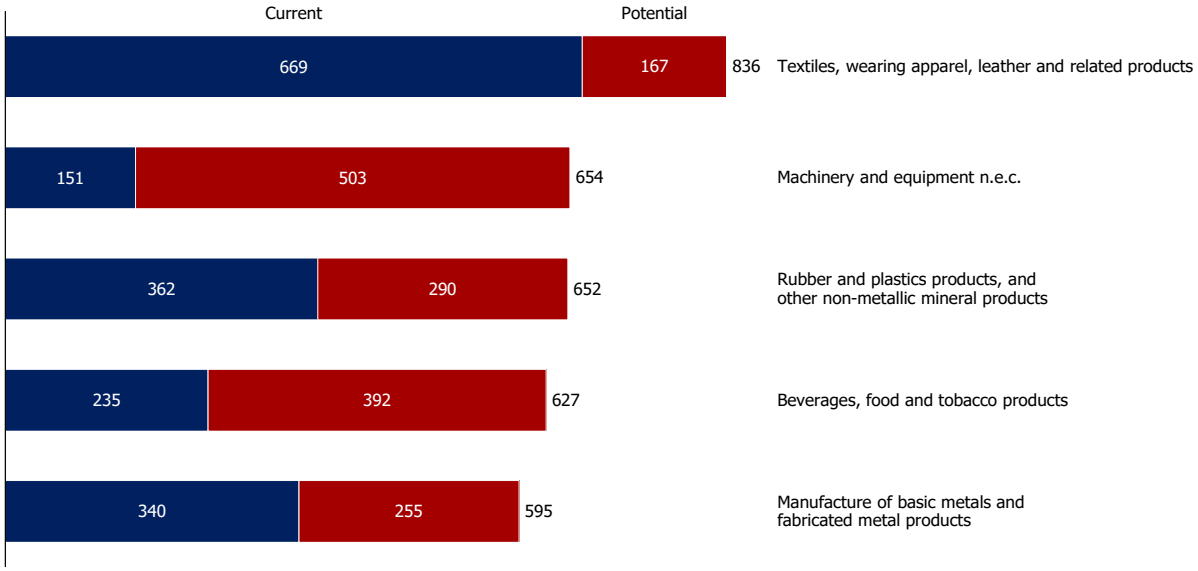
Use of IoT for logistics management has already reached EU averages in almost all sectors. What these sectors have in common is that they are export sectors. Higher exports increase the need for better integration into the EU supply chains, meaning that these sectors had to adopt their logistics management technologies more quickly. The sectors include plastics, textiles, food, and chemicals.

A high number of enterprises already use IoT for production processes (for purposes such as monitoring and/or automating the production process), and there is limited growth potential left to reach EU use levels. Machinery and equipment and food are the sectors with the highest potential in this area, since they use it less commonly than sectors such as textiles, plastics, and basic metals.

Use of IoT technologies for condition-based maintenance exhibits higher potential than other use cases of IoT. The sectors that have longer, more complex, or assembly line type of production have a higher need for condition-based maintenance. Failure to perform condition-based maintenance may lead to undesirable results such as the production line being out of schedule, deterioration of the production standards, and an increase in the share of faulty

products. The textile sector, which has already adopted the other use cases of IoT, has the highest number of current users and would have the highest number of potential users if it were to reach EU levels (Figure 12). The use of IoT for interconnected devices or remotely controlled systems is higher for sectors that assemble a higher number of raw materials, such as food, basic metals, and chemicals, with still additional potential left.

Figure 12. Enterprises using IoT for condition-based maintenance, number of firms, 2021



Source: EUROSTAT, TURKSTAT, TEPAV calculations

Use of IoT for autonomous devices is common in sectors with longer lines of production. A use case of IoT is enabling devices such as autonomous robots, self-driving vehicles, and autonomous drones with the use of AI technologies. The electrical equipment sector commonly uses IoT for autonomous devices in the EU. Use levels are still on the lower end in Türkiye, and the potential is high.

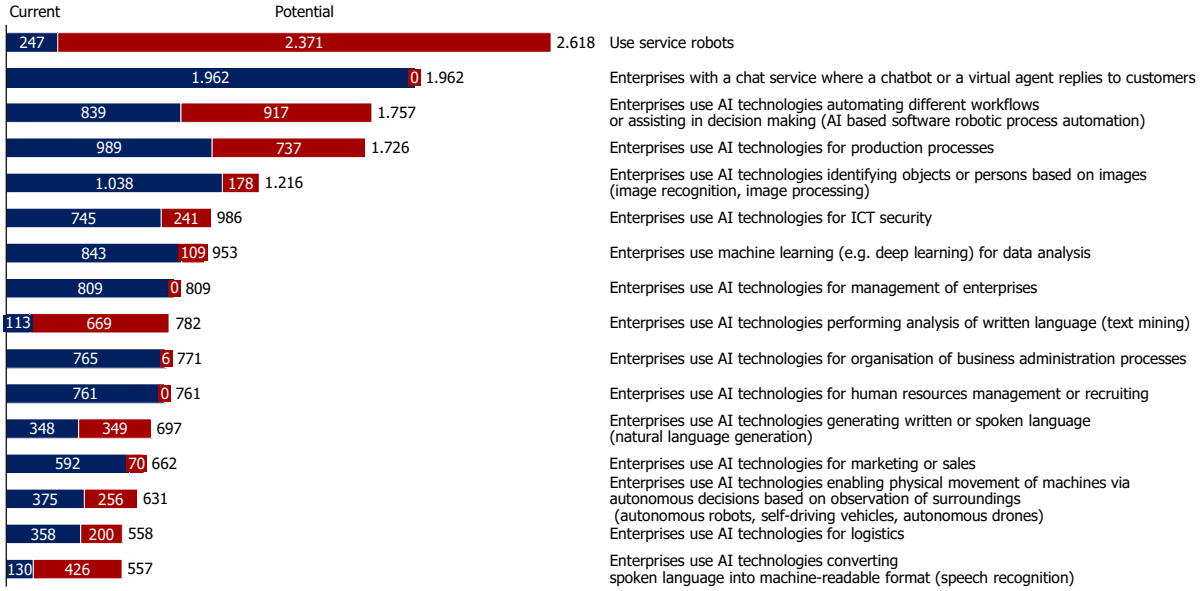
Use of IoT for purposes of customer service is commonly adopted in sectors where business-to-consumer relations are common. Sectors such as textiles or food use IoT technologies in their customer relations up to EU levels. However, the machinery sector is still yet to reach its potential, where business-to-business type of relations are more common.

Artificial intelligence is the technology area with the biggest room for growth in Türkiye. Use areas that have reached their potential are highly limited, and almost all use cases are below the rates of EU averages. The potential is high since it is a newer technology that is still growing in the global markets as well. Also, the lack of skilled labor that can work on this technology area is a reason why it is comparatively underdeveloped in Türkiye, according to the focus group meetings.

Chat robots and virtual agents are one area where Turkish firms have reached their potential in the use of AI. The sectors where business-to-customer firms are common have adopted this use of AI. This is an area where Türkiye is potentially the exporter to the EU. AI is commonly used also for marketing and sales purposes.

The use of AI in service robots is adopted by a large number of firms in the EU, whereas in Türkiye, very few are using it. The export sectors of Türkiye that have a scale-wise advantage in adopting technology have failed to do so with regards to service robots. Use levels are very high in the EU, and this is a potential area where Türkiye can be a buyer of this technology.

Figure 13. Printing and Robotics according to use purposes, 2021, number of firms



Source: EUROSTAT, TURKSTAT, TEPAV calculations

Use of AI in production processes is more common in sectors where the production is based on raw materials, such as textiles and plastics, but they are still below EU levels. Machinery and equipment have the highest potential to use AI in the production processes.

AI-based robotic software automation is another field where Turkey has high potential for growth. Some sectors, such as textiles, plastics, and basic metals, have adopted robotic software automation to some extent. Sectors with fast-paced production lines would greatly benefit from automation.

The use of machine learning for data analysis, image recognition, and image processing is common in high-technology export sectors. However, natural language processing is not common due to the barriers introduced by the Turkish language's nature.

The use of AI for ICT security is a high-potential area that we can expect to growth in the following years. High-technology sectors will have a higher need for ICT security in the near future due to the volume of data generated by digitalized production processes. Cybersecurity is becoming a growing concern for all companies due to the increasing number of cyberattacks. Information and digital systems can become vulnerable due to the low levels of awareness and inadequate use of security measures. Hence, it is safe to say that ICT security will be a growing concern with increasing potential in the near future.

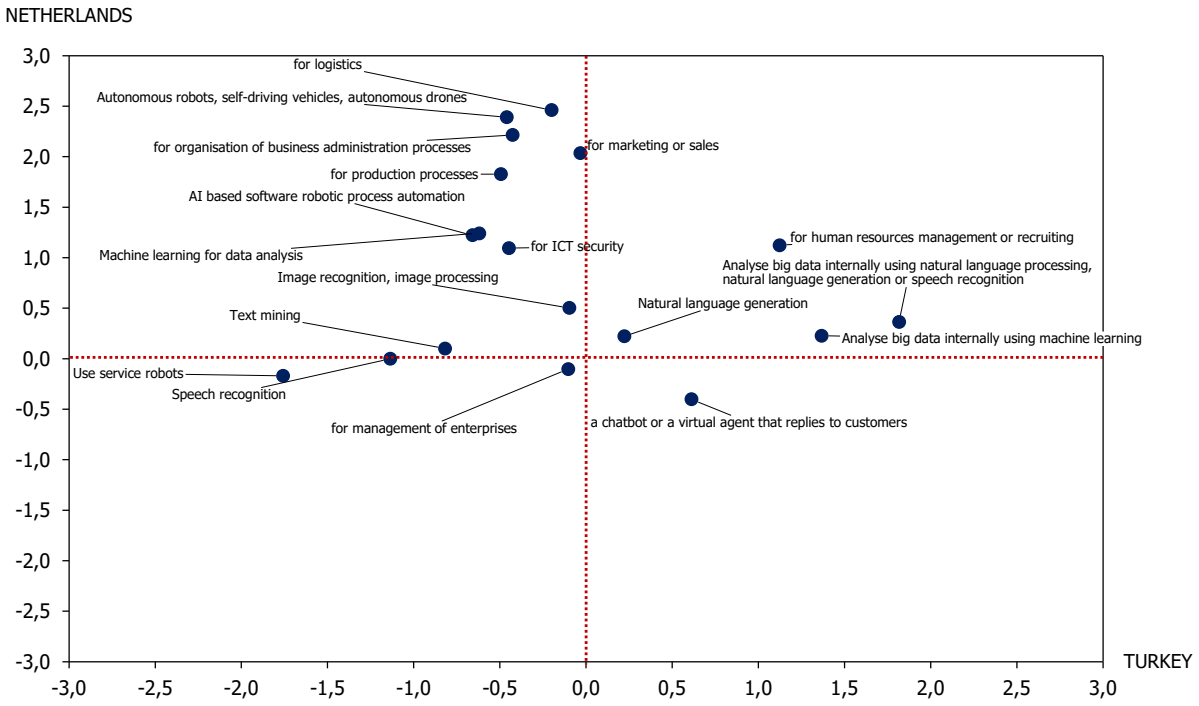
Strategy Matrix for Dutch-Turkish Collaborations

The matrices are formed according to the use levels of certain technologies in both the Netherlands, Türkiye, and the European Union. The upper part of the red dotted horizontal line

shows the technology areas that the Netherlands is using higher than the EU average. Similarly, the right-hand side of the red dotted vertical line shows the technology areas where the use levels in Türkiye are higher than the EU averages.

- If the use levels are ***higher*** than the EU averages ***for both countries***, the technologies in these areas may **entail potential collaborations for further development and specialization in that technology.**
- If the use levels are ***lower*** than the EU averages ***for both countries***, the technologies in these areas may **indicate a potential collaboration for cooperation since both countries need to improve their hand in that specific area.** The countries can come together and form a research partnership/collaboration for improvements.
- If the use levels are ***higher*** than the EU average ***in one country*** and lower for the other country for a certain technology, the country that uses ***these technologies more commonly can be the seller of that technology.***

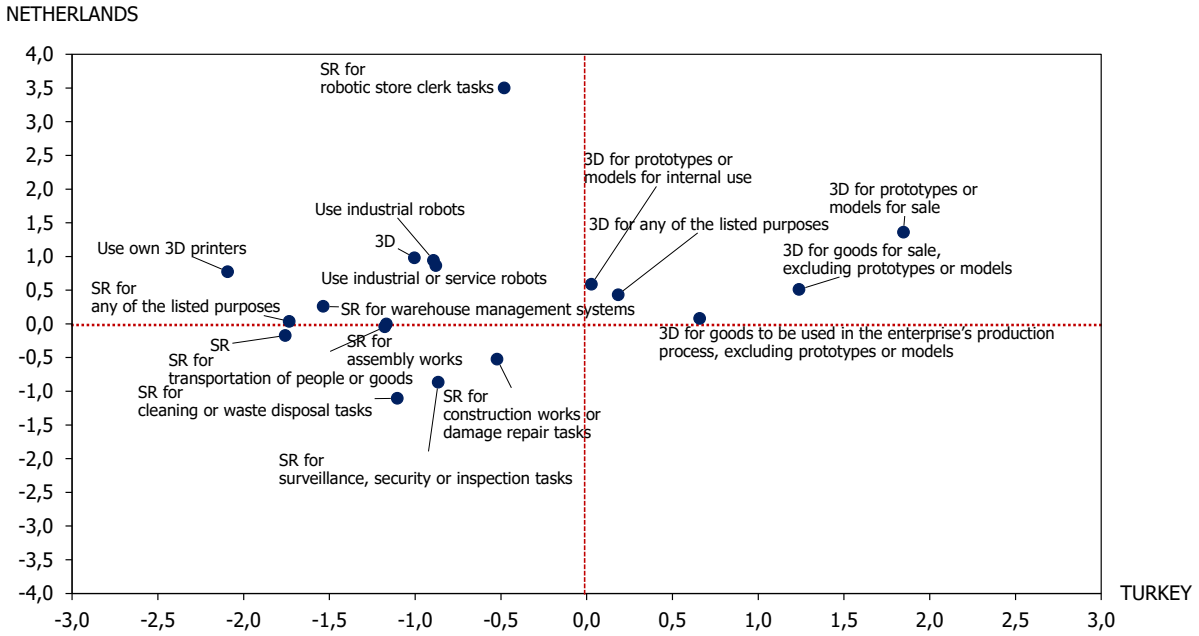
Figure 14. Strategy Matrix for Dutch-Turkish Collaborations on AI Technologies



Source: Eurostat, TURKSTAT, TEPAV calculations

Looking at the strategy matrix for AI technologies, Türkiye has a comparatively better position in chatbots/virtual agents that reply to customers. This may be a reflection of the higher number of business-to-consumer type of operations in Türkiye in manufacturing, which led to a need for tools for managing customer relations. Potential cooperation areas for increasing both countries' abilities are internal analysis of big data using **NLP & speech recognition** and **ML, natural language generation,** and **human resources management**. The Netherlands can potentially sell technologies such as autonomous robots, AI technologies for ICT security, and production processes.

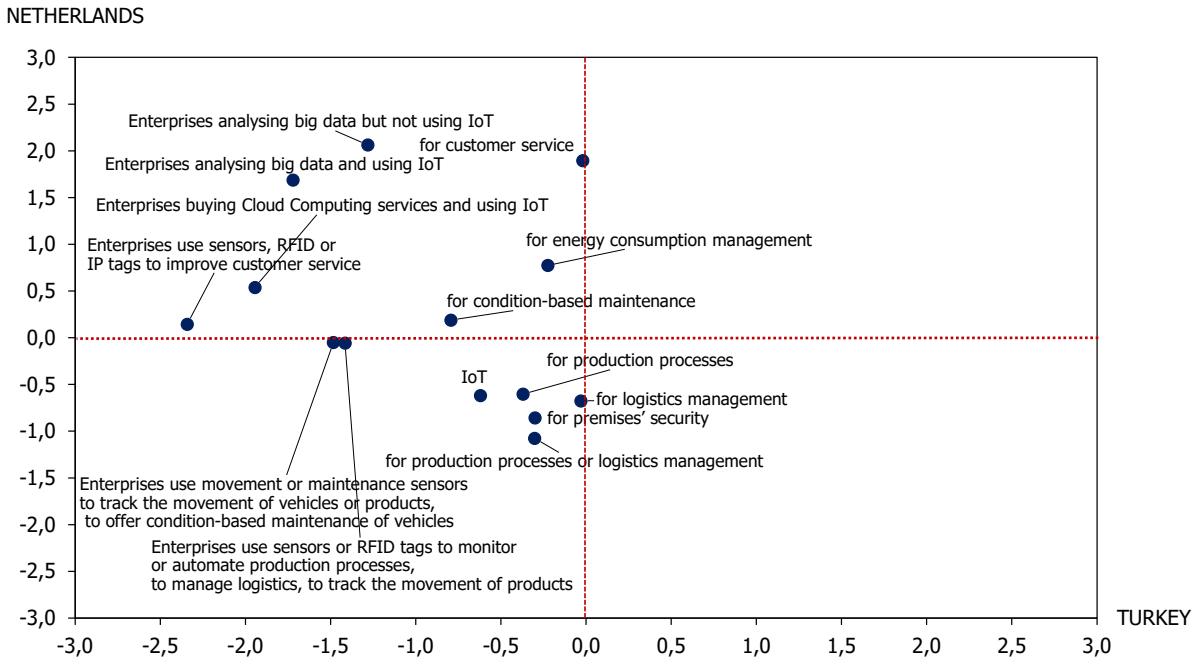
Figure 15. Strategy Matrix for Dutch-Turkish Collaborations on 3D Printing & Robotics Technologies



Source: Eurostat, TURKSTAT, TEPAV calculations
*SR is short for service robots

3D printing and robotics have a high potential for both forming collaborations between the two countries and creating sales opportunities from the Netherlands to Türkiye. Many applications of 3D printing and robotics, such as the **use of service robots for construction, surveillance, or cleaning**, are below the EU averages for both the Netherlands and Türkiye, creating an opportunity for collaboration to increase competitiveness. Another type of collaboration can be formed regarding applications of 3D printing to enhance and sustain the advantages compared to the rest of the EU. **Industrial and service robots and enterprises that own 3D printers** are more common in the Netherlands and less common in Türkiye than in the EU, which might be a reflection of Dutch companies being earlier adopters of those technologies.

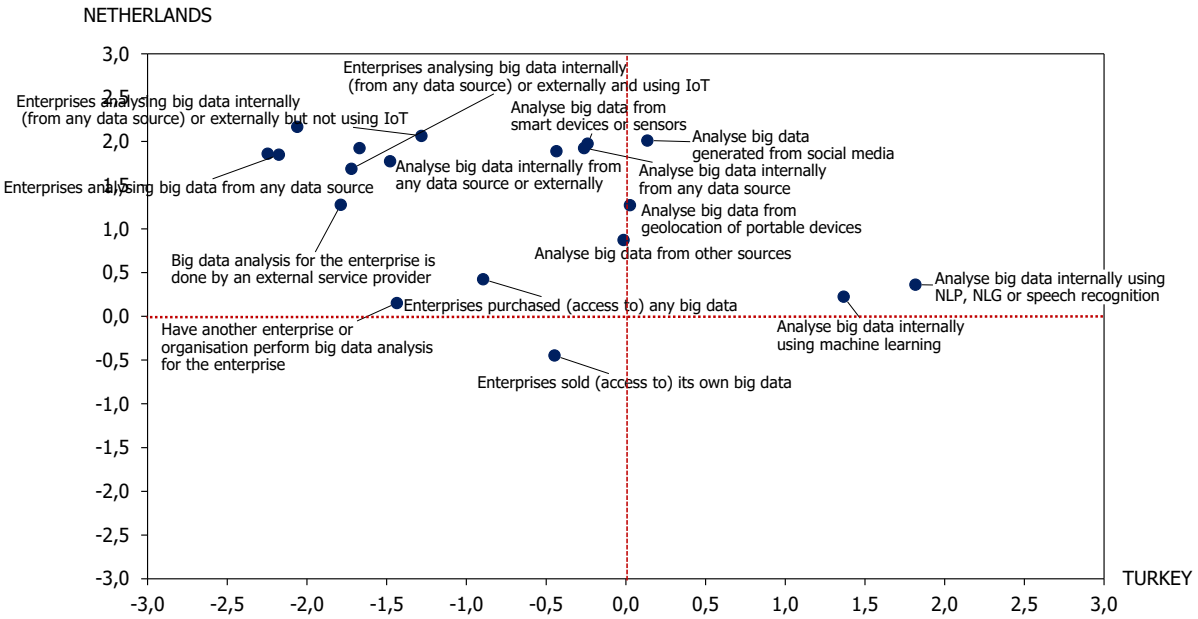
Figure 16. Strategy Matrix for Dutch-Turkish Collaborations on IoT Technologies



Source: Eurostat, TURKSTAT, TEPAV calculations

The use of IoT technologies is lower than the EU averages in Türkiye for nearly all technologies. The technology areas where the Netherlands has higher use levels than the EU averages are opportunities for trading those technologies. The use of technologies that include **movement or maintenance sensors** and **RFID tags** and **IoT for production processes** is less common in both countries compared to the EU, which can be used as a collaboration opportunity for both countries to enhance competitiveness and improve those technology areas.

Figure 17. Strategy Matrix for Dutch-Turkish Collaborations on Big Data



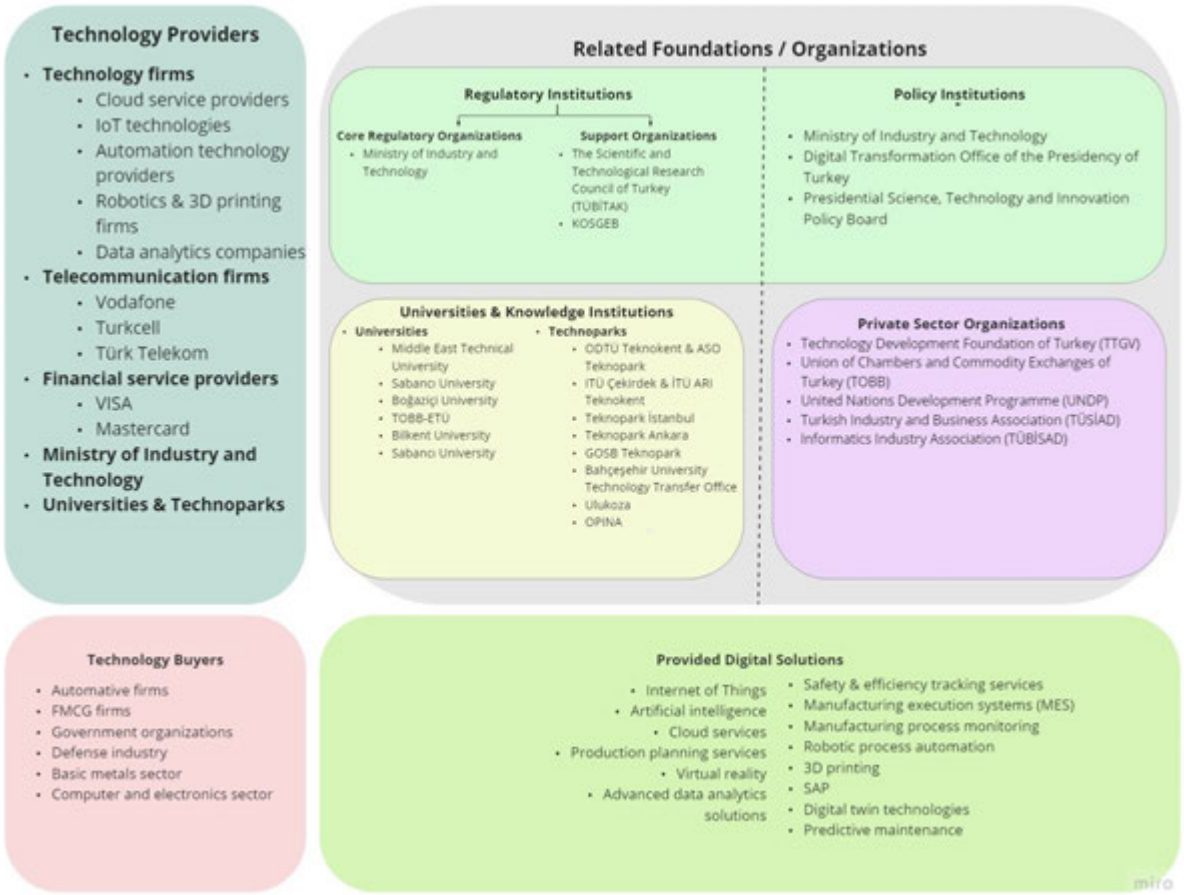
Source: Eurostat, TURKSTAT, TEPAV calculations

Big data technologies are generally commonly used in the Netherlands. Analysis of big data from geolocation sensors and social media can be considered strengths for both countries, and collaborations for further enhancements in those areas can be formed.

Stakeholder map

Below is a stakeholder map that shows a visual representation of the stakeholders in manufacturing industry in Türkiye[13].

Figure 18. Stakeholder map



Source: TEPAV visualizations

2.2. Focus group findings on the Dutch side

Focus group meetings were held with stakeholders from the Dutch side. The focus group participants were from a variety of backgrounds, such as academicians, software companies, and manufacturing technology start-ups.

Dutch firms are looking to internationalize their operations. However, their operations and collaborations are mainly limited to the EU, and very rarely to the UK and USA. When forming relationships with other countries and business partners, geographical proximity and language seem to be among the deciding factors. Business relationships are easier to navigate, and collaborations are formed with countries that are closer in both geography, culture, and

[13] For a more detailed analysis of the stakeholders, please refer to the "ISO 500 List" in Supplementary Material.

language. However, a focus group participant reported that if they were to expand their operations to the Middle East, Türkiye would be the obvious choice for opening up to that market.

Dutch companies have partnerships and collaborations with smaller startups, universities, and research institutes. The main motivation for forming these relationships is tying their work to actual research and having a readily available research base when the need for any improvements arises. These smaller start-ups are almost exclusively from the Netherlands. Universities are generally from the Netherlands, with a few exceptions from the EU (namely, Aalborg University was mentioned) and the UK. A similar trend can be seen for knowledge/research institute collaborations. Sometimes companies approach research institutes, and sometimes the other way around, depending on the needs. The companies in the focus groups named global partnerships with industry leaders such as Schneider Electric and ABB, as well as local partners such as telecommunication companies when needed.

Companies working with international partners and selling their products abroad often choose to operate in larger markets with lower prices and less strict privacy legislation. Cost-effectiveness plays a role in which market will be chosen. They also work with a local partner there. The reason for this might be that they choose to take advantage of economies of scale and further penetrate the market there by leveraging the existing network of the local partner.

There is a lack of awareness among SMEs regarding cybersecurity, which can prove to be an opportunity area. In the focus groups, a service provider that provides clients with security ratings underlined that security risks are becoming more of a common concern in the industry. However, awareness is not very high, especially among SMEs.

The need for sustainable manufacturing is increasing in European sectors, which calls for higher levels of automation and intelligence in manufacturing processes. This can be useful in forming relations between Dutch and Turkish companies, as the need for automation and intelligence in manufacturing processes to increase sustainability and efficiency will be needed for Turkish companies as well to sustain trade relations.

Companies in the Netherlands industry are increasingly focusing on predictive maintenance and energy efficiency to reduce downtime and energy waste, as pointed out by software and analytics companies. Predictive maintenance, as well as energy consumption management, are among the leading use cases in Türkiye, as pointed out in the focus groups, in addition to the findings from the surveys.

When asked, all companies with international ties expressed that they would be open to collaborating with Turkish providers and research institutes, as well as selling their products in Türkiye. Collaboration between Dutch and Turkish companies in the industry could lead to the development of innovative solutions and increased competitiveness in the global market.

3. Policy Recommendations

A good practice that could enhance the relationship between the Dutch and Turkish sides is having Digital Innovation Hubs in Türkiye, similar to the ones in the EU. The role of digital innovation hubs in the EU and in the Netherlands is to provide a supportive environment for companies and institutions to collaborate and share knowledge and expertise on digital technologies. These hubs offer firms access to technology, equipment, and other resources, as well as training and mentorship for less experienced members. The hubs can also be "centers of excellence" where firms, researchers, and experts come together to develop and test new ideas and technologies and where they can access the latest innovations and knowledge.

For the Turkish manufacturing industry, digital innovation hubs can play a similar role by providing a platform for collaboration and knowledge sharing. The lack of skilled labor and access to innovation networks, or lack thereof, was brought up in the focus groups, which can be partially solved by access to these hubs. Some good practices that can be adopted in this context include establishing partnerships between Dutch and Turkish manufacturers and institutions, providing support for the adoption and integration of digital technologies, and fostering collaborations between companies and institutions, leading to improved productivity, efficiency, and competitiveness. SMEs often lack the necessary knowledge and skillset, and digital innovation hubs can play a role in bringing those smaller enterprises together with the larger companies such as the ones in the ISO500 list, playing a key role in enhancing the role and the knowledge stock of the SMEs to play a more effective role in the innovation environment. Digital innovation hubs can play a crucial role in bridging the gap between these smaller and larger companies. By bringing SMEs together with larger companies, these hubs can foster collaboration and knowledge sharing, providing smaller enterprises with access to the necessary expertise and technology. Therefore, we recommend establishing partnerships between Dutch and Turkish manufacturers and institutions, with a focus on supporting SMEs to adopt and integrate digital technologies. In addition to the recommendations mentioned above, it is important to note that the implementation of digital technologies must take into account emerging challenges such as the European Green Deal and Privacy laws. Therefore, we recommend that digital innovation hubs in Türkiye prioritize the development of sustainable technologies and the implementation of privacy-enhancing measures, such as secure data storage and management.

One way the Netherlands can support these hubs in Türkiye is by providing funding to establish the hub and providing expertise during the establishment. Aside from these concrete efforts, the Netherlands can support this digital innovation hub by promoting its activities and helping increase the visibility of this hub and introducing it to a wider network. By providing the hub with the necessary resources, these hubs can nurture the relationship with Dutch companies, drive innovation, and create new collaboration opportunities.

In order to meet the needs of the defense industry and other strategic sectors, we recommend that digital innovation hubs in Türkiye focus on developing domestic supply chains for digital technologies. At the same time, we recommend that these hubs explore opportunities for international cooperation, including partnerships with Dutch companies and institutions. In addition to establishing digital innovation hubs in Türkiye, we recommend that

Dutch and Turkish companies and institutions explore opportunities for innovation cooperation, with a focus on developing new products and services and improving existing ones. Such cooperation can take many forms, including joint research and development projects, technology transfer agreements, and joint ventures.

The Netherlands should focus on cloud computing technologies in this context. The Netherlands has a number of companies and institutions offering cloud computing services, with more years of expertise under its belt than the Turkish counterparts for the most part. The companies in the Netherlands are well-positioned to benefit from the growing demand from the Turkish manufacturing industry.

The Netherlands has earned a strong reputation as a leader in cloud computing, owing to a number of major companies and institutions offering cloud-based services. Given their expertise and experience in this field, these companies are well-positioned to take advantage of the growing demand for cloud computing in the Turkish manufacturing industry. Some of the sub-branches of cloud computing that the Netherlands can focus on to offer services to Turkey include cloud-based data storage and management services and cloud-based cybersecurity solutions. Some sub-branches of cloud computing the Netherlands can specifically focus on to provide services to Türkiye include:

i. Cloud-based data storage and management services, where the Dutch companies offer storage and management services for large volumes of data created by the production processes, allowing Turkish companies a medium to access and analyze their data, and make data-driven decisions.
ii. Cloud-based cybersecurity solutions, where the Dutch companies offer services such as cloud-based monitoring and cyber-threat detection, for data and system security of manufacturing companies.
iii. Textiles, basic metals, machinery and equipment and plastics can be the key sectors for cloud computing services.

Regarding artificial intelligence (AI), the Netherlands has a clear advantage in some AI technologies, and the companies can benefit from the increasing demand in Turkey's manufacturing industry. Some sub-branches of AI that the Dutch companies can leverage their advantage on are:

i. Robotics and robotic process automation technologies. The need for autonomous devices and machines that perform, especially physical tasks, is increasing in demand, which is a stronger technology area in the Netherlands compared to Türkiye.
ii. The use of AI for production processes is another area the Dutch companies can sell their services and products to Turkish firms. The Dutch companies can offer a variety of technologies that provide predictive maintenance, supply chain optimization and quality control services to the Turkish manufacturing firms. For instance, to prevent failures and halts in production before they happen, AI-based predictive maintenance solutions can be useful, whereas, AI-based supply chain optimization solutions can allow companies to make better plan their productions processes.
iii. Textiles, plastics, basic metals and machinery and equipment sectors are the sectors that AI needs most stand out.

As for cooperation areas, we recommend that Dutch and Turkish companies and institutions focus on the textiles, basic metals, machinery and equipment, and plastics sectors, as they are key drivers of the manufacturing industry and can benefit significantly from the adoption of digital technologies. Specifically, we suggest that Dutch companies provide cloud-based data storage and management services, as well as cloud-based cybersecurity solutions. Moreover, leveraging their expertise in robotics and robotic process automation technologies, Dutch companies can develop autonomous devices and machines for the Turkish manufacturing industry. Finally, we recommend that Dutch companies offer AI-based predictive maintenance solutions and supply chain optimization services to enhance production processes in the Turkish manufacturing industry.

In forming these aforementioned collaborative relations, we recommend the following:

1. *Identifying potential partners to explore opportunities for collaboration:* Dutch businesses and institutions should research potential partners. This could involve attending trade fairs, networking events, and other industry events to meet potential partners.
2. *Building relationships:* Dutch businesses and institutions should work to build relationships with potential partners once they have been identified. This could involve activities such as regular communication, visits, and joint projects.
3. *Understanding the local market:* Dutch businesses and institutions should invest time and resources in understanding the local market in the cooperation areas. This could involve conducting market research, gathering information about regulations and policies, and understanding local customs and business practices.
4. *Developing specifically tailored products and services:* Dutch businesses and institutions should develop tailor-made products and services that meet the needs of customers in the potential cooperation areas, based on their understanding of the market.
5. *Establishing a local presence:* Dutch businesses and institutions should consider establishing a local presence to maximize opportunities in collaboration areas. This could involve opening local offices, hiring staff there, or partnering with a local company.
6. *Seeking support from government agencies:* Dutch businesses and institutions can seek support from government agencies such as the Netherlands Foreign Investment Agency (NFIA) or the Dutch Enterprise Agency (RVO), which are agencies that can provide information and support on doing business in the cooperation areas.

Overall, the Netherlands' strong knowledge stock and expertise in these technology areas make it a good candidate to sell its services to Turkish manufacturers. The services provided by Dutch firms can enable Turkish manufacturing companies to increase their productivity, strengthen their existing trade relations, and enhance competitiveness.

4. Appendix

(a) Appendix I

Focus group participants – Turkish side

#	Name	Firm/Institution	Sector/Industry
1.	Hasan Salih Acar	ESNEK AMBALAJ SANAYİCİLERİ DERNEĞİ (FASD)	Plastics
2.	Gülçin Kazak	SERT PLASTİK AMBALAJ SANAYİCİLERİ DERNEĞİ (SEPA)	Plastics
3.	Orhan Göçer	SEM Plastik	Plastics
4.	Mahmut Şenaltun	Oyak Renault	Automotive
5.	Özlem Günindi	Oyak Renault	Automotive
6.	Perin Ünal	TEKNOPAR	Service provider / Industry automation
7.	Eren Ertem Develi	İSR- Information Security Research Bilgi Güvenliği Araştırma Geliştirme ve Yazılım Destek Hizmetleri Limited Şirketi	Service provider / Cyber security
8.	Vedat DAVARCIOĞLU	Coşkunöz Holding	Basic metals
9.	Ali Fırat	TAİ- Turkish Aerospace Industries, Inc. TUSAŞ- Türk Havacılık ve Uzay Sanayii AŞ	Defense industry
10.	Zeliha Akça	TAİ- Turkish Aerospace Industries, Inc. TUSAŞ- Türk Havacılık ve Uzay Sanayii AŞ	Defense industry
11.	Abdullah Sarıkaya	TAİ- Turkish Aerospace Industries, Inc. TUSAŞ- Türk Havacılık ve Uzay Sanayii AŞ	Defense industry
12.	Nergiz İlhami	Sabancı Üniversitesi Tümleştirilmiş Üretim Teknolojileri Araştırma ve Uygulama Merkezi (SU | IMC)	Research center
13.	Büşra Taşçı	Sabancı Üniversitesi Tümleştirilmiş Üretim Teknolojileri Araştırma ve Uygulama Merkezi (SU | IMC)	Research center
14.	Bekir Berker Türker	Türkiye İş Bankası ve Koç Üniversitesi “Yapay Zekâ Uygulama ve Araştırma Merkezi" (KUIS AI)	Research center
15.	Dr. Öğr. Üyesi Gökhan ATALI	Sakarya Uygulamalı Bilimler Üniversitesi Robot Teknolojileri ve Akıllı Sistemler Uygulama Araştırma Merkezi	Research center

#	Name	Firm/Institution	Sector/Industry
16.	Prof. Dr. Ahmet Yazıcı	Eskişehir Osmangazi Üniversitesi Akıllı Sistemler Uygulama ve Araştırma Merkezi (ASİST)	Research center
17.	Selçuk Yarangümelioğlu	Elif Holding	Plastics
18.	Etem DERMAN	Bahçeşehir Teknoloji Transfer Ofisi (BAUTTO)	Technology transfer office
19.	Dr. Öğr. Üyesi Ali Furkan KAMANLI	Sakarya Uygulamalı Bilimler Üniversitesi Robot Teknolojileri ve Akıllı Sistemler Uygulama Araştırma Merkezi	Research center
20.	Prof. Dr. Murat EFE	Ankara Üniversitesi Akıllı Sistemler ve Teknolojiler Uygulama ve Araştırma Merkezi (ASTAM)	Research center

Focus group participants – Dutch side

#	Name	Firm/Institution	Sector/Industry
1.	Jules Oudmans	UReason	Service provider / software company
2.	Shubham Singh	Fizyr	Service providers / robotics software
3.	Elvin Lara Özdemir	Fizyr	Service providers / robotics software
4.	Dennis van den Bos	Blockbax	Service provider /software company
5.	Önder Babur	Wageningen University & Research	Researcher
6.	Rene Van Etten	ThreadStone	Service provider/ Cyber security
7.	Jitesh Kohli	Solulever	Service provider / software company
8.	Simon Jagers	Samotics	
9.	Roderik van der Touw	Alarmsecur	Service provider / IoT

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