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Getting the measure of the fourth industrial revolution: advantages and challenges of Industry 4.0 in the Turkish white goods industry

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Abstract

Purpose – Industry 4.0 (I40) is an open window of opportunity for Turkey, a developed country, to eliminate technological dependence and produce with maximum productivity. However, I40, which corresponds to the fourth wave of industrial revolutions, brings both opportunities and challenges. In this context, this study aims to reveal the foresight of managers in the Turkish white goods industry (TWGI) regarding the advantages and challenges of I40 and compare them with the literature.

Design/methodology/approach – The Delphi method was used for the study. Data were collected from managers of companies that are members of the White Goods Suppliers Association (BEYSAD). Seventy managers from 55 companies participated in the first round, and 19 managers participated in the second round of Delphi.

Findings – The results show that the most frequently cited advantages are productivity/resource efficiency, data and information-enabled effectiveness/productivity, quality 4.0 and competitiveness/strategy. The most frequently mentioned challenges are financial resources/investment, employee qualification/training, technical/processual challenges and organizational transformation/leadership.

Research limitations/implications – The sample was limited to the managers of the TWGI.

Practical implications – Players in similar ecosystems and policymakers should consider the advantages and respond to potential challenges when creating roadmaps, taking the necessary steps and positioning themselves in the marketplace. In particular, the TWGI – Turkey's showcase in international markets – should consider the undeniable benefits of the I40 transition to increase innovation.

Originality/value – The findings for the first time highlight the advantages and challenges of I40 in an industry in Turkey, and they will benefit the TWGI, which is among the leaders in Turkey in terms of digital maturity and innovation in its journey to I40.

Keywords Industry 4.0, Fourth industrial revolution, White goods, Household appliances, Delphi, Turkey

Paper type Research paper

Introduction

Humanity has witnessed four different industrial (r)evolutions since the invention of the steam engine. In the literature, the debate continues as to whether each transition period is genuinely a revolution or only the concepts used to distinguish the technological developments required by the capitalist production system (Fülbert, 2014). Regardless of these discussions, the fact that new tools and technological solutions such as the steam

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engine, electricity, IT systems, automation, IoT and cyber-physical production systems (CPPS) have accelerated the history of humanity in the last 250 years, coming to the forefront of changes. At the same time, industrial revolutions enable more production efficiency by using new machines and technologies in production processes, making it necessary for countries and communities to keep up with technology and learn how to acquire and use new tools, machines and technologies.

This paper focuses on the fourth and last Industrial Revolution, called I40, that emerged from the response to the European debt crisis. As it is known, after the third industrial revolution, most factories in developed countries moved to countries with cheap labor (Gür, Ünay, & Dilek, 2017). While the economic crisis mostly affected European countries such as the UK, Greece and Portugal, whose economic structures predominantly rely on the services sector, industrial-based economies such as Germany weathered the storm and even turned the crisis into an opportunity. It happened this way because when total income decreases during an economic crisis, the first things people abandon are services such as vacation, entertainment, finance and consultancy. Leaving agricultural and industrial products that meet daily basic needs is not as easy as abandoning the things offered by the services sector (Ünay, Karahan, Gür, & Dilek, 2017). Showing the importance of the real economy, the 2007–2008 crisis forced developed countries to seek strategies for economic protectionism and reindustrialization (Fırat, 2016; Gür *et al.*, 2017). Due to the rapid transition of some developing countries to technology-intensive production, developed countries decided to focus on automation to regain competitive advantage, as they cannot compete with developing countries in labor-intensive production in any way (Gür *et al.*, 2017), moving their production back from developing countries in the East (Barbieri, Ciabuschi, Fratocchi, & Vignoli, 2018). In short, these developments that can significantly change the power balances in the global economy are called I40. This concept was used for the first time as the name of a project announced by the German Federal Ministry of Education and Research at the 2011 Hannover Messe Trade Fair. The project mainly included German protectionist and industry-oriented policies. Then, many other countries created their own I40 roadmaps to follow unique strategies.

There is no specific definition of I40 accepted by all (Götz & Jankowska, 2017; Lu, 2017). According to Ahuett-Garza and Kurfess (2018), I40 means integrating many technologies to improve the productivity and responsiveness of a production system, while Kamble, Gunasekaran, and Gawankar (2018) and Durana, Kral, Stehel, Lazaroiu, and Sroka (2019) emphasize that I40 is a concept that includes technologies enabling the development of product quality, organizational performance and value chain. By expanding the boundaries of the concept, Vorzhakova and Boiarynova (2020) argue that I40 means the adoption of digital technologies in the enterprise and industrial management system as well as in the government management system. Nogalski, Niewiadomski, and Szpitter (2020) identify I40 with the modern economy delineated by network connections, instability of operating conditions and advancement of new technologies. On the other hand, many reports and academic studies call I40 a brand and buzzword (Glas & Kleemann, 2016; Huchler, 2017; Bíba, 2018; Germany Trade & Invest, 2018; Kheyfets & Chernova, 2019).

Just as there is no consensus regarding the definition of the concept, in the transition period to I40, we cannot evaluate the planned technology roadmaps and strategies to be pursued independently of relevant context and conditions. For example, Atik and Ünlü (2019) developed an I40 performance index with which they measured the relative performance of countries in Europe, finding that Turkey was 31st among 33 countries by I40 performance. In this case, we clearly see that Turkey needs to make much more effort compared to many European countries while transitioning to I40. Moreover, the uniqueness of the undertaken actions reveals that I40's advantages and challenges practices will also differ from country to country, sector to sector and even organization to organization. From this viewpoint, the

primary purpose of this article is to produce foresight regarding I40's advantages and challenges in the Turkish white goods industry (TWGI) which is one of the three industries with the highest digital maturity level in Turkey (TÜBİTAK, 2017). The study considered the matter through the Delphi method, grouping advantages and challenges according to their themes, and listing them by significance.

In the next section, we will present I40's advantages and challenges in light of related literature. The third section will focus on the TWGI, while the fourth section will use the Delphi method to expose these advantages and challenges in the TWGI. The research sample and steps will be explained in a detailed way in the fifth section. Subsequently, we will present the findings and conclude the study.

I40's advantages and challenges

With the transition to I40, the manufacturing industry will receive many benefits thanks to the tools and technologies of I40, driven by disruptive innovation while facing transition challenges. In the literature, the number of studies on this subject is increasing daily. We made a query on Google Scholar with the keywords and Google search operators: "advantage" * "benefit" * "opportunity" * "disadvantage" * "challenge" * "obstacle" * "barrier" AND "I40" * "Fourth Industrial Revolution." The asterisk was used to show any included words or phrases in search results, while the AND operator makes both the included words appear in the results. In other words, our search produced results that included at least one of the concepts of I40 or the Fourth Industrial Revolution and at least one of the words "advantage," "benefit," "opportunity," "disadvantage," "challenge," "obstacle," and "barrier." The date range was selected from 2011 – when the concept "I40" was first introduced – to 2019. Then, we found 380 results and scanned the titles and abstracts of the obtained studies by each of us two independently. We discovered that 28 studies focused directly on I40's advantages and challenges. Sixteen of the mentioned studies were articles, six were conference papers, five were industry reports, and the remaining one study was a book chapter.

The article by Kiel, Müller, Arnold, and Voigt (2017) is among the most comprehensive studies on I40's advantages and challenges in the manufacturing industry. This study considered the IIoT and I40 concepts synonymously and scrutinized multiple cases to identify the social, ecological and economic advantages and challenges of I40. Other researchers investigating the challenges of the new industrial revolution through the case study method are Khan and Turowski (2016). Similarly, Müller, Kiel, and Voigt (2018) model I40's advantages and challenges as the antecedents of I40's implications, testing their research model through questionnaires collected from German manufacturing companies operating in five different industries. On the other hand, Kergroach (2017) includes the challenges and opportunities of the Fourth Industrial Revolution only for labor markets, while Thames and Schaefer (2017) focus on cybersecurity as a challenge of I40. Moreover, Schröder (2016) investigates the challenges of I40 only for SMEs.

Mohamed (2018) reviews various resources, such as articles, magazines, newspapers and government reports, on several electronic databases to reveal the benefits and challenges of I40. Luthra and Mangla (2018) were the first to identify the challenges for I40 initiatives for sustainability in supply chains through a bibliometric analysis. Then, they sent questionnaire forms containing these challenges to firms in the Indian manufacturing industry and conducted an exploratory factor analysis for data reduction. Finally, they ranked the factors obtained through the analytical hierarchy process method.

We listed I40's advantages and challenges provided in the 28 studies, categorizing them according to themes (see Tables 1 and 2). We ordered thus obtained categories according to

Theme	Related advantages
Employment	gender equality, lowering cultural barriers, demographic change in the workplace, high-wage economy, increase in employment, new jobs/competencies/workplaces, reduction of routine/monotonous work, self-development, diversity, work safety, work-life balance, less physical effort, safe and attractive working environment/conditions
Productivity	lower manual tasks, cost-effectiveness/reduction, decrease in economies of scale through mass customization, decreased document and administration, change in delivery time, reduction of transportation and travel, automation, inventory reduction, resource efficiency, resource utilization
Quality 4.0	customer satisfaction, meeting individual customer needs, leanness, load balancing, lower failure rates, reducing the number of errors and delayed shipments, reliability, traceability
Flexibility	customization, ad-hoc reaction to market changes, flexible production, customization, individualization, personalization, modularization, modular products
Innovation	new business models, creating value through new services, innovative image, innovation capability, new product-oriented services
Competitiveness	competitive advantage, protection of market shares, differentiation, growth, growing sales volumes, increase in revenue
Responsiveness	change in demand uncertainty, rapid reaction, real-time data, shortened time-to-market
Sustainability	Sustainable manufacturing, environmentally sustainable manufacturing, decreased waste
Decentralization	autonomy, decentralized decision-making, decentralized production
Planning	optimized decision-making, advanced planning

Source(s): Arnold *et al.* (2016), Fonseca (2018), Hofmann and Rüsch (2017), Kagermann, Wahlster, and Helbig (2013), Karre, Hammer, Kleindienst, and Ramsauer (2017), Kergroach (2017), Kiel *et al.* (2017), Lasi, Fettke, Kemper, Feld, and Hoffmann (2014), Mohamed (2018), Müller *et al.* (2018), Oettmeier and Hofmann (2017), de Sousa Jabbour *et al.* (2018), Waibel, Steenkamp, Moloko, and Oosthuizen (2017), Walendowski, Kroll, and Schnabl (2016), Wang, Törngren, and Onori (2015)

Table 1.
Advantages of I40 in the literature

the frequency of appearance in the literature. The advantages and challenges are presented in Figures 1 and 2, respectively.

Figure 1 shows the following categories of I40's advantages: employment (21%), productivity (21%), quality 4.0 (14%), flexibility (12%), innovation (10%), competitiveness (9%), responsiveness (4%), sustainability (3%), decentralization (2%) and planning (2%). Moreover, Figure 1 indicates that more than half of the advantages stated in the literature refer to employment, productivity and quality.

Figure 2 shows that the most frequently recurring I40 challenges are employee qualification (13%), technical challenges (12%), strategy/competition (10%), cybersecurity (10%) and financial challenges (9%). These five categories constitute more than half of all challenges mentioned by the literature. We categorized the remaining challenges as change and adaptation (7%), legal and ethical issues (7%), social employment (6%), business processes (6%), leadership and organization (5%), data (5%), know-how (4%), cooperation and collaboration (3%), future viability (3%), state support (1%) and sustainability (1%).

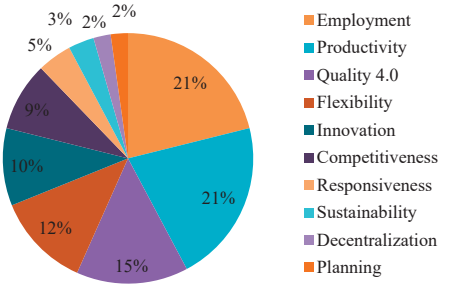
Turkish white goods industry (TWGI)

The main products of the white goods industry – a specific group of electrical appliances or durable consumer goods – are refrigerators, deep freezers, dishwashers, ovens, washing machines and dryers. Otherwise, products such as vacuum cleaners, toasters, blenders, juicers and food processors are placed in the small home appliances group of durable consumer goods, and products such as air conditioners are in the group of electrical appliances (TÜRKBESD, 2020). In 2018, the sales of the global white goods market reached 535 million units, with an increase of 1.5%, and the market size reached $213 billion, with an

Theme	Related challenges
Employee Qualification	employee qualification and acceptance, human resources, lack of skills and competencies, training, low-quality jobs, new competencies, renewed training/education policies, professional development
Technical Challenges	horizontal/vertical integration, lack of integrity, mismatch between developed and needed technologies, development of smart devices, product availability, technological and process integration, insufficient IT structure, construction of the network framework, comprehensive broadband infrastructure, connecting the physical, embedded and IT systems
Strategy and Competition	competitiveness, lack of digital strategy, strategic challenges, lack of internationalization, industrial structure of SMEs
Cybersecurity	security, data privacy/protection/security, network security, IT security, lack of standards, safety issues
Financial Challenges	financial resources and profitability, lack of financial resources, investment issues, lack of a clear business case/business propositions, lack of short-term profitability, need for investment, costs exceed the benefits
Change and Adaptation	flexibility, lack of courage to change, new business models, reduction of innovation periods, unwillingness to change
Legal and Ethical Issues	product liability, intellectual property, legal regulations, regulatory framework
Social Employment	inequalities and social cleavage, job losses, lower wages, new ways of working
Business Processes	inadequate processes, end-to-end engineering
Leadership and Organization	organizational challenges, resistance by employees, contradictory interests, organizational transformation, employee fear, lack of leadership and experience
Data	big data analysis, data integration, data ownership
Know-How	lack of knowledge about technology providers, need to protect know-how, system modeling
Cooperation and Collaboration	involvement of customers/suppliers, lack of unified communication protocol, lack of local networks
Future Viability	standardization, transparency
State Support	lack of support
Sustainability	sustainability

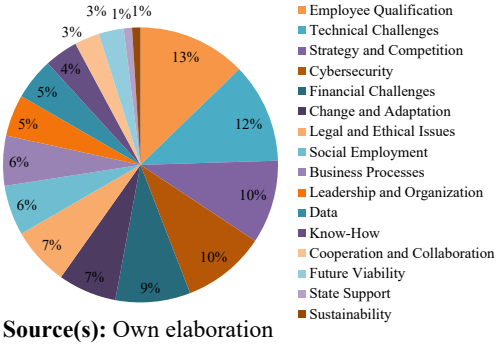
Source(s): Arnold *et al.* (2016), Davies (2015), Fonseca (2018), Horváth and Szabó (2019), Kagermann *et al.* (2013), Kergroach (2017), Khan and Turowski (2016), Kiel *et al.* (2017), Küsters, Praß, and Gloy (2017), von Leipzig *et al.* (2017), Luthra and Mangla (2018), McKinsey&Company (2016), Mohamed (2018), Müller *et al.* (2018), Schröder (2016), Stock and Seliger (2016), Thames and Schaefer (2017), Vaidya, Ambad, and Bhosle (2018), Walendowski *et al.* (2016), Wang *et al.* (2015), Wang, Wan, Li, and Zhang (2016), Zhou, Liu, and Zhou (2015)

Table 2.
Challenges of I40 in the literature



Source(s): Own elaboration

Figure 1.
Categories of the I40 advantages in the literature



Source(s): Own elaboration

Figure 2.
Categories of the I40 challenges in the literature

increase of 8%. The largest white goods manufacturer in the world is China. Turkey is the world's second-largest and Europe's largest white goods manufacturer. In white goods manufacturing, Turkey is followed by Brazil, the USA and Poland. In 2018, as shown in Table 3, the world's largest exporters of white goods were China, Mexico and Turkey, respectively (Özden, Seheri, & Ersan, 2019).

Turkey produces 25 million units of products annually, exporting approximately 75% of its total production, while 95% of the white goods sold in Turkey are manufactured in Turkey (Demirgil, 2019; TÜRKBESD, 2020). TWGI is one of the leading industries in Turkey thanks to its technologically advanced manufacturing structure, high export rate and the employment it creates (TÜRKBESD, 2020). When considering the four main white goods products – refrigerators, washing machines, dishwashers and ovens – Turkey's white goods industry grew by 7.3% in 2017 due to an increase in domestic sales, while it shrunk by 1% in 2018 (Demirgil, 2019). According to the data shared by the White Goods Manufacturers' Association of Turkey, values regarding white goods manufacturing, domestic sales, export and import are shown in Table 4 (TÜRKBESD, 2020).

Turkey's primary export market is Europe, with an export volume of over $2bn, and 77% of white goods were exported to Europe in 2018. The UK (17%), France (10%), Germany (9%), Poland (7%) and Spain (6%) are the countries with the highest share of imports from Turkey (Özden *et al.*, 2019).

Currently, eight white goods manufacturers operate in Turkey (see Table 5). According to the 2019 Lovemarks of Turkey determined by IPSOS, the most loved brands in the white goods category were Arçelik, Bosch, Beko and Vestel, in this order (MediaCat, 2019). Apart from the leading manufacturers, almost 500 small- and medium-sized subindustry firms operate in Turkey (Avcıoğlu, Özata, Nirun, & Gürel, 2018; Demirgil, 2019). While 60,000 people are directly employed in the white goods industry, 600,000 people are employed in the

Dishwasher		Refrigerator		Washing machine		Oven		Total export	
Germany	947	China	4877	China	2637.7	China	2862.6	China	10,997.4
Poland	801.8	Mexico	3573.3	Poland	1295.9	Mexico	545.7	Mexico	4119
China	620.1	Thailand	1506	Turkey	1008.7	Italy	425	Turkey	3057.2
Turkey	549.2	Korea	1337.8	Thailand	919.2	USA	343.7	Poland	2097.7
Italy	199.6	Turkey	1192.6	Germany	632.2	Turkey	306.8	Germany	1579.2
World	4253.6	World	18329.7	World	9330.7	World	5953.2	World	37,867.2

Source(s): Trade Map (2020)

Table 3.
The world's largest exporters of white goods for 2018 in USD thousand

	Product (unit)	2016	2017	2018	2019
Manufacturing	Refrigerator	7,035,807	7,410,926	7,213,153	6,446,600
	Deep-Freezer	1,175,604	1,362,584	1,393,087	1,181,873
	Washing Machine	7,830,640	8,249,291	8,030,335	7,495,900
	Dishwasher	3,969,792	4,496,400	4,707,608	5,285,303
	Oven	4,693,408	5,260,705	5,171,564	5,275,521
	Dryer	1,530,930	1,652,197	2,023,011	2,512,367
	Total	*26,236,181*	*28,432,103*	*28,538,758*	*28,197,564*
Import	Refrigerator	93,816	186,032	102,958	89,953
	Deep-Freezer	275,634	377,166	237,175	204,75
	Washing Machine	237,930	231,571	119,474	37,799
	Dishwasher	140,201	190,168	81,944	6,508
	Oven	53,404	57,938	31,334	8,555
	Dryer	54,788	60,258	53,200	42,775
	Total	*855,773*	*1,103,133*	*626,085*	*390,341*
Domestic Sale	Refrigerator	2,039,575	2,170,836	1,810,238	1,719,567
	Deep-Freezer	648,289	936,489	818,218	766,617
	Washing Machine	2,121,619	2,354,768	1,948,671	1,853,693
	Dishwasher	1,572,950	1,803,554	1,460,700	1,332,131
	Oven	994,833	1,122,249	946,768	816,737
	Dryer	92,530	145,117	125,598	166,410
	Total	*7,469,796*	*8,533,013*	*7,110,193*	*6,655,155*
Export	Refrigerator	4,970,895	5,049,836	5,378,140	4,777,024
	Deep-Freezer	877,763	843,251	886,650	717,872
	Washing Machine	5,997,406	6,136,475	6,248,615	5,673,874
	Dishwasher	2,501,892	2,878,943	3,335,317	3,931,054
	Oven	3,745,978	4,178,674	4,319,221	4,411,664
	Dryer	1,453,574	1,552,522	1,924,620	2,363,550
	Total	*19,547,508*	*20,639,701*	*22,092,563*	*21,875,038*

Source(s): TÜRKBESD (2020)

Table 4.
Data on manufacturing, domestic sales, export, and import

Manufacturer	Some brands
Arçelik	Arçelik, Beko, Grundig, Blomberg, Elektrabregenz, Arctic, Leisure, Flavel, Defy, Altus, Dawlance
B/S/H/	Bosch, Siemens, Gaggenau, Neff, Thermador, Balay, Coldex, Constructa, Pitsos, Profilo, Junker, Viva
Vestel	Agora, Atlantic, Celcus, Clayton, Digihome, Dikom, Electra, Finlux, Graetz, Icecool, Laurus, Linetech, Luxor, Regal, Schöntech, Vestfrost, Wellington
Indesit	Indesit, Hotpoint-Ariston
Kumtel	Kumtel, Luxell
Simfer	Simfer
Candy Group	Candy, Hoover, Rosières, Baumatic, Iberna, Jinling, Otsein, Süsler, Vyatka, Zerowatt
Silverline	Silverline, Esty

Source(s): Own elaboration

Table 5.
White goods manufacturers in Turkey

broad ecosystem of the sector, including subindustry companies, retail sales networks and aftersales service networks (Demirgil, 2019).

Methodology

We used the Delphi method and conducted almost the whole study process online. This forecasting method was first introduced to forecast technology-based moves in the Cold War

era (Custer, Scarcella, & Stewart, 1999), later developed by Olaf Helmer, Norman Dalkey and Nicholas Rescher for the Rand Corporation in the 1950s (Rescher, 1998). Although these researchers developed the method, the method was conceptualized as "Delphi" by Abraham Kaplan, one of the Rand Corporation employees (Keeney, McKenna, & Hasson, 2011). According to the developers of this method, the Delphi method was developed to get feedback from a group of experts by presenting a series of in-depth questionnaires to them to reach a consensus most reliably (Dalkey & Helmer, 1963, p. 458). The strength of the Delphi method is that the participants are anonymous and isolated from each other, so no participant can be more dominant than the others and affect the opinions of other participants; neither can the participants feel pressured to agree with the majority (Rowe, Wright, & McColl, 2005; Sinha, Smyth, & Williamson, 2011; MacLennan, Kirkham, Lam, & Williamson, 2018). Moreover, the method allows for the effortless involvement of participants from different regions (Wijnen-Meijer, van der Schaaf, Nillesen, Harendza, & ten Cate, 2013).

The original Delphi method's process consists of posting questionnaires to an expert panel in two or more rounds. The first questionnaire asks open-ended questions to gain experts' views on a particular topic. Researchers put together and analyze the opinions collected from the experts and send to the same experts a second questionnaire form, which conveys statements or questions. Then, the experts rank or rate the statements in the second questionnaire. The rounds continue until a consensus is reached among the experts (Keeney *et al.*, 2011). Delphi must have at least two rounds to receive feedback and review old responses. Round 3 is not needed if there is a consensus on all statements in the second round (Keeney *et al.*, 2011). There is no standard lower limit for consensus (McKenna, Hasson, & Smith, 2002). For instance, Boyce, Gowland, Russell, and Goldsmith (1993) determined the threshold value as 66%, while McKenna (1994) determined it as 51%. On the other hand, McKenna *et al.* (2002) and Keeney *et al.* (2011) decided to set the lower limit as 70%, and Brinkman *et al.* (2016) set 80% as the cut-off value.

The Delphi method does not have a standard sample size. The literature shows a sample size between 4 and 3000 (Campbell & Cantrill, 2001; Nayyar, Yasmeen, & Khan, 2019). In fact, it is considered enough to have 15–20 participants (Ludwig, 1997; Hsu & Sandford, 2010; Brinkman *et al.*, 2016).

In the first round of our study, the questionnaires were sent to 182 white goods companies, which comprise all members of the White Goods Suppliers Association (BEYSAD) of Turkey and the leading white goods manufacturers in Turkey. The main reason why we selected this industry for the study was that it is one of the three industries with the highest digital maturity level in Turkey (TÜBİTAK, 2017). The high digital maturity level of the sector showed that it was also more mature in I40 practices compared to other sectors. Therefore, it would be more reasonable to reveal I40's advantages and challenges in a sector with its high maturity level. On the other side, Turkish manufacturing companies face the risk of losing their competitive advantage due to the I40 paradigm's emergence, although, for a long time, they have been taking advantage of low labor costs. Especially, for the competitive sectors of developing and technology-dependent countries, it is essential to present customized approaches by revealing the current status (Yıldırım & Demirbağ, 2019).

The managers of the white goods companies were asked to indicate and briefly explain at least three challenges and advantages of I40. Seventy managers from 55 companies participated in the questionnaire and responded to these two open-ended questions. All these 55 domestic and foreign companies have at least one manufacturing facility in Turkey: 26% of the companies target the local, regional or national market and 74% target the international or global market. Of the participating companies, 67% are medium-sized, 6% are small-sized and 27% are large. Moreover, 50 of the 55 surveyed companies (91%) are suppliers, while the remaining five (9%) are manufacturers. All the managers were familiar with the concept of I40 and had led at least one project related to I40. On the other hand, out of

the 70 managers, 2 (3%) were company owners/partners, 10 (14%) were general managers, 12 (17%) were directors/coordinators/assistant general managers or group managers, 13 (19%) were factory managers and 33 (47%) were unit managers or assistant factory managers.

A list was created by bringing together all the statements collected from managers, and a total of 308 advantages and 261 challenges were gathered, including repetitions. After all the statements were compiled, the repetitive ones were reduced, and the frequency of repetition of each statement was noted. Later, we joined and thematized all similar statements because categorizing similar statements makes the second-round questionnaire easier and visually attractive for the experts to complete (Keeney *et al.*, 2011). Relevant studies in the literature were also considered when creating the themes (Arnold, Kiel, & Voigt, 2016; Hofmann & Rüsch, 2017; Kiel *et al.*, 2017; Luthra & Mangla, 2018; Müller *et al.*, 2018, de Sousa Jabbour *et al.*, 2018; Horváth & Szabó, 2019; Fonseca, Amaral, & Oliveira, 2021).

After we organized the lists, we designed the Round 2 questionnaire. In this form, the statements collected from managers, the themes and the repetition frequencies of statements were gathered in two separate tables. As preferred by many studies (Lakke, Wittink, Geertzen, van der Schans, & Reneman, 2012; Brinkman *et al.*, 2016; Nayyar *et al.*, 2019), ours also employed the dichotomous scale. Two options were added to the columns next to each statement and theme in the tables: agree and disagree. Finally, the phrase "if you disagree, please specify the reason" was added to the last column in both tables.

The second round of questionnaires was sent to 46 managers who volunteered to participate in the second round via e-mail. Because we did not receive enough answers, we sent the e-mail for the second time. At this stage, 19 participants responded to the questionnaires.

As in the study by Brinkman *et al.* (2016), we decided for the lower limit for the consensus rate to be 80%. Participants generally fully agreed on the appropriateness of items and related categories. Therefore, there was no need to conduct the third round.

Results

Tables 6 and 7 show the advantages and challenges of I40 collected from the managers in Round 1, the repetition frequency of each by managers, the categories determined by the authors, and the managers' consensus rate in Round 2. Surprisingly, a full consensus was achieved on all advantages.

It may seem surprising that full consensus was achieved in the second round, even on the advantages and challenges that were mentioned by only one manager in the first round. However, we asked managers to indicate at least three challenges and advantages in the first round. Naturally, instead of thinking for a long time and listing many items, one manager mentioned a few advantages and challenges that first came to mind. Since things that first come to mind do not generally reflect extreme considerations, agreeing upon them is expected.

In Figure 3, we present the advantage categories we determined. The most frequently mentioned advantages are gathered under the categories of productivity/resource efficiency (29%), data and information-enabled effectiveness/productivity (18%) and quality 4.0 (14%). These three categories include more than 50% of all advantages. The categories that followed are competitiveness/strategy, financial benefits, speed and flexibility, sustainability, human resources and innovation.

The categories related to I40 challenges are depicted in Figure 4. The most frequently mentioned challenges were financial resources/investment (23%), employee qualification/training (19%), technical/processual challenges (10%) and organizational transformation/leadership (10%). The least repeated challenges were related to cooperation (3%), cybersecurity (3%) and competition (3%).

Advantages of I40	Frequency	Consensus rate
(1) Competitiveness and Strategy		
Competitive advantage, competitive power	15	100%
Customer satisfaction	10	100%
Use of advanced technology, smart systems	4	100%
Reputation	3	100%
Company's growth, capacity increase	1	100%
Performance analysis	1	100%
Value chain integration	1	100%
The right investment plan	1	100%
(2) Innovation		
New service/business models	2	100%
Innovation	2	100%
(3) Data and Information-Enabled Effectiveness and Productivity		
Traceable processes, accurate/traceable data/process management, traceability	15	100%
Real-time data analysis, improved analysis capability	10	100%
Real-time information flow, real-time production tracking/reporting	6	100%
IoT	4	100%
Data collection, database expansion	3	100%
Data-driven decision making	2	100%
Fast and easy access to data/information	2	100%
Controllability, increased measurement and control capability	2	100%
Standardization, digitization of all processes	2	100%
Data security	2	100%
Faster communication	2	100%
Data warehouse	1	100%
Increased data processing speed	1	100%
Organizational memory	1	100%
AI solutions	1	100%
(4) Productivity and Resource Efficiency		
Productivity	24	100%
Automation, less labor-force, less manual activity, reduced need for blue-collars and human, more production with the same people	18	100%
Lean production and processes, just-in-time production	9	100%
Production planning systems	8	100%
Early warning systems, instant intervention	6	100%
Predictive and autonomous maintenance	4	100%
Inventory control systems, improved inventory management	3	100%
Increased OEE values, real-time OEE measurement	3	100%
Low resource usage	2	100%
Less space consuming	2	100%
Integrated production	2	100%
Waste elimination	1	100%
Raw material saving	1	100%
Saving on equipment, fewer machines needed	1	100%
Easier and error-free shipping processes	1	100%
Decreased documentation	1	100%
Production mechanism	1	100%
Optimization of maintenance activities	1	100%
Self-awareness of components	1	100%

(*continued*)

Table 6. Advantages of I40 in Turkish white goods industry

Advantages of I40	Frequency	Consensus rate
(5) Quality 4.0		
Quality	19	100%
Reducing human errors	9	100%
Standardized production, minimizing variability caused by people	7	100%
Reducing errors, flawless processes	5	100%
Minimizing losses caused by human or machine	3	100%
(6) Financial Benefits		
Cost reduction	26	100%
Profitability	4	100%
Profitability analysis	2	100%
Reducing labor costs	2	100%
(7) Human Resources		
Minimizing OHS risks	6	100%
Ergonomics	1	100%
Competency	1	100%
More fair and measurable performance systems	1	100%
(8) Speed and Flexibility		
Customized and flexible production	8	100%
Time savings	4	100%
Increase in production speed	4	100%
Quick decision-making	2	100%
Faster processes	2	100%
Increased operational speed	1	100%
Faster process analysis	1	100%
Shorter setup times	1	100%
(9) Sustainability		
Sustainability	8	100%
Energy saving	8	100%

Table 6. **Source(s):** Own elaboration

Conclusion

Our study asked managers of companies operating in the TWGI about I40's advantages and challenges in the form of two open-ended questions with the use of a two-round Delphi method, reaching a consensus about relevant advantages and challenges, which we categorized, and the managers' opinions about the appropriateness of the classifications were transferred to the second round of Delphi. Furthermore, we isolated I40's advantages and challenges highlighted in the literature to later compare them with those mentioned for the TWGI.

The advantages of the I40 transformation were divided into nine categories. The most frequently mentioned advantages by managers were productivity and resource efficiency, data and information-enabled effectiveness and productivity and quality 4.0. The study also sorted the advantage categories of I40 in the literature by appearance frequency, so the most frequently repeated advantages were employment, productivity and quality 4.0. What proved to be the most repeated advantages both by managers in the TWGI and the I40 literature were productivity and quality 4.0. Essentially, since I40 is defined as the integration of modern technologies into production systems that increase productivity and quality (Ahuett-Garza & Kurfess, 2018; Kamble *et al.*, 2018; Durana *et al.*, 2019), we expected to find that the first advantages of I40 for both the managers and the literature would be

Challenges	Frequency	Consensus rate
(1) Technical and Processual Challenges		
Poor infrastructure	8	100%
Technological integration, difficulty in reorganizing production lines and all systems	4	100%
Challenges with the installation	3	100%
Increased failures due to digitalization	2	89%
Incompatible machines in the machine park, old machines not suitable for transformation	2	100%
Systems without common interfaces	1	100%
Process flow challenges	1	95%
OT/IT convergence	1	100%
Modeling the data management system	1	100%
Big data analysis	1	100%
Continuous monitoring of system updates	1	100%
(2) Organizational Transformation and Leadership		
Traditionalism, classical approaches, habits	5	100%
The lack of awareness/mentality on the transition to I40 in the organization	3	100%
Lack of leadership and belief	2	100%
Change of organizational culture	2	100%
Role conflicts	2	95%
The prejudice of the company owners	1	100%
Transforming the hierarchical organizational structure	1	95%
Communication problems	1	100%
Lack of management support due to uncertainty	1	95%
The difficulty of reorganizing	1	100%
The difficulty of the adaptation process	1	100%
Difficulty in convincing the capital owners	1	100%
Internalizing the benefits of I40	1	100%
Managers who treat their employees with mildness	1	95%
Lack of managerial skills	1	95%
Baby boomer decision-makers, decision-makers who cannot keep up with technology	1	100%
(3) Strategic Challenges		
Short and long-term transformation goals not clearly defined, unrealistic goals	4	100%
Difficulty in building a technology roadmap	2	100%
Lack of time for the project	2	100%
Building new business models	1	100%
Long-term project/work requirement	1	100%
(4) Cybersecurity		
Cybersecurity, security concerns	8	100%
(5) Competition		
The difficulty of being an SME	2	100%
The emergence of technology monopolies and closures of small businesses	1	95%
The difficulty of being a supplier industry	1	100%
Market persistence	1	95%
The industry that cannot keep up with technology	1	100%
Product variety	1	100%
Being dependent on technology suppliers, lack of autonomy	1	95%
(6) Cooperation: Supply and Value Chain		
Lack of domestic technology partners	3	95%
Lack of qualified firms	2	100%
Lack of reliable partners	1	100%
Difficulty in transferring academic knowledge to industry	1	100%
Inability to establish cooperation culture	1	95%

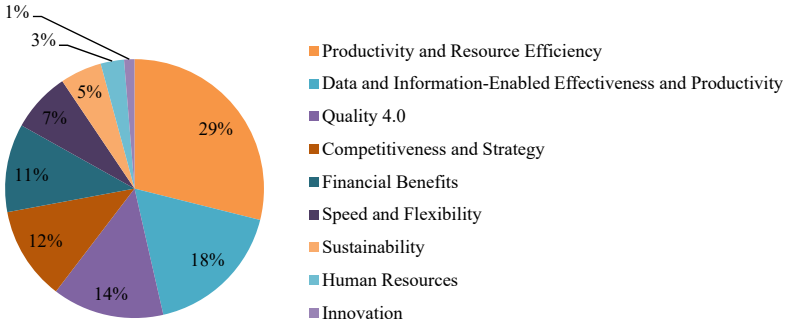
(*continued*)

Table 7. Challenges of I40 in Turkish white goods industry

Challenges	Frequency	Consensus rate
Communication problems with foreign technology suppliers	1	95%
(7) Future Viability		
Improper design of the new system, risk of negative profit due to wrong implementations, starting off on the wrong foot	5	100%
Copying I40 applications from external companies without becoming a lean enterprise, ensuring stable production conditions and having competent employees	2	100%
Unplanned and quick implementations	2	100%
Strategic needs incorrectly identified	2	100%
Risk of making the company a technology dump	1	100%
(8) Financial Resources and Investment		
High investment cost	45	100%
Difficulty in finding financial resources	6	100%
Avoiding investment, the difficulty of the feasibility study	3	100%
Increase in unit cost postponed investment decisions due to the high ROI	2	100%
High maintenance costs	1	100%
High automation costs in Turkey	1	100%
Difficulty in measuring financial return	1	100%
Limited and expensive external competencies	1	100%
(9) Employee Qualification and Training		
Lack of skills and competencies	28	100%
Lack of well-educated employees	7	100%
Lack of qualified workforce/department/team to transform	6	100%
Lack of qualified engineers	3	100%
Lack of qualified operators	2	100%
Lack of technical staff	2	100%
Difficulty in training the workforce who will conduct the transformation	1	100%
Ignoring the training of all employees on I40	1	100%
(10) Public Context		
Lack of government support/incentives	5	100%
Lack of legislation/legal regulations	3	100%
High dependence on foreign technology	2	100%
Political uncertainty	1	100%
Data ownership	1	100%
Lack of technological infrastructure in Turkey	1	100%
Lack of awareness-raising activities targeting manufacturers	1	100%
(11) Lack of Knowledge and Experience		
Lack of information on I40	7	100%
Lack of experience/know-how	6	100%
Lack of successful business cases	2	100%
Deciding how to get started, uncertainty	2	100%
Lack of practitioners in the industry, consulting in name only	1	100%
Information asymmetry between technology providers and companies	1	100%
(12) Employee Resistance and Unemployment Threats		
Unemployment	8	100%
Resistance to change	7	100%
Fear of job loss in employees/blue-collar workers	5	100%

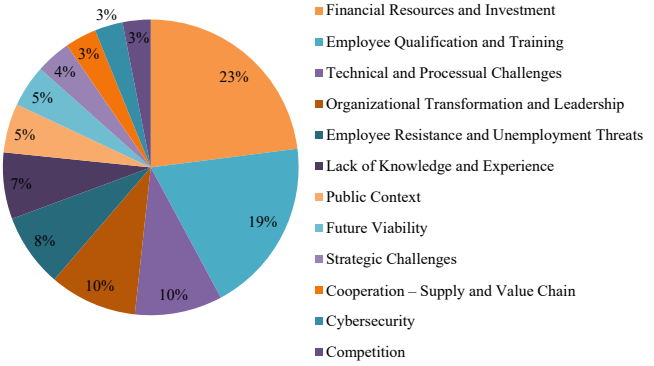
Table 7. **Source(s):** Own elaboration

productivity and quality. However, while the most repeated advantage of I40 in the literature is employment, only 3% of the advantages expressed by the managers referred to human resources. As the advantages of I40 are presented on a sector-specific basis and from the



Source(s): Own elaboration

Figure 3.
Categories of the I40 advantages in the Turkish white goods industry



Source(s): Own elaboration

Figure 4.
Categories of the I40 challenges in the Turkish white goods industry

viewpoint of managers, it is not surprising that employment – which includes more macro issues such as the increase in employment – appears not among the most recurring advantages.

However, the employment theme also consists of factors that the managers noticed, namely, reduction of routine work, new workplaces, diversity in organizations, work safety and an increase in work-life balance. Although the employment benefits of I40 are frequently mentioned in the literature, I40 has not yet provided a significant advantage regarding employment for the TWGI. Another striking finding is that while innovation appeared in a significant position among I40's advantages in the literature, it is the least important advantage for the industry. Nevertheless, it is a great opportunity for developing countries like Turkey to focus on the transition to I40 by keeping up with technological changes, which is only possible with technological learning and innovation (United Nations Industrial Development Organization, 2018). It is essential that the white goods industry – which is Turkey's showcase in international markets – should consider the undeniable benefit of I40 transformation to increase innovativeness in terms of R&D, innovation, branding, design, economies of scale, compliance with EU standards, qualified employment, export income, automation and sustainability (Sanayi Gazetesi, 2021).

Of course, the TWGI will not gain all the advantages from the digital transformation and transition to I40 in the same period. Some advantages will appear in the short or medium

term, while others will be achieved in the long term. In other words, advantages such as productivity and resource efficiency emerge in the shorter term, while advantages regarding innovation or employment may require medium- or long-term solutions. In this context, we may think that the white goods industry has not yet reached a sufficient level of I40 maturity. As the I40 maturity level increases, the industry will be able to gain advantages in innovation, employment and sustainability. Further research is recommended to better reveal the I40 maturity level of TWGI.

The following advantages are emphasized both in the literature and by the managers of the TWGI: innovation, sustainability, quality, productivity, flexibility, competitiveness, responsiveness and employment. On the other hand, while decentralization and planning appear in the literature, these are not mentioned as advantages by the managers. The advantage denoted by managers, although absent from the literature, is financial benefits. Since most of the TWGI are SMEs, it is reasonable to find financial benefits among the advantage categories.

The challenges of I40 in the TWGI consist of 12 categories. The most frequently mentioned challenges by managers were financial resources and investment, employee qualification and training, technical and processual challenges and organizational transformation and leadership. On the other hand, the challenges of I40 most frequently mentioned by the literature were employee qualification, technical challenges, strategy and competition, cybersecurity and financial challenges, respectively. The fact that most of the participating companies were SMEs could explain why financial challenges were mentioned as the top issues. Employee qualifications, technical challenges and financial challenges were frequently raised both by the literature and the managers. However, challenges related to strategy and competitiveness were not critical for the TWGI; they were for the literature. Likewise, cybersecurity was frequently repeated in the literature, while it was one of the least mentioned challenges by the managers, who, in turn, indicated the least frequently strategic challenges (4%), cooperation (3%), cybersecurity (3%) and competition (3%).

The fact that the most common difficulties for the TWGI were financial resources/investment, employee qualification/training, technical/processual challenges and organizational transformation/leadership reflects that the industry is still in the transition phase to I40. As a brand-new paradigm, the transition toward I40 requires high investments, competent employees and successful leadership. Furthermore, we should not forget that some technical and processual challenges, due to their nature, may appear at a high level in radical transformation processes. However, once the transition period has been overcome and systematic processes based on continuous improvements have been created, technical and processual challenges will arise rarely. We believe that with the increase of the I40 maturity level of the TWGI, the least encountered difficulties will become the most critical problems, namely, strategy, cooperation, cybersecurity and competition. Although there appear to be differences among categories, the challenges mentioned by the literature and the managers largely overlap.

We believe these findings will benefit the I40 journey of the TWGI. In their plans and actions, the industry and policymakers should also focus on minimizing the challenges revealed in this study.

The sample in our study was limited to the managers of the TWGI. Including other stakeholders in future studies may provide more comprehensive findings, thanks to different perspectives. Comparisons with countries such as China – Turkey's competitor in the white goods industry – can also provide valuable outputs. Moreover, a similar study could be conducted to establish the most important I40 categories in other competitive sectors of Turkey. Finally, I40's advantages and challenges are categorized in this study with the Delphi method, so future studies could employ other methods to define the weights of each category, such as the analytic hierarchy process (AHP).

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