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The automotive sector in Mexico: The impact of automation and digitalization on employment

- Jorge Carrillo (El Colegio de la Frontera Norte)
- Adriana Martínez (ENES-Universidad Nacional Autónoma de México)
- Octavio López (Instituto Tecnológico de Hermosillo)
- Martha Díaz (Instituto Tecnológico de Hermosillo)

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▶ Abstract

In recent years, an important debate has intensified regarding the impact of the implementation of automation and digitalization on employment. There are different studies and positions in this regard, and although these technologies are being used more and more in different sectors, the automotive industry stands out as a large consumer and producer of new technologies, such as those associated with Industry 4.0.

This study describes the implementation of automation and digitalization processes in two automotive plants and analyses their effects on employment. The cases of Toyota-Guanajuato and Ford-Hermosillo are presented. These plants were established in Mexico during different waves of industrialization. They have increased automation and digitalization, albeit at different stages and degrees of development. A qualitative methodology is used based on guided visits to the plants, review of internal documents and face-to-face interviews with managers and workers. The fieldwork was carried out at the end of 2021 and in the second half of 2022.

The study provides an overview of these plants and documents the automation and digitalization processes of these two companies, including the current technologies used, and how they shape the organization of work, the occupational composition, the salary structure, and the volume of employment. The results of the study put into question the argument that automation and digitalization are causing unemployment, deskilling, and job insecurity in this sector.

Keywords: automation, digitalization, Industry 4.0, employment, automotive, Mexico

List of abbreviations and acronyms

4M	Man, Method, Material, and Machines
AMIA	Asociación Mexicana de la Industria Automotriz
AGVs	Automated Guided Vehicle
BEVs	Battery Electric Vehicles
CTM	Confederation of Mexican Workers
CEMA	Connectivity, Electrification, Diverse Mobility, and Autonomous Driving
EVs	Electric Vehicles
FPS	Ford Production System
GNP	Gross National Product
HSAP	Hermosillo Stamping and Assembly Plant
HR	Human Resources
I4.0	Industry 4.0
IMSS	Instituto Mexicano del Seguro Social
ICE	Internal Combustion Engine
IACNA	International Automotive Components North America
ILO	International Labour Organization
JIT	Just in Time
MRP	Material Requirement Planning
MNEs	Multinational Enterprises
OECD	The Organization for Economic Co-operations and Development
OEMs	Original Equipment Manufacturer
OICA	International Organization of Motor Vehicle Manufacturers
RFID	Radio Frequency Identification
RVC	Regional Value Content
R&D	Research and Development
SQDCPME	Safety, Quality, Delivery, Cost, People, Maintenance and Environment
SITIM-CTM	Sindicato de Trabajadores de la Industria Metal Mecánica, Automotriz, Similares y Conexos de la República Mexicana
SUVs	Sports Utility Vehicle
TMMGT	Toyota Motor Manufacturing of Guanajuato
TPS	Toyota Production System
UAQ	Autonomous University of Queretaro
US	United States
USMCA	The United States-Mexico-Canada Agreement
VWMs	Volkswagen Motors

▶ Introduction[1]

The importance of discussing automation

Automation not only forms part of the manufacturing industry, but it is constantly improving and spreading, with varying, and sometimes contradictory, labour impacts. On one hand, automation may be accompanied by unemployment and deskilling, while on the other, it may require job reskilling and the hiring of people with different skills. In this sense, there is an important debate around the impacts on work of the implementation of new technologies, such as automation, robots, and digitalization (Autor et al. 2020; Anzolin 2021; Krzywdzinski 2021). In simple terms, automation refers to tasks performed by intelligent, reprogrammable machines (Kamaruddin et al. 2013), and it also refers to the replacement of labour by (relatively autonomous) machine input (Eurofound 2018). According to Anzolin (2021), automation emerged in the 1960s with the implementation of the first robotic arms in industrial production and, since then, has increasingly expanded, driven by new technologies (such as computerized numerical control and more recently, robotics).

Since the 1960s, factories in the global North have gradually moved towards greater automation and digitalization. But the global South is not that far behind. In multinational companies, especially those in the automotive sector, low wages and the massive availability of flexible labour are no obstacle to the incorporation of more automation, digitalization, and even research and development (R&D) activities (Cantwell 1994; Florida 1997; Krzywdzinski 2017), as the continued automation in emerging economies improves firms' competitiveness (Butollo and Lüthje 2017). According to Butollo et al. (2022), some authors argue that the effects of automation could make labour cost differentials increasingly obsolete; while at the same time, Industry 4.0 (I4.0) could favour the intra-regional allocation of firms close to each other (De Propris and Pegoraro 2019; De Propris and Bailey 2020), and network and logistics technologies may (simultaneously) deepen global fragmentation (Sturgeon 2019; Butollo 2020; Raza et al. 2021).

While automation has been characterized as an evolutionary process (Brynjolfsson and McAfee 2014; Harteis 2018; Arslan et al. 2021), digitalization and technologies associated with I4.0 are transforming it in a substantive way, for example, with the adoption of collaborative robots or artificial intelligence (Anzolin 2021). Although there is no single and accepted definition of I4.0[2], it refers to the unification of digital technologies with conventional industry, allowing devices to communicate and interact with others and to collect and evaluate data in real time for optimized costs and quality, robots with great autonomy and flexibility, and advanced manufacturing techniques (Cotet, Balgiu and Zalesti 2017; Rodic 2017). Another eclectic definition for I4.0 would be the connectivity and integration of data throughout the value chain based on automated production systems, with autonomous and interactive learning, and digital technologies at the core (Smit et al. 2016; Sukhodolov 2019; Propis and Bailey 2020). Recently, Axis (2019) identified a set of new technologies associated with I4.0,[3] spreading widely through multinational enterprises (MNEs) in a variety of economic activities, and particularly, in manufacturing. Global consulting firms claim that the implementation of I4.0 will be inevitable. PwC stated that while the level of advanced digitalization in 2018 reached just 33 per cent in global industrial companies, it had increased to 72 per cent by 2020.[4] According to TechAisle, the Internet of Things (IoT) could exceed 75 per cent of all medium-sized companies and 33 per cent in small ones (Dealer World 2018). A central debate revolves around those who highlight the effort and investment in I4.0 by large corporations, particularly in human talent (Cotteleer and Muprhy 2019), versus those who emphasize the high risk of job loss derived from automation (Frey and Osborne 2013; Cebreros et al. 2020).[5]

[1] The authors wish to thank the companies for their valuable support without which this research would not have been possible. Special thanks is extended to Francisco García, President of Toyota Guanajuato who was extremely open to the research project throughout the process. Also we want to thank Alejandro Coronado, Risk Manager at Ford Hermosillo for all his support. We also want to thank Fernanda Bárcia de Mattos and Guillaume Delautre for their critical reading, as well as Gail Friedman for reviewing the English. The views expressed in this paper are those of the authors and do not necessarily represent the views of the ILO.

[2] The term Industry 4.0 was coined by de German Government in 2011 at the Hannover Messe Fair to Promote its strategies plan, the High-Tech Strategy 2020 Action Plan (Kagerman, Wahsler and Helbig 2012).

[3] Additive digital manufacturing (3D printing), machine learning, augmented reality, virtual reality, autonomous robotics, collaborative robots, massive data analysis (Big Data), autonomous guided vehicles, cloud computing, block chains, cybersecurity schemes, Internet of Things, computational vision, census and digital data collection, advanced simulation/digital modelling, vertical and horizontal software integration, digital twin, real-time process monitoring, intelligent energy management. For a description of these technologies, see Axis (2019, p. 21), available at https://vp.inteliaxis.com/PDF/Bajai40.pdf.

[4] PwC Global 4.0 Survey carried out in 26 countries with 2,000 companies (PwC 2016).

[5] "Almost two thirds of total employment [in Mexico] is at high risk of automation; slightly more than half if we only consider employment in the formal sector" (Cebreros et al. 2020 p. 2).

The importance of automation in the automotive industry

The importance of automation in this industry is largely due to its backward effect, with the technological trends adopted by the automotive industry affecting various economic activities. The automotive industry is considered the industry of industries, and its enormous backward effect impacts sectors as diverse as mining, plastics, rubber, glass, metals, textiles, electronics, metalworking, energy, infrastructure, telecommunications, and others.

Likewise, the automotive sector has been one of the pioneering industries in the introduction of automated processes. It has the largest stock of robots in manufacturing and is often touted as being at the forefront of automation. The automation and digitalization of production processes have shaped the automotive industry for several decades (Butollo et al. 2022; Krzywdzinski 2021; Pardi et al. 2020). This industry has also shaped production models that have been emulated in other industries throughout the world, such as Fordism, Lean Production, and even the implementation of Industry 4.0 (thanks to Ford, Toyota, and German companies, respectively) (Boyer and Freysenet 2003). Furthermore, this sector is not only a consumer of I4.0 technologies, such as big data, artificial intelligence, machine learning, and collaborative robots, but also develops them.

According to our review, the main trends or axes transforming the automotive industry are Connectivity, Electrification, diverse Mobility, and Autonomous driving (CEMA). Connectivity is the process of transferring data from one device (sensor or control) to another or to the cloud through the internet. It forms the information, telecommunication and technological link between people, machines, and the Internet of Things. Electrification refers to the move from powertrains to hybrid-electric cars and fuel cell technologies. Mobility is associated with the expanding sharing economy and changing consumer preferences, moving from individual purchases to car-sharing, car-pooling, cellular vehicle-to-everything, and car-to-x connectivity. Autonomous entails the shift from driver assistance systems – already found in several new vehicles – to fully autonomous driving systems as technologies mature.

CEMA is affecting the manufacturing process. For example, connectivity implies many more sensors in a car, including in the tires; and electrification entails fewer parts and components in a vehicle and, consequently, fewer suppliers and jobs, and possibly different types of jobs. Ford, for instance, recently announced that it would displace 8,000 jobs from its plants in North America due to the change from internal combustion engine (ICE) models to electrical vehicles (EVs) (Naughton and Ludlow 2022). Although the automation and digitalization processes are key elements for CEMA, particularly in the manufacturing process as they are transversal to the various I4.0 technologies, the impact of these technologies on work is still under debate. For example, Krzywdzinski (2017) and Butollo et al. (2021) analyze the entry of I4.0 in the German and Chinese automotive sector and emphasize the uncertainty and experimentation at work.

The importance of automation in the Mexican car industry

The importance of automation in the Mexican automotive industry is directly and indirectly reflected in various elements. First, the Mexican automotive industry is almost 100 years old, and has passed through various waves of industrialization. This has allowed for the observation and evaluation of the adoption of automation and digitalization processes. Original equipment manufacturers (OEMs) and global suppliers are located throughout Mexico and their plants have automated processes, implemented digital technologies, and started I4.0 projects. More importantly, companies have expectations of growth and of catching up with the new wave of electrification.

Second, the automotive industry is of enormous importance to Mexico, representing 18.3 per cent of manufacturing gross national product (GNP), and 32 per cent of manufacturing exports. Every state in the country is host to at least one of the more than 3,000 automotive manufacturing establishments. Almost all OEMs have a presence in Mexico (figure 1), as do the largest 100 global suppliers. This industry is also highly labour intensive, with more than one million workers in Mexico[6], representing 21 per cent of the total number of employees in manufacturing (AMIA 2022).[7] Therefore, changes in the patterns of employment and supply chain are of great economic relevance.

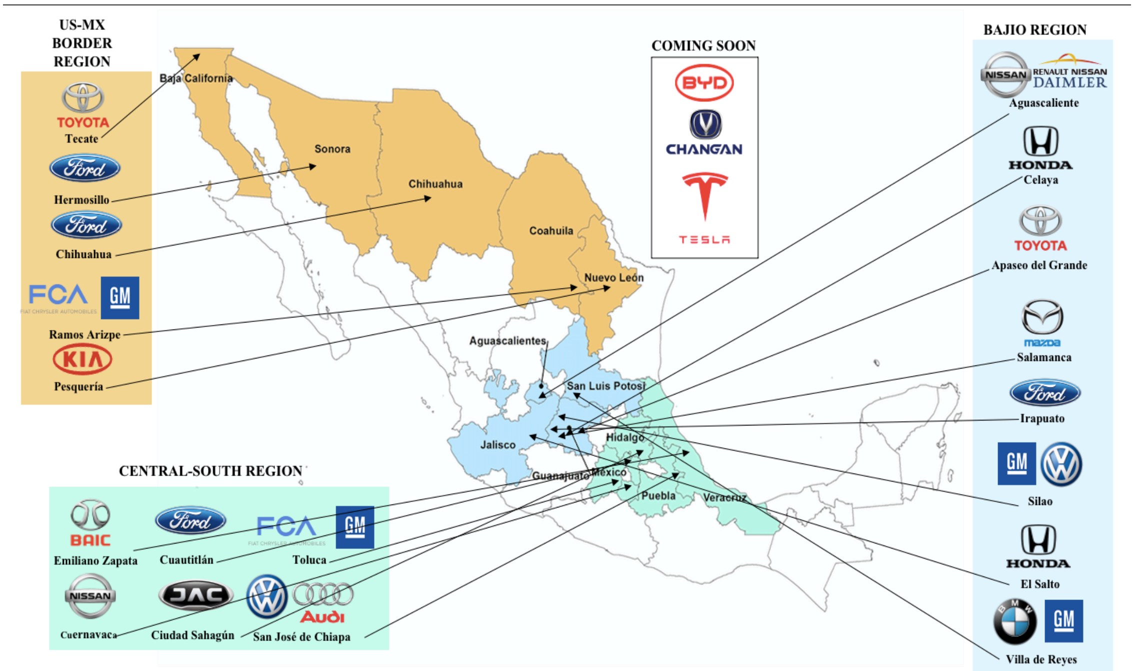
Third, Mexico has earned global recognition as an automotive manufacturer. It is currently ranked 7th largest producer of vehicles in the world (OICA 2022) and 4th in auto parts (AMIA 2022). In just fifteen years, total production almost tripled,

6 Data prepared from the database of the Instituto Mexicano del Seguro Social (IMSS) Open data of employees in the formal private sector in Mexico, available at http://datos.imss.gob.mx/group/asegurados.

7 Data from Economic Census 2019.

from 1.5 million units in 2004 to 4.1 million in 2018, while its export registered a nearly 300 per cent accumulated growth (OICA 2019).

Figure 1. Automotive OEMs in Mexico



Source: Authors.

Fourth, Mexico is an interesting case for understanding the opportunities and challenges of automation, digitalization, and I4.0 in an emerging market. It is a semi-peripheral automotive industry (Domanski et al. 2014) that operates under an integrated North American production system, and whose central role is exports to the US market. There are no Mexican OEMs and most of the main companies are foreign owned. It has relatively low costs and is currently under intense scrutiny regarding union democratization. Furthermore, it is under debate whether this semi-peripheral model is in decline or if the industry will be restructured. On one hand, forecasts to 2029 suggest that ICE vehicle production is expected to remain within the current geographic footprint in North America, and battery electrical vehicles (BEV) production is projected to be more concentrated in the United States (Dziczek 2022). On the other hand, Mexico is increasingly producing high-value cars, such as SUVs, pick-ups, and premium models, and is moving, albeit slowly, towards BEVs. Ford assembled the first made in Mexico EV (Mustang Mach-E), curiously, in its oldest plant, established in 1964. Some companies have stated that they will soon manufacture EVs in the country, as well as possibly establish an electric battery plant, such as Tesla recently announced. Also, Mexico has lithium, a core mineral for EV batteries, and, consequently, the government is establishing a program for its exploitation.

Fifth, the inclusion of women in manufacturing. As ILO (2021a) pointed out, much attention has been devoted to studying the impacts of technological upgrading and automation on employment; yet there is little evidence on the processes behind these outcomes and why they seem to further reinforce, rather than alleviate, gender inequalities. The Mexican case partially fills this gap. Although the OEMs in Mexico have traditionally been characterized by the extremely low incorporation of women in production processes, the export auto parts maquiladoras (usually global suppliers) have traditionally employed many women (Carrillo 1992; Carrillo and Gomis 2013). The increase in automation and digitalization in the automotive sector has been accompanied by an increase in the industry's employment of women. According to the

IMSS[8] database, female participation in OEMs has increased from 5 per cent to 20 per cent in this millennium (from 01/2000 to 01/ 2023), while women's participation in auto parts production has risen from 36 per cent to 43 per cent in the same period.

Sixth, the regional and national context has changed. On one hand, the United States-Mexico-Canada Agreement's (USMCA) new rules of origin for the automotive sector imply not only greater regional integration,[9] but, of particular importance for this study, includes requirements in terms of wages: 40 per cent of light vehicles and 45 per cent of pick-ups must be produced in plants where workers earn at least $16 an hour.[10] Labour obligations are also a core part of the USMCA. The agreement establishes that union democracy must be verified in collective negotiations, and panels need to be created to resolve disputes. On the other hand, the current Mexican administration is increasing the minimum wages and paid leave, has prohibited labour outsourcing (with some exceptions) (Brito et al. 2022), and has created a new system for union transparency and democratization.

Following the above justification for this study, the rest of this document is divided into five sections. The first presents our research goals and methodology, including the criteria for choosing firms to study. The second section overviews the profiles of the two plants that were selected for case study. The third provides a description of technologies at the plant level. In the fourth section, we present interview findings, focusing on the drivers of and challenges to automation. We then compare the two plants in terms of work organization, occupational composition, wage structure, and technologies' impact on employment. Finally, the discussion and conclusions are presented in the fifth section.

[8] These data were prepared from the database of the Instituto Mexicano del Seguro Social (IMSS) Open data of employees in the formal private sector in Mexico, available at http://datos.imss.gob.mx/group/asegurados.

[9] Regional value content (RVC): from 62.5 per cent to 75 per cent for cars and pick-ups. Plus, RVC for core, main and complementary parts. Plus 70 per cent for steel and aluminium purchases.

[10] All currency refers to US$.

▶ 1. Research goal and methodology

The automotive industry in Mexico has been widely studied. Much of the research has focused on economic performance and production models (exports, productivity, value added, value chain, among other variables) (Álvarez and González Marín 2017; Moreno Brid et al. 2021; Ortiz, Carbajal and Moral-Barrera 2017; Arteaga 2020; Covarrubias 2020; among many others). Various publications have also examined employment and labour conditions (Middlebrook 1988; De Buen 2011; Covarrubias and Bouzas 2016; Arteaga 2020; García-Jiménez et al. 2021, among others). Recently, pre-pandemic studies on OEMs showed the diversity in terms of automation (box 1). Notwithstanding the findings of these studies, understanding the implementation of new technologies and their labour impact requires further qualitative research.

The main goal of this research is to gain a better understanding of how processes of industrial automation and digitalization are implemented in the manufacturing industry of an emerging economy, and how this affects employment and labour organization. We study two final assemblers' plants in the automotive industry in two Mexican regions.

The relevance of this study lies in the fact that it presents first-hand information, recent, and authorized by companies, on automation and digitalization processes framed within I4.0 trends. Likewise, the study focuses on one company which began operations with state-of-the-art technology, and another undergoing a process of significant technological restructuring. This allows for the comparison of plants established in Mexico during different industrialization waves and greater understanding of changes in employment and work, and their relationship with new technologies.

The study is based on one industrial segment: final assemblers, also referred to as OEMs. Although the pyramidal structure at a global level, and particularly in Mexico, comprises few final assembly companies and a long list of Tier 1 and Tier 2 global supplier companies, the OEMs continue to be the main drivers of the sector and maintain leadership in supply chain governance.

Our study consisted of two phases. In the first phase, we selected two OEMs in Mexico and obtained economic, technological, and employment data. The Japanese company, Toyota Guanajuato (TMMGT), and the American company, Ford Hermosillo (HSAP) were selected. We later undertook plant visits and interviewed managers. The second phase consisted of semi-structured interviews. Over both phases, we conducted a total of 22 face-to-face interviews with managers and workers, and five additional online interviews. The average interview duration was 35 minutes at TMMGT and 60 minutes at HSAP. We also conducted three interviews with local government officials in Guanajuato.[11] The fieldwork was carried out in December 2021 (first phase), and August-September 2022 (second phase). Between October 2022 and January 2023, further interviews were conducted for consistency and to fill information gaps.

[11] The external actors interviewed participated in the negotiations to locate the company in Guanajuato.

▶ Box 1. Automation in some automotive OEMs in Mexico

Volkswagen-Mexico, Puebla. Innovative company. It has a transversal modular shared platform that manages the standardization of four families of modules (electrical-electronic, bodywork, engine, and running gear). Drivers: ergonomics, sustainability, safety, efficiency, quality, connectivity, and profitability. The plant has about half of its processes automated, with stamping, painting, and quality control the most automated. It automates only to increase worker safety and quality when repetition of tasks is high. Volkswagen's corporate culture is expressed in innovative concepts that enable improvements in relations with the union and in working conditions (Bensusán and Gómez 2017).

Ford-Hermosillo, Sonora. Began with lean production and, between 2004 and 2005, invested heavily in introducing a flexible manufacturing system that positioned the company at the forefront of global automotive technology. It has been estimated that the plant has 172 robots in the different production areas (Contreras and Díaz Muro 2017).

Ford-Cuautitlan, Estado de Mexico. After reopening in 2010, it is now a high-tech plant that incorporates a new stamping area with a line of five high-productivity presses, 270 robots, and online measurement systems, with adjustable ergonomic platforms in the trim area. In the painting area, the modern 3-wet process has been incorporated. Wage growth has lagged technological upgrades (Contreras and Díaz Muro 2017). To date, it is the only plant that manufactures EVs in Mexico.

Mazda-Salamanca, Guanajuato. 40 per cent of work processes involve automation technologies; painting was fully automated, and the staff intervenes only in detail or with quality problems (Salinas, Carrillo and Uribe 2018).

Honda-Jalisco. Production is mainly manual, with only two robots in bodywork (Morales and López 2018).

Nissan-Aguascalientes. Plant 2 is the most automated in the Nissan complex (Maza, Chávez and García 2018).

Audi-Puebla. Highly automated. In terms of work processes, 40 per cent include computerized systems and 40 per cent include automated equipment. The bodywork area has 1,440 machines (600 Kuka robots) with 600 employees; the painting area is fully automated and employs 400 people. (Reyes, Sánchez, and Martínez de Ita 2018). The premium vehicles are manufactured with state-of-the-art technologies (Miranda Bello 2022).

BMW-San Luis Potosi. The plant has state-of-the-art technology, is highly automated and robotized (992 robots). Working conditions are improving, as well as economic and non-economic benefits, in addition to salaries and social benefits granted by the labour law (Sánchez González 2022).

Source: Authors.

2. Firm profiles

2.1. TMMGT, Toyota Guanajuato

Toyota Motor Manufacturing de Guanajuato (TMMGT) started operations in December 2019, with an initial investment of $700 million, at Apaseo El Grande. The state of Guanajuato, located in the central region of Mexico, constitutes an automotive cluster with seven OEMs and 500 part-suppliers. TMMGT sits on 620 hectares of land, with 240,000m^2 of construction. The location was chosen for its strategic position and infrastructure (it has access to two railway lines).

The production in 2021 was 100,000 vehicles a year with 2,233 total employees, of which 27 per cent were women. The plant increase production capacity by 38 per cent since January 2022 (to 138,000 units) and 515 more workers were hired. It will begin operating a new platform in December 2023, adding another 465 new employees. Toyota chose Mexico to produce 100 percent of the Tacoma pick-up models sold in North America. This plant, along with Toyota Tijuana, are the only ones that globally produce the Tacoma model. Currently 95 per cent of production export goes to the United States. The manufacturer has the following areas: stamping, bodywork, welding, painting, assembly, and quality control. In addition, they have a training area, and a water treatment plant that recycles 80 per cent of the water required in the plant, with 20 per cent used for irrigation. The production of hybrid or electric versions of the Tacoma will depend on market demand (Production manager interview, TMMGT).

The organization of work is based on the flexible model of lean production.[12] The plant functions according to the Toyota Production System (TPS).[13] According to Toyota, the TPS consists of three principles: Just-in-Time, standardized work and Kaizen, and Jidoka,[14] in other words, minimization of waste, continuous improvement, and obsession with quality (Womack et al. 1990). These principles imply various practices or techniques for the implementation of TPS, such as quality circles, work teams, job rotation, Andon system, etc. The TPS is adopted in all Toyota affiliates, but with certain adaptations to regional contexts (Abo 1994, 2014). Specifically, TMMGT has a flat organizational structure and seven categories from the President to blue-collar workers. Production is organized in teams, and each team has one group leader. Great part of team members is unionized in the Sindicato de Trabajadores de la Industria Metal Mecánica, Automotriz, Similares y Conexos de la República Mexicana (SITIM-CTM). To shorten the learning curve at the start of operations, TMMGT transferred engineers from the Toyota plant in Tijuana to Guanajuato and located them in key positions. This ensured the rapid transfer of the Toyota TPS model.

To achieve productive efficiency, and just-in-time production, TMMGT has thirteen global suppliers. These suppliers work within the Toyota industrial campus, employing 2,604 workers. Employees of suppliers are distinguished by the color of their vests or helmets. The suppliers have the same union as Toyota but slightly lower wages and social benefits.

2.2. HSAP, Ford Hermosillo

Hermosillo Stamping and Assembly Plant (HSAP) started operations in 1986 in the northern border state of Sonora. The plant was built with an investment of more than $500 million to supply subcompact cars to the North American market. It was an icon of the new export-oriented model that began to take shape throughout Mexico in the nineties, mainly in the northern region. The plant is built on 280 acres of land, with its facilities using nearly 64 acres. In 2002, the firm invested more than a billion dollars in the installation of a CD3 platform, and more recently, over a billion dollars was again invested in the facility for a CX430/P758 platform.[15] Since its inauguration, the plant has been recognized for its high productivity and competitiveness (Shaiken 1990; Sandoval 2016; among others), and has been one of the highest productivity facilities of Ford Motor Co.

[12] This model has been emulated in many industries and regions throughout the world (Janoski and Lepadatu 2021).

[13] According to Janoski and Lepadatu (2021, p. 4) the term “lean” is not the best description of Toyotism model [coined by Bergreeen 1992]. They propose a more appropriate term for Toyota lean system: “lean-long-term, and loyal.”

[14] JIT = Do what is necessary, when it is necessary, using what is necessary and at the necessary time. JIDOKA = Autonomy of machinery and people to prevent and solve problems. Quality is produced at the source (in machinery it refers to automation and in people to own-initiative or self-activation); all sources of low quality must be removed or rectified through Total Quality Control. KAIZEN = continuous improvement to solve problems and innovate (Toyota Motor Co. 1996).

[15] The next model or design change will take place in the next five to eight years.

The HSAP plant has a total of 3,400 employees in 2022, 18 per cent are women, and 88 per cent of the workforce is unionized. The plant performs under the Ford Production System, with a flat organizational structure. It incorporates the following areas: stamping, bodywork, painting, assembly, logistics, quality control, test tracks, vehicle shipping area, and reservoir water in a storage tank. All areas seek to introduce innovative production systems with sustainability standards.

The plant was recently upgraded to produce the Bronco Sport and Maverick models under the same platform. These models are produced only at the Hermosillo plant for the entire world. In 2021, more than 109,000 Ford Bronco Sport units were manufactured for export (90 per cent to the United States), and 6,000 Ford Maverick units for sale in Canada, Mexico, and South America. The Bronco model was designed mainly by Mexican engineers, and more than 70 per cent of the components were designed in Mexico (Ford MX 2021). HSAP production has varied considerably according to the models produced. For instance, 235 thousand units in 2009, 385 in 2013, and 205 in 2019. In 2021, due to the pandemic and problems in the supply chain, it produced only 167,000 units, but in 2022 it recovered, and it is expected to produce 252,000 vehicles.

HSAP developed an in-house supplier industrial park and hosts 16 global suppliers with three more nearby. There are five logistics companies, two of which undertake 437 daily movements to and from HSAP using 102 trucks. Suppliers' plants in Mexico represent 56 per cent of the total suppliers and 60 per cent of these are on the industrial campus. It is assumed that about 27 per cent of the total production cost is due to moving materials (interview with Ford's manager, December 2021). DHL Supply Chain, Schnellecke Logistics, Penske Logistics, TLM auto transporting, and Ferromex supply the logistics systems and moving parts and vehicles. Most exports to the United States are by railroad.

The organization of work is also based on lean manufacturing. HSAP implements the Ford Production System (FPS).[16] The FPS (Ford Motor Co. 2004) consists of continuous improvement, and integrating a global, flexible, and disciplined lean production system that encompasses a set of principles and processes to promote lean manufacturing. Key elements include autonomous work groups, zero tolerance for waste/defects, globally aligning manufacturing capacity to market demand, optimizing production for better performance, and reducing overall costs to drive business. The FPS was standardized in all Ford plants by 2013 and comprises two aspects: (a) a set of metrics ("measurables"), that help to meet daily objectives through the scorecard SQDCPME (Safety, Quality, Delivery, Cost, People, Maintenance and Environment), and (b) unified key processes (help clarify how work should be done at different levels of the organization with standardized work, confirmation processes, data and time management, continuous improvement, goal deployment, and visual management).

[16] They called it Ford Global Production System.

▶ 3. Description of technology

3.1 TMMGT, Toyota Guanajuato

Automation in Toyota Guanajuato extends to most areas (box 2). Regarding robots, the plant had 127 units in 2021. Bodywork concentrates about 54 per cent of the robots, the painting area 35 per cent, and stamping 8 per cent. In relative terms, TMMGT has 12.5 employees for each robot in the stamping area, 8.6 in painting and 5.8 in welding. In the most labour-intensive department, final assembly, there are 243 employees for each robot. All robots are Japanese.

As of the expansion of productive capacity in 2022, 49 new robots were installed, with 59 improvements and/or automation of existing assets, and 179 additional assets (systems or automations in previous processes). A new paint plant was built for the truck bed. Previously, the cabin and the truck bed were painted in the same industrial warehouse. With the new platform at the end of 2023, 171 new robots will be incorporated, with four new automated lines, and 117 new pieces of equipment.

▶ Box 2. Automation at TMMGT

- Stamping: 12 robots.
- Press: latest technology generation.
- Body: 58 robots, 1 robot for training, 4 AGVs, and an automatic transporter.
- Welding: 50 per cent automated.
- Painting: highly automated.
- Assembly and quality: mostly manual, but with pneumatic stations, and few robots.

Source: Authors, based on 2021 company information.

Two pillars of the Toyota Way are respect for people (caring for workers and their families) and continuous improvement (Kaizen).[17] Based on these precepts, TMMGT is developing human talent capable of managing the new digital technologies. According to the engineer responsible for the introduction of emerging technologies, the company has two objectives: "one, not to develop multiple options for the same problem, and two, not to install 'black boxes', that is, technologies that we do not know" (Project manager, TMMGT). In other words, TMMGT does not seek to develop multiple solutions for the same problem, and on the contrary, attempts to align resources. In accordance with this vision, the plant implemented I4.0 technologies in the production process. The company has a Committee of Emerging Technologies, which aims for technologies to provide strategic information in real time to make decisions, using the 4Ms (Man, Method, Material, and Machines).

TMMGT collaborates with the Autonomous University of Queretaro (UAQ) to develop talent with digital skills through a postgraduate program in artificial intelligence, machine learning, big data and analytics. In 2021-2022, they jointly developed five projects that use I4.0 technologies. TMMGT and UAQ engineers work as a team on specific projects.[18] These digitalization projects have not displaced blue-collar workers, technicians, or engineers; on the contrary, the developments have focused on creating better working conditions that also translate into greater productivity. It is important to note that the engineers involved have developed greater digital capacity (box 3).

▶ Box 3. I4.0 TMMGT and UQA collaborative projects

AVS (Automated Vision System)[1] robot for weld burr detection. Burrs generated in the welding process cause quality and safety problems. Team members used to visually detect and make repairs manually.

[17] The Toyota Way includes four main categories: philosophy, process, people and partners, and problem solving (Martínez 2021, p. 101).

[18] This Types of collaboration between TMMGT and UAQ has driven a transfer of knowledge that Noteboom (2008) refers to as "processes of exploration" that allow a company to innovate by absorbing external knowledge.

Software for fault trend detection. Equipment failures have negative impacts on production as they imply overtime work to correct mistakes. The manual and visual system has been replaced by integrated software to obtain information, including sensors which send alerts, predicting losses and failures, and providing solutions.

AVS robots for error detection in confined spaces. Line production with little accessibility is difficult to monitor. The manual and visual system has been replaced by AGV "rovers" (with vision system and artificial intelligence) which can access and detect possible faults.

[1] The Toyota's AVS is known in the literature as AGV (Automated Guide Vehicles).

Source: Authors, based on company information.

3.2 HSAP, Ford Hermosillo

The plant has been recently upgraded, after competing with other Ford's affiliates, for the launch of the Bronco and Maverick models. The most significant changes were in the painting area, which were completely renovated. HSAP has 941 robots for welding, sealing, handling of parts, transfers, and painting. It is in the bodywork area that their presence is most predominant (box 4). The collaborative robots are most visible in the bodywork, pre-assembly, and assembly line areas. While robots have the power to turn heavy transducers, employees have greater sensitivity for fine-tuning the final screwdriving. Because of the plant's location near the Sonora desert, the facility has reduced its water usage by 40 per cent since its inception. All activities are recorded in a hub system (correct assemblies, defective assemblies, torques, and delays), a tool that allows efficiency to be measured in real time with the traceability of defects or line stoppages.

Regarding I4.0, Ford Motor Co. has a vision for their affiliates: collaborative robots, and exoskeletons. Only the first has been successfully implemented at HSAP; instead of exoskeleton, finger and back equipment are being developed due to the high temperatures in the city. All these efforts, such as automation, new generation robots, cobots, big data, logistics systems, etc, have meant a 25 per cent savings in the time required to make platform changes for the new models in the plant. Two digital systems, Visual Factory and Smart,[19] enable integration in the final assembly area, providing support for the complexity resulting from the number of available options for each vehicle. This process of efficiency with complexity is directly linked to the CEMA trend mentioned in the introduction.

▶ Box 4. Automation at HSAP, 2021-2022

- Stamping: high speed and more versatile press line, producing 960 pieces per hour. 22 robots. 190 workers perform tasks of classification, inspection, and placement of parts in racks and deliver them to the Body area.
- Bodywork: new-generation 757 robots execute 100 per cent of welding points (2,800) and cameras with vision systems detect errors in the process; 680 employees.
- Painting: high level of automation, 155 robots; robot arms with eco technology consume 60 per cent less energy. 400 workers applying body seam seals or wallpapering for two-color options, and quality inspection. This area is free of residual water.
- Final assembly: seven robots are used to handle large or heavy parts. Screens have replaced paper throughout the entire process. Robots and employees work together. 1,300 workers. This process requires fewer robots but is more dependent on digitizing the system. It has the capacity for flexible manufacturing: mixed options based on customer requirements.
- Quality control: two robots. Internal test track, quality inspection, and road test. 200 workers. All data are collected onto a computer system to verify electronic parts.

[19] The possibilities are configured mainly on the internet sites of the firms in the United States. Two main systems "Visual Factory" and "SMART" derive from this: programming of workstations to assemble the different options, and coordination of the delivery of materials to the assembly lines.

- Logistics: computer systems are used to track logistics inside and outside the plant; the JIT relies on electronic orders to extract parts from storage. The design of routes to supply parts to assembly lines is supported by computer aided design systems.

Source: Authors, based on company information.

▶ 4. Interview findings

4.1 Drivers of automation and technological upgrading

Automation and digitalization at Ford Hermosillo and Toyota Guanajuato are broadly driven by three motives: (a) economic, focused on productivity, efficiency, consistency, quality, and flow; (b) social, focused on occupational safety and health, and (c) environmental, focused on water consumption.

Productivity and efficiency: The key role of platform changes

There are substantive differences between the plants, according to their age; consequently, there are different drivers of automation and technological improvement. In TMMGT, the official kick-off of activities was in December of 2019 and was largely based on the production model of Toyota, responding to the concept/philosophy/statement that processes must be easy, simple, and flexible.

> *"(…) the technologies that they selected to start the plant were aligned with that way of thinking. State-of-the-art equipment introduced to measure and set flexibility and agility as a foundation, for example, in terms of presses in the stamping area, as well as new technologies in the welding area, mainly in the process for assembling the cabin. We used a method called jigless, in which several robots were utilized to place all the pieces in their position and well the cabin". (Assembly group manager, TMMGT)*

Despite its relatively recent inauguration, the Toyota plant increased its production capacity in 2022. Not only was new automated equipment installed, but a new painting plant was also built. Further increase in automation is expected in 2023 with the introduction of a new platform.

For its part, HSAP is an older plant, 36 years old. It has more automation than TMMGT in most of the processes, while the final assembly is on the same system. One of the main drivers of automation and digitalization in HSAP is the upgrade of platforms for introducing new vehicles, as shown in table 1. The key changes summarized in the table evidence the increased use of automation, robots, digitalization, and training programs.

In the painting area at HSAP, almost the entire process has been modified. The facilities designed to produce the models of the current platform and new generation robots were incorporated into the painting activities that were previously carried out manually on the CD3-CD4 platform. However, manual activities are still required due to certain optional features of the new models, i.e. roofs in different colors or the application of seals, which require the sensitivity of manual work. Robots have enabled the increase and maintenance of production rates, currently at 63 units per hour. The goal is to increase the production rate to 73 units per hour, which the plant has never achieved.

In the stamping area, few changes are evident. Where changes have been introduced, they are aimed at reducing the quantity of equipment for greater efficiency. A high-speed stamping press was installed replacing three previous generation presses. The upgrade was accompanied by new generation robots handling the sheet steel components for stamping, as well as the use of various types of controllers.

The impact on the number of employees is less noticeable in the installation of windshield glass. Technicians, with mechanical help, manipulate the part to a position where a robot transfers it to apply the seals, and then to another robot for installation. In these cases, the use of automation has sustained production rates, and eliminated work risks.

▶ Table 1. Technology and models by platform at HSAP

Platform	CX3	CD	CD4	CX430, P758
Models	Focus ZX3	Fusion, Milan, Zephyr	Fusion, MKZ	Bronco, Maverick
Period (introduction and end)	1987-2004	2005-2011	2011-2020	2020-

Production Rate (Units per hour)	23 to 45	Up to 63	Up to 63	Will increase up to 73
Changes in Automation	Automated stamping presses, first robots in bodywork; heavy tools	Increasing number of robots in stamping, body and painting. Some robots in final assembly and electric tools	Increasing and upgrading robots in stamping, body and painting. More robots in final assembly. Upgrading electric tools	New generation of robots in body and painting. New generation of stamping presses. Wireless electric tools

Source: Authors, based on interviews and plant visits.

Consistency and problem solving

Associated drivers of automation are consistency, production, and the capacity of robots to perform a variety of operations. The Ford managers interviewed agree on the importance of achieving consistency in production through the use of robots. This is not simply a matter of increasing production rates, but also sustaining these rates. The stamping manager provided a comparison of units per hour from when HSAP produced on the CX3 platform: it increased from 25 to 63 units per hour with the incorporation of robots, which would otherwise have been impossible. The managers, who also have significant bodywork experience, commented on the relationship between technicians and robots, as well as on the new capabilities of the latter:

> *"[…] Really the intention of automation was to increase the capacity of production. Here in this plant, it happened around 2004 when we launched the CD3 platform, which was the first Fusion we did; back then, we ran three: Ford Fusion, Mercury Milan, and Lincoln Zephyr. The capacity at which the plant ran before was a maximum of 45 units per hour and it took much more time. Before, we were making 23 units per hour, it grew until reaching a maximum of 45 units per hour, with around 400 robots installed, and the same quantity of people, right? Around 400-500 technicians.*
>
> *[…] In 2004, we launched that platform; we went to 55 units per hour. Then it grew until we hit the 63, which is the maximum we have run in this plant. The quantity of robots grew by 50 per cent. We reached more than 600 robots. However, the number of people stayed around 400-500 people. The trade-off was that to increase production capacity, the robots took most of the jobs that were done by people… The workload of the people got reduced, but the quantity of the cycles done per hour increased and that allowed for more productivity.*
>
> *[…] For this new platform, we grew a little bit more in the body area, right now there are around 760 robots approximately. We run 63 units per hour, the capacity of the line could speed up to 75 units per hour. The operations are now simpler. Now the robots do more work with greater variety of operations. Before it was practically only welding; now, they're loading parts, welding, stamping, applying adhesive, doing some types of special welding, mix welding, [and] laser welding. They do edge. They do drilling. Now they do inspections… The truth is the variety of activities industrial robots now do has grown". (Stamping manager, HSAP)*

As has been mentioned, the area of final assembly is less automated and more labour intensive in both plants. Although there are some robots, final assembly has been impacted more by digitalization, with consistency and problem solving as the main drivers of this process in the area. To maintain a certain production pace and a continuous flow, as well as to solve technical problems that delay production and generate more work, the two companies have implemented digital technologies. For example, at the Ford Hermosillo plant, there are two distinguishable systems: the factory information system and the material, administration and logistics system. These function at two different levels: "Autocall" for internal logistics, and "Broadcast" for just-in-time logistics of campus-manufactured components (i.e. its 16 on-site suppliers). Broadcast is a file shared with suppliers several times a day, containing information on the vehicles programmed for production and their characteristics and options. It allows three hours to prepare the components and materials. This adds complexity to the manufacturing process as well as to the automation of certain processes and affects work organization. The process of information sharing with suppliers is similar at TMMGT, which also has an industrial campus and several on-site suppliers.

Automation in material logistics, in addition to helping choose the correct part, allows for the ordering of more components. The process at HSAP works as follows: as purchases are made (i.e. parts are picked up), the number of pieces in the container decreases; when a lower limit is reached, the system automatically requests another container from the warehouse, the order is activated, prepared, and supplied to the line just-in-time; the full container remains and the empty container is returned to the warehouse, and the cycle is constantly repeated.

The area manager at HSAP described the operation before automation and how it currently works:

> *"[…] The material was requested using cards, literally, that the guys in the line would put in a mailbox and some guys from materials collected those cards, and they took them to a place called the smart booth. From there, there was the famous 'panini', which was a giant machine that sorted the cards collected, let's say, on each line and that's how the orders were made, they were completely let's say in a certain way…. a little manual". (Team manager chassis, HSAP)*

> *"[…] I believe that when we changed to the CD4 model back in 2006, the 'Autocall' system was implemented there, as well as all the 'Smart' that was carried out through buttons in all the stations. The technician pressed a button and with this an order was generated in the Smart system...and the Smart system, through the Broadcast and the BOM (bill of materials), discounted the part of the system...and it is time to reorder". (Team manager chassis, HSAP)*

The broadcast system works in a similar way, but for components that are supplied just-in-time from campus vendors in Ford Hermosillo. It uses information from the paint bank, which are the units that are ready for the final set. Here the order for assembly is programmed approximately six hours in advance, and the information is displayed to the corresponding manufacturer. There are approximately 19 supply companies working under this system. In each case, the manufacture of parts is programmed, containers are placed in the order in which they will be manufactured, and they are subsequently shipped to HSAP via land. This process is described by the area manager as follows:

> *"[…] Well, through certain systems we also have suppliers who send us the material in sequence, which we call just-in-time, which can be an IACNA or it can be a Martinrea, the signal also reaches them and they build through the same programming as us… through how we are going to produce and that is what they ship to us. They are shipping to us, basically every two hours we receive shipments at our assembly just in time and they focus on the same old system… that by discounting they get a signal through the automatic discount. We are doing our MRP's (Material Requirement Planning), and supply it to that material supplier, which are specifically some like Martinrea, IACNA, Antolin who are the ones who build us sequence and they supply them here. We call them just in time because…the 'buffer' is always two hours…" (Team manager chassis, HSAP)*

About 4,553 components move onto the production lines from storage or from 16 just-in-time Ford Hermosillo suppliers, each with different options. Just-in-time involves 432 daily trips using 102 transport units. The enormous importance of suppliers and the logistics of delivery in the two plants analyzed is evidenced by the fact that there are thousands of supplier employees working inside the OEM facilities. HSAP has more than 3,300 supplier workers, while TMMGT has more than 2,500 supplier workers. Interestingly, in both cases, 51 per cent of the total number of employees, are employed by suppliers with the remaining 49 per cent by the OEM plant.

Quality and continuous improvement

Automation in vehicle final assembly is driven by quality improvement through error-free assembly and efficient material supply. At Ford Hermosillo, this was initially a manual process: technicians would first read the instructions from a printed sheet with the list of features, and depending on the options, would choose tools and the components to install. As the process progressed, the steps completed were marked on the sheet. With the CD4 platform, the system has been automated and rather than the "traveling sheet", display screens have been installed at each workstation. Now when the unit enters the workstation, the system detects the option and displays the characteristics of that option on the screen, with process instructions. If an electric tool is required, the system will advise what to use to adjust the corresponding component; it is programmed to control the number of turns and the amount of torque that must be applied to each screw or nut.

To manage the use of materials in the production line, error-proof "poka-yoke" devices have been incorporated using barcode readers and "pick to light" devices. In both cases, the technician "purchases" the component using either of the two systems. A purchase is understood as the process of removing a component from its container, which, when the barcode is captured, is removed from inventory, and registered as part of the unit. Alternatively, when various components are required, depending on the vehicle option, a second device is activated: when the unit enters the workstation, a light turns on in the container that corresponds to the part to be installed; the technician takes the component and presses the switch to finalize the purchase.

Whenever new technology is introduced, affected employees must work as a team to reach consensus, and each area is required to give their approval. Both plants highlighted this issue:

> *"[...] at Toyota we always have discipline when it comes to technology, in this case any change to technology must be agreed upon, documented, and tested. Then, we have the tendency to make documents where everyone, that means stakeholders, agree and we sign that we have already done this test, we are going to do this other test and if everyone agrees...one day it will be implemented". (Project development and engineering manager, TMMGT)*

> *"[...] at HSAP the concept of technology and continuous improvement is highlighted, automation is not a phenomenon alien to the plant. The difference is 'intelligent' automation, which provides data and information on almost all processes, facilitates the analysis of problems, and allows more time for technicians and engineers to search for solutions, innovation, faster and more effective reaction times, and above all, adapting faster to change". (Assistant plant manager, HSAP)*

In the same way, engineers are being encouraged to mine data to start getting involved in its use for continuous improvement projects. As TMMGT staff mentioned:

> *"[...] That is the improvement mindset, if the engineers have time, they can search for these solutions, the data is there already, but we need to dedicate the time to the analysis of information". (Assistant plant manager, TMMGT)*

Occupational safety and health

Greater ergonomics is a driver of automation. Ergonomics is a condition for safety in the workplace and every change in processes is reviewed with this focus. The launch of new models in HSAP has enabled the company to invest further in equipment and tools with an ergonomic focus. In fact, HSAP has personnel specifically dedicated to ergonomics.

In TMMGT, vehicle production is a highly manual process. Nevertheless, there is automation, which allows for better use of materials, better quality, greater safety, and greater efficiency of the workforce. Three criteria are used for employing automation: level of exposure to risk or to mental overload, dirty processes, and processes that do not provide added value.

Similarly, in HSAP a driver of automation is preventing or reducing exposure to physically demanding work. Although on a smaller scale, electrical adjustment tools have two benefits: consistency and avoiding exposure to physical work. One of the first women on the production line at Ford Hermosillo, recalled:

> *"[…] Definitely, anthropometrically speaking, we did not have the skills for the tools. They were pneumatic torque tools that impacted on the body; always bruised… I came home exhausted, until the moment I understood all the workers in the automotive industry had the same problem". (VRT technical support, HSAP)*

Another female worker also commented:

> *"[…] Everything was manual, you can see my hands all torn to pieces. All manual, that is, they were devices that the company put on given the force that the men had, and I had to recharge, because I had to get the*

> *job done, I will tell myself. And some torques that now come quickly, before we used to do it with some big tools by hand". (Control point, HSAP)*

As mentioned, in final assembly the use of automation eliminated exposure to awkward work postures and manual handling of heavy loads. The occupational safety and health issue was also highlighted as contributing to greater productivity and consistency, as a result of the adoption of more robots. The manager of the area explained it as follows:

> *"In final assembly, the incorporation of robots occurred in the previous platform. Robots install the windshield glass, both front and rear, the dashboard, and the batteries for the hybrid options. Likewise, automation has favored ergonomic work. Previously they were manual activities, heavy and demanded a certain level of precision; now with robots, and vision and image recognition systems, it has been possible to sustain production rates and consistency in the installation of parts". (Manager of final assembly, HSAP)*

As a consequence of ergonomic improvements in the automation process, the number of women employees has risen. Since the launch of the CD3 platform in 2005, the number of female personnel in Ford Hermosillo has increased. For the launch of the models on this platform, modifications were made to the production processes, including electric tools and ergonomic criteria, all of which made female work more feasible. Since then, the number of women employees has maintained an upward trend. Ergonomics have aimed to reduce the effort needed to install parts and components, while electrical tools reduce the physical effort needed to use weight tools. These technologies have facilitated the participation of women in production and benefits both women and men.

In line with ergonomics as a driver of automation, a manager commented on the technological adaptations need to allow more women to be incorporated into production:

> *"[…] The plant has already assimilated the presence of women in production, approximately 20 per cent of the technicians are women… Based on this change, the workstations had to be adapted, from the anthropometry of the work to changing the types of tools; this has allowed more women to be gradually incorporated into the productive departments". (Assistant plant manager, HSAP)*

Striving for safer work environments has led TMMGT to develop digitalization projects, an example of which is the use of drones. In the trailer yard, 500 units of materials are received every day to be used in the daily production. Previously, an electronic system that indicated how each driver should park was used. Often, these instructions were not followed and thus when material was required, trailers were not in the correct position. To overcome this, a worker and a pick-up truck were positioned at each trailer to scan and check against the system, a process that took four hours. To increase productivity and reduce risks[20], a system of inspection using drones was developed. These fly over the trailers and scan a RFID sensor attached to the trailers in the reception booth. The position of each trailer and its cargo is thus instantly read. This has reduced the scanning time to 30 minutes and increased worker safety.

Environmental sustainability

In TMMGT, efficiency and sustainability are both drivers of automation of the painting of units, considered a key process.

> *"[...] In the painting area, new material technologies were introduced for the metal surface preparation area. The application booths were fitted with the latest technologies, which made the paint emission control management application more efficient. In the spray booths, for example, we do not use water to capture excess applied paint; The entire vapor extraction and control system is dry, therefore we have zero gas emissions into the atmosphere, and we also have zero disposal of hazardous waste". (Paint group manager, TMMGT)*

[20] Moving in the middle of hundreds of trailers is a high risk for people who walk.

4.2 Challenges to automation

The only barrier mentioned in interviews was that of robotics in the final assembly area. In the event of a possible fault in the process, the introduction of robots has certain disadvantages as the time required to correct or solve a fault is far greater and thus line stoppages have greater cost implications. If a line stops due to a person, it is relatively easy to substitute them or to make necessary changes. Apart from this, the interviewees did not mention any explicit barriers to automation and digitalization at either company, although they did identify certain challenges. Three challenges were highlighted: loss of staff, financial resources, and culture.

Automation, workers and skills

Instead of dismissing workers, the companies are retraining workers and shifting their jobs within the factory. This assumes both the internal mobility of workers to other jobs, as well as skills reconversion (e.g. Piore and Sabel 1984; Adler 1988). For example, men and women who operate the new automated equipment, shifted from line operators to maintenance technicians; while those who were already maintenance technicians needed new training. The fastest growing segment in the automated areas at Ford Hermosillo is precisely that of maintenance technicians, who need to reprogram robots and to do preventative maintenance.

Financing automation and technological upgrading

Budgets may constitute a challenge since changing platforms and upgrading technologies are expensive. Each platform implies a major change and represents an opportunity to secure new projects. While these are MNEs, their budget is not unlimited. Ford Hermosillo compete with other affiliates to obtain the new business (new models or expansion). As mentioned by a union representative, management carefully selects the projects to be promoted and competes for resources, considering, among other things, profitability, and performance indicators. Budgets are assigned from the corporate headquarters and decisions around it are vertical. In this regard, he commented that:

> *"[...] They know that we need to be the best, not just here in Mexico, but in the world, so that there will continue to work here in Hermosillo. If not, without even thinking about it, they would take the projects to other plants, regardless of the size". (Union representative, HSAP)*

For example, as of the launch of its third shift in 2023, HSAP plans to increase the share of women employees from 20 to 30 per cent, and for all employees it will be 27 per cent more people. The risk manager noted that the increase in women workers requires certain adjustments, implying expenses in terms of design, installation, and maintenance, as well as greater anthropometry. It also may require the modification of plans to upgrade technology.

> *"[...] To incorporate more women, more than 50 per cent of the stations needed such modifications, that include lift assist, lower reaction pistols, reaction bars, fixtures and/or articulated arms". (Risk manager, HSAP)*

Organizational culture and young workers

Both plants work with similar production models: lean production or lean manufacturing. This model requires standardization, discipline, and commitment, which, according to the interviews conducted in both companies, can be challenging. The Ford Production System at HSAP, for example, has safety standards that demand a commitment and discipline that, according to management, younger workers may not have. The plant's assistant manager mentioned that HSAP uses a strategy of communication and exchange of experiences to resolve this issue, and mentioned:

> *"[...] because young people want everything to happen quickly, it is hard for them to understand that some learnings happen over time. This is one of the biggest challenges". (Assistant manager, HSAP)*

This issue was not evident in the case of the Toyota Production System at TMMGT, as the company makes an effort to promote human talent:

> *"[...] At Toyota, respect for people is one of the pillars of our philosophy, which is why the selection process includes knowing the abilities and preferences of the candidates in order to be able to place them in related processes that meet their personal abilities". (Public relations manager, TMMGT).*

Regarding the challenge of the better use of data generated by new technologies, responses in the two plants varied. Interviewees at Ford recognized data mining as a significant challenge. New technologies are creating millions of data points, and their use, analysis and proposals require much effort, knowledge, and creativity, particularly on the part of engineers and system experts. As such, a specialized area may be required in the near future. At the Toyota plant, technological projects that involve artificial intelligence in the different processes are being developed in close collaboration with local universities (in Guanajuato and Queretaro). Toyota engineers are trained at universities and, together with research professors, develop new technologies for solving problems on the production line.

4.3 Work organization, occupation composition, and wage structure

Generally, in our case study, the introduction of new automation technologies has not led to worker displacement. Rather, work organization, occupational composition, and wage structure have remained unchanged with workers operating the new machinery and equipment. To ensure that these automation and digitalization processes are implemented smoothly, both plants maintain a flat organizational structure, with few differences between occupational and salary levels, and both have the benefit of collaborative unions. The two companies have more similarities than differences in terms of their organization. The fact that automation and digitalization do not result in the displacement of workers is associated with the increased demand for vehicles in the United States and, consequently, with the need to employ more people. A recent French study by Aghion *et al*. (2022) found that the impact of capital investments on employment, including modern automation technologies, is positive, even for unskilled industrial workers, but only in industries that are exposed to import competition, due to business-stealing across countries. This seems to also be the case for Toyota Guanajuato and Ford Hermosillo.

Visits to the companies and interviews revealed similarities in the organizational structures of TMMGT and HSAP that have not been impacted by the automation and digitalization, such as:

- flat structures regarding job positions and salary categories;
- lean organization with very few managers;
- departmental structure of the manufacturing area (stamping, bodywork, painting, and final assembly);
- production lines with workstations in each area or department;
- organization in teams:
  - between 5-6 operators at TMMGT and 10-14 at HSAP working in teams are positioned at each production line;
  - each team has one team leader (a blue-collar unionized worker);
  - every 4-6 teams have one supervisor (Toyota refers to this supervisor as a group leader, while at Ford they are known as process coaches) (white-collar and non-unionized in both cases);
  - supervisors report to team managers;
- focus on enhancing working conditions;
- various suppliers with thousands of employees working inside the OEM plants;[21]
- all employees are Mexicans, except for the financial treasurer at Toyota Guanajuato.[22]

As mentioned above, the two automotive plants are large employers, generating thousands of jobs. HSAP employs 3.4 thousand people and TMMGT a little more than 2.2 thousand. Although Ford Hermosillo is 1.5 times the size of Toyota Guanajuato, the occupational structure by department at both plants is similar. Final assembly is the most labour-intensive area, followed by welding, and painting. These three departments concentrate 78.2 per cent of the total workforce at Ford, and 67.4 per cent at Toyota. Considering the high level of automation in the presses, welding, and painting areas, it is noteworthy that both companies are still so labour-intensive.

Regarding union participation, both plants are unionized by the Confederation of Mexican Workers (CTM). All production workers are unionized, while the "administrative" workers or white-collar employees are non-unionized in both cases. The workforce at Ford Hermosillo currently comprises 3,400 employees, of which 3,000 are unionized technicians (blue-collar workers or hourly staff). Non-union personnel, known as salaried staff or "administratives" (white-collar workers) is made up of 400 employees. This means that 88 per cent of Ford's workforce is unionized. The average tenure for hourly workers

[21] Regarding suppliers, see Annex A.

[22] The Mexicanization of management in export manufacturing has been recognized in academic studies (Dutrénit, Vera-Cruz and Gil 2003; Carrillo 2016).

is 15 years, and the average for salaried employees is 12 years. In the case of Toyota Guanajuato, of the 2,233 employees, 1,638 are unionized, that is, 73 per cent of the total employed. Employees average seniority is three years. TMMGT is leaner than Ford in this regard.

Organizational structure

Toyota Guanajuato has only seven hierarchical levels from the President to the blue-collar workers (called technicians), and less than ten salary categories for technicians and white-collar workers. All team members are unionized in SITIM-CTM. According to its ladder system, an operator (team member) reaches the highest salary level in 36 months. The next person in the chain of command is the team leader (unionized) and then the group leader, who is an administrative or "trusted employees" – as Mexicans refer to non-unionized workers. Specialists (the lowest administrative level), who support production, are of the same hierarchical level as the group leader. In both production and administration paths, these levels are followed by assistant managers, managers, the general manager, vice president and president.

The priorities of TMMGT are to develop team members with superior capabilities, to become the most competitive light vehicle pick-up truck plant in North America in 2022, and to be the best place to work in town, according to the presentation given to the research team during the factory visit in December 2021.

In the case of Ford Hermosillo, operators belong to the Sindicato Nacional Progresista de Trabajadores de Ford Motor Company and the Industria Automotriz, CTM. Each production employee has an annual performance review based on the objectives derived from the scorecard mentioned above. This system has enabled the plant to perform extremely well. In 2022 it won the President's Quality Award which positioned it as the best Ford plant in North America. One interviewee commented:

> *"[...] This plant is an example on a global level. In fact, it has been a school... people come here and go to other plants. Plants have closed. In Mexico, the Cuautitlan plant was closed for a while. In Brazil, Argentina, the US and Canada, plants have been closed. So, if we don't focus on being the best, the work can disappear very easily..." (Union representative, HSAP)*

According to the work organization at HSAP, in final assembly, for instance, there are two team managers, one for trim and one for chassis. The team managers report to the area manager, in this case the final assembly manager. This scheme is repeated for all areas: stamping, bodywork, painting, quality control and even for support areas such as repairs or maintenance. The team leaders are production or maintenance line technicians, the process coaches are engineers, generally recent arrivals. Interview findings suggest that there is no direct promotion from team leader to process coach in this plant.

Occupational composition

The salary structure for unionized workers is also leaner in Toyota than Ford. The former has nine levels, including at each extreme, new staff and the team leader, and the latter has fifteen levels. Although they both have a flat occupational structure, the departmental composition of the two plants is a little different, as TMMGT reported 17 areas and HSAP ten. In the same way, the TPS at TMMGT is more efficient than the Ford Production System at HSAP, despite the fact that both plants produced a similar volume of vehicles in 2021. Notwithstanding the above, the forecast for the year 2022 is that HASP will produce 80 per cent more vehicles than TMMGT, so the former turns out to be more productive.

In terms of occupational composition, in 2022 Toyota Guanajuato employed 24 per cent less people than Ford Hermosillo but the American firm produced a much greater number of vehicles (83 per cent more) using more robots than the Japanese company (5.3 times more). In relative terms, when comparing the employment structures, the areas of final assembly, body work, and stamping occupy fewer people in Toyota than in Ford (12, 3.3 and 1.4 percentage points, respectively), however, Toyota employs more people in quality control (7.7 percentage points) and painting (4.5 percentage points) (table 2). Although these differences can be considered minor in relative terms, if we consider the number of robots by area, they become more significant. For instance, in bodywork (welding) the ratio of robots per employee is 1.1 at HSAP and only 0.2 at TMMGT. It is also noteworthy that even though the Japanese company is far less robotized, it employs fewer people in highly automated areas such as stamping and bodywork, and even in final assembly. In other words, Ford's greater production volume and employment compared to Toyota is associated with higher levels of automation. In 2022, HSAP produced 252 thousand units with 3.4 thousand employees; while TMMGT produced 138 thousand vehicles with 2.2 thousand workers; at the same time, Ford uses 941 robots and Toyota only 176 robots.

▶ Table 2. Distribution of employees by area and total employment, 2021 and 2022 (per cent)

	TMMGT	HSAP
Stamping	5.6	7.0
Welding (Bodywork)	17.8	21.2
Paint	16.9	12.4
Final Assembly	32.6	44.6
Quality control	13.1	5.4
Others	13.9	9.4
Total employment (persons)	*2 233*	*3 400*

Source: Authors, based on information provided by the companies.

Both plants promote their internal labour markets rather than hiring people from outside when vacancies open (Doeringer and Piore 1985), and encourage the acquisition of skills through training (Piore and Sabel 1984). Toyota has a policy to train workers for different tasks through job rotation, which has the overall impact of increasing worker productivity. As their areas of specialization increase, employees move up the occupational structure. Workers can be promoted to positions of greater responsibility, as can technicians and engineers. Soft skills (e.g. leadership) are also considered important. Two managers commented:

> *"[...] we assume that if you are doing your job well in this area, you can also do it well in another... because we know that with the tools we have within the company, it is nothing more than problem solving... this versatility exists in the company, because there are people who are subject matter experts, who are technicians, who are specialists and who are the ones who know the details of the processes; however, you need someone to coach them, to lead them, someone who can help them bring their process to a project". (HR manager, TMMGT).*

> *"[...] I came to Toyota 19 years ago working as an engineer in the maintenance area and from there I have rotated through various functions of the company, having responsibilities not only for maintenance, but also for the environment, safety, hygiene, cabin production, quality control. I am currently in the assembly area as a group manager". (Group manager, TMMGT).*

For the promotion of shopfloor workers (team members), a performance evaluation is conducted at TMMGT. Education levels are also considered, including whether they have a completed or truncated degree:

> *"[...] in terms of development, promotion, and everything else, yes, there have been cases where we have promoted team members obviously to team leader positions. Some have already been promoted to group leader level, which is already a supervisory level, and in some cases to engineering levels... it is a relatively young plant, people still do not have much experience, we have to consider the fact that they either have a truncated or finished degree, this is a factor; the other one is in terms of performance, how they have shown their capabilities, how they have shown their potential development at work." (Assembly group manager, TMMGT)*

> *"[...] when there are colleagues' promotions to a higher position, in the case of production colleagues to team leaders, a call is launched with a series of requirements. Obviously there are also a series of aspects that limits who can participate in such promotion. They can't have faults or corrective actions, but the call is open to all colleagues. For promotion purposes we do not directly participate, this is done through the company, but we do recommend it to all the colleagues so they don't miss it, and so that they try to have good behaviour, because this will be the basis for promotion". (Union representative, TMMGT)*

Regarding differences between men and women, the risk manager at TMMGT noted that there were no differences in terms of performance related to gender.[23] Currently, there are few female group leaders. Nevertheless, it is expected that their numbers will increase given their good performance.

Wage structure

In relation to salaries, Ford and Toyota employees have competitive local incomes. They have a flat salary structure, and collective agreements establish salary levels, social benefits, and forms of promotion. In general terms, the salaries and benefits are similar despite the enormous difference in the number of years the two plants have been operating: TMMGT began operations three years ago and HSAP more than three decades ago.

The salary in Ford-HSAP has a structure with only 12 levels. The hourly salary for each level is established in the collective bargaining agreement. To reach the next level, workers must have positive evaluations of performance and seniority. To access the two highest levels, vacancies are required, that is, these positions are opened when senior staff retire. Regarding social benefits, vacation days increase according to the tenure of the worker. Overtime is paid in accordance with the provisions of the federal labour law. The facility has a canteen as well as transportation services for personnel. The company gives leave with and without pay. There are also paycheck benefits for maternity, marriage, and deaths.

In the case of TMMGT, their salary structure is narrower than Ford's, with only nine levels. The different benefits are presented in the collective contract (box 5). Additionally, the company provides a transportation service for employees and a dining room, both shared with on-site suppliers to avoid differences between Toyota's employees and its suppliers. The company has a wellness program that is imparted in person at the company gym, and via zoom for those workers who cannot stay after their shift to exercise. Both modalities have been well received by the workers. For female team members there is a nutritional program, in which they are informed of the different changes that they will undergo during pregnancy. The union supports social security procedures for women, and in addition, there is a lactation room.

The two companies pay above average salaries in their respective locations, although these are substantially lower than those paid at Ford or Toyota North America. Based on wages by category for unionized employees at both plants, workers are paid almost the same in the two plants. TMMGT pay on average $2.4 an hour and HSAP $2.6. The extremes range from $1.6 for entry-level workers to $3.6 for team leaders at Toyota, and $1.4 and $3.7 at Ford.[24] It is important to note that these salaries do not include social benefits, bonuses, or any other type of benefits. The ratio between the pay of the highest and lowest earners in HSAP and TMMGT is 2.6 and 2.2, respectively. In other words, wage differences between operators (technicians or team members as they are called) are minimal. Wages of the administrative staff (non-unionized) are higher than those of the unionized workers due to the differences in terms of occupations (compositional effect): while the monthly salary for the highest unionized staff is approximately $1,114, the lowest non-union staff salary is approximately $1,232 at Ford-Hermosillo.

▶ Box 5. TMMGT economic benefits above the federal labour law

- Eight days of paid leave and 51 per cent higher pay on vacation days. Every year between years 3-14 at the firm, the worker earns two extra days of paid leave.[1] From 15 years onwards, the worker earns two additional days of paid leave for every five years of work;
- Christmas bonus: bonus payment equivalent to 26 days of work;
- Savings fund: 8 per cent;
- Weekly grocery vouchers equivalent to $8.66;
- Weekly bonuses for punctuality and attendance ($9.11)[2], turnover shift bonus ($3.14), and shift bonus ($6.27);
- Life insurance;
- Major medical expenses;
- Transport service;

[23] HSAP conducted a quantitative study to evaluate the differences between men and women regarding quality defects, line stoppages and number of bathroom breaks. No differences were found.

[24] Banco de Mexico exchange rate, April 2022 average, 1 US dollar = 20.09 Mexican pesos.

- Food service.

[1] The Mexican federal government issued a decree to double the mandatory vacations days (from 6 to 12 days) from January 2023. This implies that the union and the company will negotiate the increase in vacation days soon, accordingly with the new law.

[2] Banco de Mexico exchange rate, April 2022 average, 1 US dollars = 20.09 Mexican pesos.

Source: Authors, based on information provided by the companies.

4.4 Impacts on employment

Employment quality is a complex issue. According to the ILO (2021b) the measurement of decent work considers 40 indicators. In more simple terms, for companies like Ford and Toyota, quality at work has two main components: the economic and the work itself. The first comprises wages, economic benefits (required by law and beyond) and non-economic benefits (transportation, food subsidies, social security); while the second encompasses the duration and intensity of the workday, the environment in which activities are carried out, occupational safety and health, and participation in the definition of work tasks. Although this study did not focus on the quality of work per se, but rather on the effects on employment derived from automation, some indicators were highlighted in the interviews and in site visits, such as wages, job security, upward mobility, and the work environment. Special attention needs to be given to training, and job rotation. The training and job rotation systems in the studied plants are essential under the TPS and FPS models. These organizational models provide greater flexibility to the workforce, in such a way that with the changes derived from automation and digitization, workers are easily retrained to meet the needs of new technologies and internal mobility between jobs and areas.

As mentioned previously, the introduction of automation and digitalization has generally not led to worker displacement, but rather, to re-training and internal mobility of workers. Workers are either reassigned to other areas or posts or reskilled to maintain the same job position. As already indicated, in context of the TMMGT's production capacity expansion in 2022, both new equipment and new jobs were introduced. Some workers relocated to the new production lines and there were no significant changes in shifts, internal activities, or trainings programs, as stated by the public relations manager. According to interviews at Ford Motor Co, this process (technological upgrading) will move current employees to more specialized and less mechanical tasks, to achieve both greater comfort and productivity. Although the objective of automation is to make the processes within the plants more efficient, the firms also seek to modernize and manage more qualified and satisfied employees.[25]

We found neither individual nor collective resistance to automation and digitalization so far. Changes, in terms of more shifts, pace of work due to the speed robots, or less worker autonomy, are related with expansion capacity rather than with automation. According to interviewees, where automation has displaced personnel, workers have been assigned new activities and received the necessary training for these positions. In final assembly, no worker displacement has resulted from automation. Regarding technology and wages, the collective bargaining contracts in both Ford Hermosillo and Toyota Guanajuato are reviewed every two years and no relation was found between wages and technological changes.

The finding that workers are not displaced but, rather, undergo requalification contrasts with the classic perspective of Braverman (1974) and others who argue that there is a job de-skilling process associated with increased automation.[26] For his part, Krzywdzinski, (2017, p. 4), citing other authors, highlights that more than an uniform de-skilling trend, what is observed is a polarization of skill requirements and structures in companies. Again, respondents in Toyota and Ford plants pointed out that with automation, both lower-skilled workers and higher-skilled staff undergo training and re-skilling or are in a continues training process.[27] This positive relationship between new technologies and skill levels is also noted in other studies, such as Piore and Sabel (1984) and Adler (1988). The only critical aspect mentioned in our interviews was the increase in the pace of work. Some of the impacts derived from automation, robotization and digitization in the plants studied are discussed below.

[25] Ford of Mexico, www.ford.MX.

[26] "...using technology as a deskilling tool..." Krzywdzinski, et al. 2022, p.16, quoting Friedman 1977.

[27] We consider that this occupational segregation can be explained by the labour market and is observed in automotive plants independently of the level of technology implemented. It would, nevertheless, be worth exploring whether there is less occupational segregation in the less automated plants in the country.

Training, re-skilling and/or continuous training and skills development process

The training of workers is essential for these companies. The TPS and FPS systems themselves assign a key role to this activity not only for the good performance of teamwork and quality, but also for continuous improvement, standardization, and self-activation of workers.[28] At the Toyota plant, the implementation of automation and digitalization imply adapting some training programs where necessary, although the training process itself remains the same. TMMGT has three stages for the training of new workers which is carefully monitored. Workers first undergo a 5-day training program for new operators, with quality and TPS covered in three days, and human resources in two days (workers are provided with information about payroll, unions, security, etc.). Following this training, they are assigned to an area, and again, will receive specific formal training for their job. Second, this training is conducted in the "dojo" space (training center located within the production line), where workers will generally remain for two to three weeks, until they are able to move to the shopfloor. They may also spend more time in the "dojo", depending on the role they are performing or whether they require certification, which typically lasts three months. Third, training is done on the production line until enough experience is gained to work independently. This training process is continuous and undertaken whenever new jobs are added. Training did not change in context of the plant expansion in 2022 nor with the arrival of more equipment and technology. Training programs were, of course, updated if the adoption of new equipment had new requirements, however, it is highlighted that the structure remained the same.

An area of opportunity that Toyota has found to promote skills development, related to the introduction of new technologies, is the development of soft skills, such as creativity, teamwork, problem identification and solving, and resilience, among other. Skills not learned in a course are achieved through projects, such as collaborative I4.0 projects between TMMGT and UQA.

In the case of HSAP, all operators receive training to work as technicians, including on the use of production systems, tools, quality specifications, safety, and ergonomics, among other topics. Production workers are focused on multitasking; and skills improvement of each team member is planned according to a system of labour competencies. When the training period is completed, workstations and activities are assigned according to the skills requirement of each task, until the end of the learning curve. During this training process, each employee is accompanied by a more senior technician. With technological changes, some of the training programs are updated and new ones are established. The person responsible for training at Ford indicated that with each technological change, all workers involved are trained, regardless of whether they stay in the same position or are moved to other positions. Training is provided by HSAP personnel, as well as by the company responsible for implementing the new technology.

Strengthening internal mobility and job rotation

In the bodywork area at HSAP some former line production technicians have been moved to maintenance tasks. One maintenance technician, with more than 25 years of experience in the company, described the technological changes and its effect on labour:

> *"[...] Obviously when one makes lines more efficient, and not minimizing human resources...[workers] need to be relocated. This is the part that I do not like, but I also know that it is a change that must be made; it is to improve, at the end of the day. In some cases, at least in the experience that I have, well, it is not precisely that a person is let go, no, this person is usually relocated". (Maintenance technician, HSAP)*

> *"[...] In fact, whenever there are deficiencies, manufacturing is called, why? Because we cannot lose sight of the fact that this is a business and that there are people wanting to consume the product that we make. Almost always every time there is going to be automation, the truth is it is going to improve the process, to improve safety, improve ergonomics and thus we have never allowed people to simply be let go when there is automation to improve the efficiency of the line or stations. People are always relocated". (Union education secretary, HSAP)*

As part of the lean manufacturing system, job rotation (mobility between job positions) is critical to achieving company objectives. Job rotation of workers is important for both Toyota Guanajuato and Ford Hermosillo. At HSAP, technicians rotate between shifts each month. As the president of TMMGT mentioned, they work hard to prepare and train employees

[28] See footnote 13, self-activation refers to quality at source, which is elaborated by the one's own initiative.

so they can go to work and be efficient. This does not only refer to technical matters, but includes inculcating the "Toyota way", which takes time. The company expects commitment from its employees, and employees expect the same commitment from the company.

Due to the imminent expansion of the plant, Ford Hermosillo recently announced that a third shift will be added in 2023, as well as two shifts on Saturdays. This will increase the need for personnel with the skills necessary for applying seals, as well as for wallpapering in the various color options for roofs. The firm expects to hire more women for these activities as productive capacity increases.

Similarly, the strategy of equipping employees with greater skills through training programs (upon entry, later, on-the-job training) and job rotation, are more associated with the DNA and organizational model of TMMGT and HSAP than with the implementation of automated and digitalized processes. In no case did interviewees mention that automation and digitalization modified the occupational composition in any way.

Regarding work hours in HSAP, technology does not modify shifts, but does facilitate greater consistency in processes, especially in the most roboticized areas. Changes in hours of work are related to changes in the demand for vehicles and, of course, with plant production capacity. As was indicated, given the increase in demand, the company has included a third shift, which will affect working hours. Intensity of work is related to the speed of the production line, and once again, is linked to the demand for vehicles. Workers can express their opinions and propose improvements to processes through established internal mechanisms.

According to the OECD (2020), one of the references for defining the balance between work and personal life is the number of hours worked per week. Extended work hours can have negative health effects and increase stress levels. In the interviews, respondents were asked about the time they dedicated to family and personal life. The responses were diverse, but there was agreement on the importance of maintaining family relationships and dedicating time to spend together. Some of the female technicians interviewed recognizes the need to have the support of their partner and family, while emphasizing that the family also demands work.

Increase in women's participation

Finally, regarding the employment of women the two companies follow a policy of gender inclusion. And perhaps more importantly, according to the interviews, both companies plan to increase female participation in the ongoing process of expanding their productive capacity in Mexico – as discussed above. In the case of Ford Hermosillo, there are 614 women employees, representing 17 per cent of total unionized workers (510 female production workers), and 26 per cent of non-unionized administrative employees (114 women). The average tenure of hourly salaried technicians (unionized) is 15 years.

According to the HSAP risk manager, the tasks performed by women are not concentrated in a particular area but are dispersed throughout both the production and support areas. Women are found in assembly lines for doors, sliding rubbers, window glass, harness routing, etc.; in the trim area, in the installation of moldings; in painting, in sealing and polishing processes; in stamping, in the assortment of material to racks coming out of presses; in bodies, in assortment of parts for the side cells and doors; and in the quality inspection area.[29]

Since its establishment, the Toyota Guanajuato plant has actively sought to hire female personnel. Currently, 27 per cent of the workforce is comprised of women, or 595 women. In the manufacturing area, 29 per cent of unionized workers (475 people) are women, mostly from Celaya and its surrounding areas, with a low percentage from Queretaro. The average age is 27 years old according to information shared by the company. In the case of non-unionized workers, 120 are women (20 per cent). Despite the limited time that Toyota Guanajuato has been in Mexico, its gender inclusion policy has been clear. In only three years, it increased the percentage of women employed in production from 20 to 27 per cent. The following testimonies clearly express this vision and tendency:

> *"[...] Through our marketing we are looking for people to understand that just because we make cars, it doesn't mean that this work is only for men. In our materials we explain that there are various processes, and that we, as a company, are focused on making safe processes... we do not hire men or women, because any process can be done by both men and women. However, we have carried out campaigns so that more*

[29] The areas with few women are those of maintenance and those involving the carrying of heavy parts, such as seat assortment, tires and engine decking in final assembly, in the closure area where the doors, hoods and trunks are installed, or in the movement of dies with cranes and the paint booths.

> *women come to our recruitment process, and I can now tell you that two years ago we were at 24 per cent, and right now we are at 29 per cent… there is no more to add, we don't specify that a certain job has to be done by a man or by a woman, for us it is indifferent, it is more about the capacities, the abilities". (HR manager, TMMGT)*

> *"[…] we have a percentage of women, around 75 per cent men – 25 per cent women. I think there are many factors, perhaps there are still some cultural issues that do not permit women to work in an industrial environment with rotating shifts. It is complicated, the family plays a big role, and in some way limits the number of women who can access this kind of work. At the beginning, we started, I think, with 20 per cent, and it has been a challenge to reach 25 per cent, we hope to be able to continue this trend". (Assembly group manager, TMMGT)*

> *"[…] Right now, we have 1,638 unionized colleagues, of these 1,163 are men and 475 are women, that is, 71 per cent men and 29 per cent women. It is important to highlight that before, in the automotive sector, especially in assembler's part, there were no women in the production lines. Since we started, the number of unionized colleagues has grown; the average age of workers is 25 years". (Union representative, TMMGT)*

Several testimonials link the quality of work to technological changes. They mainly refer to changes in automation and, particularly, in equipment and tools, which seek to lighten physical work and avoid work risks. This change facilitates the employment of female workers on the shopfloor.

Regarding where women are located at TMMGT, a company manager affirmed that there are no special stations for women nor are there stations comprising exclusively women, and mentioned the following:

> *"[…] At Toyota, the philosophy is to provide the same opportunities and responsibilities for all without distinction of gender… [nevertheless] we want women to participate more in Toyota Guanajuato every day, so we are promoting in the community the opportunities that we offer to women at Toyota in order to have a greater number of candidates in our selection processes." (Public relations manager, TMMGT)*

Perceptions about automation.

Line production workers are aware of the need to automate. They understand that they are part of a global company and that their work depends on positive results that will position their plant among the best in the company, and thus they will continue to be assigned projects in the future. In this regard, it is notable that technological changes have also needed to be made to achieve the objectives of assembly quality: consistent production rhythm, high efficiency, and highest return on investment.

Various interviewees perceive the introduction of new technologies positively. This includes not only managers and engineers, but also technicians and even union representatives. The excerpt below from TMMGT's union representative clearly exemplifies this perception:

> *"[…] As you know, in the automotive industry, the automation process has been progressing at a very rapid pace, robotics has advanced a lot, and new technologies in this industry have an impact because it is part of the competition; however, not everything is robots, the workforce continues to be a factor…I think the workforce is most important in this process. And the impact? Well, since we have been related to Toyota, we have not had anything alarming, nothing in which the technological impact affects the workforce and create cuts for this reason. I think it has been a balanced adjustment between the entry of new technologies and the hiring of labour". (Union representative, TMGT)*

Deskilling

One concern is the risk of losing skills or autonomy because of automation, however, on the other hand there is the pressure of cycle time. This concern was expressed by one of the managers at HSAP:

> *"[…] over time, technology, like pick lights, like the scanners that have been helping us to do this work, and the 'traveling letter' were eliminated. That is, people right now, I don't know if it is for better or worse, but*

people already...he doesn't know how to read that letter. It depends on whether the pick lights turn on, whether the scanner buys it, or the scanner doesn't buy it, so I say, maybe that's a paradox, right? A contradiction, because before people had more in-depth knowledge of when it was the option or that part that they were going to put in. The same, before the cycle time was a minute and a half, right now the cycle time is 45 seconds, well it can't, it's too long and depending on the time". (Team manager chassis, HASP)

5. Discussion and conclusion

The automotive industry in Mexico occupies an important position, both economically as well as socially, regardless of the fact that the country follows a semi-peripheral model (Domanski et al. 2014) with no domestic auto assemblers. More a than a million people are employed by suppliers and final assemblers makes the issue of automation and digitalization a critical issue for the future of the industry. On one hand, and as indicated at the beginning of this document, automation, robotization and digitalization have been implemented in OEM plants in Mexico, although at different speeds and magnitudes. On the other hand, employment has increased, with expectations of further growth due to the projected increase in EV production in Mexico, the expansion of companies such as those studied, or the enthusiasm for nearshoring and its "enormous potential" (Garrido 2022).

Mexico has a highly specialized automotive industry. Apart from a few large Chinese companies, practically all OEMs have plants in Mexico, as do most global auto parts suppliers. Although the speed of transformation is slower in the car industry in Mexico than it is in the United States or China, automation and digitalization are being implemented in different regions across the country. The adoption of state-of-the-art technologies in the sector has become a first-hand necessity for companies wishing to remain competitive.

The main objective of this research was to understand the implementation of automation and digitalization processes in the manufacturing industry in Mexico and their effects on employment including gender dimensions, and labour processes. We selected two OEM plants from the automotive sector that are implementing new technologies, albeit at different stages and degrees of development. Case studies of the Toyota-Guanajuato and Ford-Hermosillo plants were taken as sample-cases for this study.

The general conclusion of this research is that automation, robotization and digitalization in the plants under study have not been associated with worker unemployment. This was echoed by a recent study, based on French data, that came to the same general conclusion regarding the impact of automation in global manufacturing plants (Aghion *et al*. 2022). Our findings indicate that, despite constant technological change with the implementation of new automated machinery, new tools, new generation robots and technologies associated with Industry 4.0, fundamental transmutation is more likely to occur when new vehicles are incorporated, and platforms for the assembly of these units, are replaced. In model change processes, platforms are transformed, creating opportunities for the adoption of new technologies. In addition, companies take the opportunity to give vacation time to workers, and are thus able to carry out technological replacement, work reorganization, and training programs, etc. This study also shows that companies take advantage of the opening of a new plant or the major expansion of an already established one, to implement new technologies and best practices available on the market. Thus, **production capacity expansion and platform changes, usually associated with increases in productivity and efficiency, are key drivers of automation and digitalization.** The increase in productivity in the cases studied has not only implied the adoption of new technologies, but also maintaining consistency and problem solving in a continuous flow process. In this sense, the quality and continuous training of workers, in collaboration with machinery, equipment and tools, are key in this process. This combination of elements are drivers of automation and digitalization in the plants selected for case study.

According to our study, **the trajectory of Ford Hermosillo shows that periods of platform change and the corresponding implementation of greater automation and digitalization to manufacture new models, have not displaced people**. It should be remembered that HSAP has been operating in Mexico for 36 years, and the volume of vehicle production has increased substantially since then. Workers affected by the technology and who are not needed in the new positions and/or work tasks, are relocated and receive new training. Similarly, workers who remain in their jobs also undergo training to perform their work efficiently and ergonomically with the new technologies. Companies in Mexico are obligated to implement equipment and tools that provide greater safety at work.[30] They also seek to maintain employee satisfaction and worker permanence, as job availability and turnover rates are relatively high in the regions where these plants are located. In this sense, **occupational health and safety is also an important driver of automation and digitalization**.

[30] Official Mexican Standard 035 and 036 issued by the Ministry of Labor and Social Welfare regarding the identification and prevention of psychosocial risk factors in the workplace (NOM-035) and ergonomics standard (NOM-036) are mandatory and were published in the Official Journal of the Federation on October 23, 2018, and November 23, 2018.

Table 3 clearly shows the consistent increase in demand for vehicles, with a yearly increase in production volume, the number of robots, and the number of employees for the period 2021-2023. **In accordance with the evidence collected, we therefore maintain that the arrival of new models and the implementation of new technologies expands business without reducing employment**. On the contrary, the workforce increases, and there is no evidence that the volume of employment in the Mexican case will decrease as a result of automation and digitalization in the OEM plants studied. Similarly, in the case of recently established companies and/or those with a planned expansion, such as Toyota Guanajuato, we found that the incorporation of new technologies does not imply displacing workers out of the company, but rather, improving the digital skills of some technicians and engineers, and relocating displaced employees within the plant.

However, the increase in productivity, technology and employment is not even. As evidenced by the data presented in table 3, as production capacity expands, new jobs are created, and the technological area is strengthened. A virtuous circle appears to exist. Despite this, it is important to highlight certain nuances, such as the fact that workers have not been displaced, but the labour intensity of production changed in the plants. In addition, people may not be laid off, but there may also be fewer new hires, which means lower employment elasticity of growth in these companies, as a result of new technologies, and the high number of supplier staff working within the firms analysed. Based on the information provided by the companies (table 3) we identify two patterns for this post-Covid era:

- Relatively slow productivity increase, with greater technological intensity, and less employment growth at Toyota. While the number of robots per worker is increasing (39 per cent from 2021 to 2022 and will reach 97 per cent in 2022-2023), the rate of employment increases more slowly (0.9 and 20.6 per cent, respectively). Productivity increased 37 per cent from 2021 to 2022 and will be reduced to -26 per cent due to the learning curve for the entry of the new Tacoma model.[31]
- High productivity increase, with constant technological intensity, and high employment growth at Ford. While the number of robots per worker is decreasing (-15 per cent from 2021 to 2022 and -21 per cent in 2022-2023), the rate of employment growth is increasing (from 18 to 29 per cent). Productivity increased 50 per cent.

In other words, and as we have noted previously, in the two automotive companies under study, new technologies have not been associated with job displacement. This, in itself, is a major finding. A second important finding is that the technological, employment and productivity configuration is different in each company. Therefore, as long as the demand for vehicles made in Mexico continues to increase, it is likely that the virtuous cycle will continue, but with different paths depending on the strategy of the companies.

▶ Table 3. Production, employment and robots by company, 2021-2023

Company	Year	Vehicles production	Total employment	No. of Robots	Robots per worker	Vehicles per worker
TMMGT	2021	100 000	2 233	127	0.06	44.8
	2022	138 000	2 252	176	0.08	61.3
	2023	123 000	2 717	347	0.13	45.3
HSAP	2021	167 000	2 870	941	0.33	58.2
	2022	252 000	3 400	941	0.28	74.1
	2023*	383 000	4 370	941	0.22	87.6

Note: * forecast.
Source: Own elaboration based on companies' information.

Companies often decide to introduce new technologies as a strategy to reduce risks at work and to lighten activities carried out by the workers. While this is associated with an ergonomic perspective, it is also a response to the increased intensity of work resulting from increased productivity. As was noted by an interviewee at Ford Hermosillo:

[31] In 2023 the Tacoma model will change completely. The new model (920A) will start production in November and includes hybrid versions. This is a major shift with platform change. Normally, with the entry of new models there is a start-up curve, and the production rate is reduced, with fewer vehicles produced temporarily.

> *"[…] The trade-off was that to increase production capacity, the robots took most of the jobs that was done by people… The workload of the people got reduced, but the quantity of the cycles done per hour increased and that allowed us more productivity". (Stamping manager, HSAP)*

The implementation of new tools, equipment, and automation, especially in the final assembly line, also favours the inclusion of women in the workforce. Although this is a traditionally male-dominated work environment, there is a clear intention to hire more women for production processes, and the implementation of new technologies ensures that work is both less physically strenuous and safer. Currently, a little less than a quarter of total production workers are women, but this proportion is expected to increase in both plants soon.

In general terms, this positive trade-off between increased automation and increased employment, training, and workplace safety, only works if demand for vehicles in Mexico continues to grow. The projections for car sales for the coming years and the high dependency on the US market suggest that while the geographic footprint of ICE vehicle production remains in North America (Dziczek 2022), more hybrid and EV production should also occur. Other authors have estimated that the impact of capital investments on employment, including modern automation technologies, is positive when companies are exposed to import competition, even for unskilled industrial workers, due to business-stealing across countries (Aghion et al. 2022). This general finding reflects the cases of TMMGT and HSAP analyzed here well, as, despite their solidity in the region and their high levels of competitiveness, they still need to compete for new projects in order to maintain their upgrading trajectory.

Finally, based on the interviews and the plant visits, it appears that neither the cost of labour nor labour conflict in Mexico are drivers of automation and digitalization. In the two companies studied, labour costs are extremely low in relation to North American affiliates, and Mexican unions are highly collaborative. Unilateral policies by MNEs in determining technology and labour conditions are a characteristic of the Mexican semi-peripheral system of integration with the United States, which has been based on the absence of freedom of association and collective bargaining, and low salaries (Bensusan and Carrillo 2021). Nevertheless, the labour situation is changing due to conditions imposed by the USMCA and the current Mexican labour reform (Garcia et al. 2021).

When comparing the Toyota's central region facility and Ford's northern plant, important similarities and differences can be identified. In relation to the common aspects directly or indirectly associated with new technologies, the following are highlighted:

- *Automation.* When these plants were initially established, the best technologies available were implemented. Regardless of the start date of operations, Ford Hermosillo (1986) and Toyota Guanajuato (2019) are currently characterized by state-of-the-art technologies. Their stamping, bodywork, and painting areas are highly automated, and include new generation robots.
- *Digitalization.* Both plants have I4.0 projects. Ford has developed a I4.0 vision and collaborative robots, while Toyota has a I4.0 technology committee and is implementing artificial intelligence projects.
- *Production platform.* Both have a single platform, although Ford has greater flexibility to assemble two very different models.
- *Role, expansion and employment*. Both plants are mandated (by their headquarters) to produce their models (Tacoma, Bronco, and Maverick) for the entire world. No other plant produces them.[32] Both plants also have expansion programs (for 2022-23): 40 per cent greater production capacity at Toyota, and a third shift at Ford. Both plants are highly labour intensive (engaging between 2.2 to 3.4 thousand employees) and this appears unlikely to change in the short term, particularly if, as this study has shown, there is no labour displacement and new jobs become available. In both TMMGT and HSAP, new technologies (machines, robots, equipment) complement worker tasks without generating tension, at least not explicitly.
- *Inclusion.* The participation of women in employment is increasing. They currently comprise 27 per cent of the workforce at TMMGT and 18 per cent at HSAP. Gender inclusion is especially evident in the most labour-intensive area, i.e. final assembly, where the input of ergonomic and digitalizing equipment goes beyond automation. In addition, HSAP plans to increase the participation of women to 30 per cent in 2023.

In terms of differences associated with technologies, the following were noted:

[32] The Tacoma model is produced only in Mexico by the two Toyota plants established in the country: Tijuana and Guanajuato.

- *Production.* Although in 2021 TMMGT and HSAP produced similar amounts of vehicles (more than 100,000 units per year), differences skyrocketed in 2022. The Ford Hermosillo plant expected to produce more than 250,000 units by the end of 2022, in sharp contrast to 138,00 units by Toyota Guanajuato. This growth is associated with the new model of vehicle.
- *Robotization.* TMMGT has far fewer robots (176) than HSAP (941). Currently (2022), for every robot there are 15.6 employees at Toyota and just 3.6 at Ford. This difference is clearly observed in bodywork, the area that traditionally has the most robots in automotive assembly plants: while for each robot there are almost six employees in TMMGT, there are only 0.8 in HSAP (in 2021). In other words, Ford has more robots than people in this area. The differences in robot-to-worker ratios at plant level in 2022 (5.3 times more robots in Ford than in Toyota) are not offset by differences in production (1.8 times more vehicles in the former relative to the latter).

The best explanation that we found for this gap is twofold. First, productive capacity is disparate. Ford's productive capacity is higher than Toyota's. HSAP already has the capacity to produce more than double of what it currently produces and with the third shift this volume will increase further (see table 3). Also, their two vehicle models involve more complexity and more robots.[33] Second, organizational strategies associated with corporate vision and practices differ. Although both companies implement lean manufacturing as a productive model, each has developed their own path. Toyota is highly committed to eliminating overproduction, obsessed with quality, and invests less in new model launches.[34] Less than 75 per cent of welding points are made by robots. Thus, Toyota appears to be more restrained when it comes to automating. Ford has a more aggressive approach to automation, with 100 per cent of welding points done by robots, and it pushes harder to increase productivity. We suggest that the automation strategy of each company is linked, on one hand, to their Japanese or American management culture, and on the other hand, to their productive model (TPS is leaner than FPS). All seems to indicate that HSAP seeks to increase productivity while TMMGT seeks to boost human talent.

- *Ecosystem linkages.* Toyota has a good relationship with the Autonomous University of Queretaro. Out of this cooperation, engineer work teams have been built for the development of I4.0 projects to solve technical problems in the company. Despite Ford´s extensive trajectory in Hermosillo, the company's links with local universities are more informal. Likewise, while the state governments initially supported both plants, currently, the Guanajuato government is more active in this regard than the Sonora authorities.

Finally, both the information obtained, and the opinions expressed in the interviews with personnel of both plants show that the implementation of automation and digitalization in manufacturing processes has not been a threat to workers in terms of dismissals. On the contrary, we found a positive impacts on employment (new hires) and on labour dynamics:

- Increased female employment. Considering that automotive OEMs in Mexico have traditionally been characterized by employing mostly men, it should be noted that equipment, tooling, collaborative robots, and workstations have been transformed to facilitate the work of women and men. We suggest that, together with digitalization, new technologies have contributed to inclusion.
- The process and organization of work, as well as job quality, have been impacted. Automation reduces time, burden, and risk for workers, minimizes material waste, and increases precision and production capacity.
- Automation has favored public-private institutional cooperation for knowledge-intensive technological projects, especially with the education sector.

Nonetheless, interviewees highlighted important challenges:

- External events to the industry[35], disruptive or cyclical, create economic uncertainty which poses a challenge for new investments in technological upgrading, and may involve the dismissal of workers.
- The increases in production volume and productivity have implications in terms of maintaining consistency, the need for changes, overtime, and shifts increases.
- The challenge of greater analysis or better use of data generated by new technologies (in HASP).

To conclude, we found no open resistance, opposition, or reluctance on the part of workers nor the unions to automation and digitalization in either plant. Interviews revealed that employees with extensive experience in the companies studied, either engineers or technicians, play an essential role in mediating and supporting adoption processes and ensuring the

[33] Each model has three different versions.

[34] Excessive production resources, overproduction, excessive inventory, and unnecessary capital investment.

[35] Such as wars, pandemics, or natural disasters.

correct application and use of technologies. Engineers responsible for introducing new technologies have also noted an enrichment of tasks and in particular, a significant improvement in digital skills, as we have shown in TMMGT regarding the I4.0 projects and their collaboration with the UAQ university.

Corporate policy, emanating from the countries of origin, does not, at first, seem to be that different, as both plants, Japanese and American, compete in their own niches to attract business, be competitive and the best in their area of specialization. Consequently, both companies plan to elevate the organizational and technological capabilities of their employees. The president of Toyota, for example, mentioned that there are patents pending that were developed by local engineers committed to innovation. Notwithstanding this, our findings shows that Toyota Guanajuato is leaner than Ford Hermosillo; but no more productive. This suggests that the country of origin has a significant influence on organizational performance associated with the implementation of new technologies and their impact on employment.

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▶ Annex A: Establishment profiles

▶ Table A1. Toyota Guanajuato

Basic information about the establishment	Name of the company/establishment	Toyota Motor Manufacturing de Guanajuato (TMMGT)
	Type of business entity	Toyota manufacturing plant
	Name of corporation	Toyota Motor Corporation
	Geographic location	Municipality: Apaseo El Grande State: Guanajuato Country: México
	Sector of economic activity	Automotive industry
	Year of establishment	2019
	Number of employees	2 233
	Type(s) of goods/services provided	Production of pickup vehicles, namely Tacoma D-cab, and Tacoma C-cab
	Main market	97% export (95% to US and 2% to Canada)
	Annual revenue for the whole company	$263.7 billion (Toyota Corporation, 2021)
	Form of employee representation within the establishment	Union: *Sindicato de Trabajadores de la Industria Metal Mecánica, Automotriz, Similares y Conexos de la República Mexicana* (SITIM-CTM)
Information on adopted technology	Year when technology was introduced	2020
	Reason(s) for technology adoption	Safety Quality Cost savings
	Application areas	Stamping, Bodywork, Painting
	Main purpose/ use of the technology	Offer solutions to technical problems
	Maturity level in the uptake of technologies	High. Workers are skilled, with formal education and in-house training

▶ Table A2. Ford Hermosillo

Basic information about the establishment	Name of the company/establishment	Hermosillo Stamping and Assembly Plant (HSAP)
	Type of business entity	Ford manufacturing plant
	Name of corporation	Ford Motor Corporation
	Geographic location	Municipality: Hermosillo State: Sonora Country: México
	Sector of economic activity	Automotive industry
	Year of establishment	1986
	Number of employees	3 400
	Type(s) of goods/services provided	Production of Bronco Sport SUV in four options and the Maverick Truck in three options
	Main market	Bronco: 94% US, 2% Mexico, and 4% South America Maverick: 82% US, 10% Canada, 3% Mexico, 4% South America, and 1% Others
	Annual revenue for the whole company	$136 billion (Ford Motor Co., 2021)
	Form of employee representation within the establishment	Union: *Sindicato Nacional Progresista de Trabajadores de Ford Motor Company y de la Industria Automotriz*, CTM
Information on adopted technology	Year when technology was introduced	2004-06; 2010-11; 2020. Technological changes occurs each time the platform changes
	Reason(s) for technology adoption	To increase production Maintain consistency Prescriptive maintenance (robots make automatic self-reports) Quality Safety
	Application areas	Stamping, Bodywork, Painting and Assembly
	Main purpose/ use of the technology	Increase the speed and consistency of production
	Maturity level in the uptake of technologies	High. Workers are skilled, with formal education and in-house training

Source: Authors, based on company information.

▶ Annex B: Information on interviews and fieldwork

TMMGT

On December 1, 2021, the research team visited Toyota Guanajuato. Protocols, a plant tour and interviews were given by a total of ten people, four of which were managers.

The visit's programme was the following:

- Arrival at the plant, including security protocols for visits and COVID-19.
- Presentation of the Program "Comite Nuevas Tecnologias".
- Plant tour (two hours)
- Lunch break
- Presentation "Program Fresh Engineers"
- Interview with the president of TMMGT

After the first visit to Toyota, the researchers requested a second visit for interviews with nine employees, and a formal process of approval began. TMMGT asked for a formal request and to have access to the interview guidelines. The researchers signed an agreement, and were allowed to conduct and record the interviews. The research team was requested to conduct all interviews in up to two days, with interview duration no longer than 30 minutes.

TMMGT's management selected those who would be interviewed, in accordance with the profiles requested by the research team. The researchers also interviewed three government representatives who participated in the negotiation for locating the plant in Guanajuato. All interviews were conducted in person.

Later, based on the recommendations of the international project managers, the research team asked TMMGT for additional information, which was generously provided.

▶ Table B1. Second phase interviews at TMMGT

	TMMGT	Public Servants
Managers	6	3
Engineers/technicians	4	
Union representatives	1	
Total	11	3
Women	1	
Average interview duration	35.2 min.	52 min.
Number of interview days	4	1

HSAP

On December 10, 2021, members of the research team visited Ford Hermosillo and had face-to-face interviews with three managers: plant manager, human resources manager, and safety and health manager. The researchers explained the scope and relevance of the project and asked about the possibility to engage the plant in the project. The plant manager requested a formal letter, and the team was later given authorization at the corporate level.

On March 24, 2022, members of the team were informally allowed to visit HSAP. The four-hour tour included protocols, a guided visit and interviews with two managers, from the body and paint departments.

The site visit's programme was the following:

- Arrival at the plant, including security protocols for visits and for COVID-19.
- Tour of the bodywork area

- Tour of the painting area

During the plant's visit, the tour started at the bodywork area, where the researchers observed the construction process of the vehicle from the beginning. The different configurations of the robots' tools could be observed in operation while they performed welding and applied resins, among other tasks. It was explained to the researchers that the robots are of a new generation and that they were completely updated for the launch of the platform of the new models, replacing entirely the previous robots. The bodywork area had been expanded to increase production capacity due to the forecasted demand for the two models produced at the plant. In the stamping area, the team was shown a new press for metal parts, introduced due to the need to increase production capacity and to be able to make quick changes. This equipment replaced three pieces of equipment with the previous technology. The second part of the tour went to the painting area, where the research team observed new generation robots in the paint application process. The facilities are completely new, the area was redesigned to accommodate larger models. It was also possible to observe manual activities, where workers' skills are decisive in achieving quality output. The areas visited are the most automated in the plant.

On September 9, 2022, team members made a second visit to the plant. The researchers were attended by the safety and hygiene supervisor, and toured the final assembly area and observed the automation processes and the design of the workstations. There are few robots in this area, but there are automation processes for handling information for technicians and for the material supply system for assembly lines. The changes made to the workstations involved modifying the dimensions, tools, and handling of materials, specifically to include women. These changes were made for the outgoing platform, CD4, but were maintained for the new platform, which is a larger vehicle. In this part of the vehicle construction process, the work is more physically demanding, and the worker must walk next to the unit while the components are installed.

Interviewees were selected by management in collaboration with the research team. Special care was taken to include women and to select employees which had been with the company long enough to experience technological upgrading. Later, based on recommendations from ILO officials, the research team conducted additional informal interviews to fill gaps in information.

▶ Table B2. Second phase interviews at HSAP

	HSAP
Managers	4
Engineers/technicians	4
Union representatives	1
Total	9
Women	3
Average interview duration	59.9 min.
Number of interview days	3

ilo.org

International Labour Organization
Route des Morillons 4
1211 Geneva, Switzerland

European Commission
Rue du Champ de Mars 21
1050 Brussels, Belgium