MAGICIAN

AUTONOMOUS DEFECTS DETECTION AND REPAIR IN MANUFACTURING

PROJECT NO

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MAGICIAN

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EXECUTIVE SUMMARY

This deliverable defines the initial user requirements for automation and robotics in car manufacturing by applying a human-centred and socio-technical approach. Based on desktop research and a baseline study conducted before the MAGICIAN system trial, it explores how automation and robots may interact with existing work practices and organisational structures. This document identifies preliminary considerations for the MAGICIAN system while also reflecting on broader requirements for automation developments that may extend beyond the project's scope. These initial requirements will be iteratively tested and refined as the project progresses.

More specifically, D2.2 presents a detailed analysis of car manufacturing work environments, drawing on baseline study findings to explore current processes, organisational structures and how production line workers, developers and managers conceptualise robotisation and automation. It outlines how robotic systems may be integrated into car manufacturing and formulates initial user requirements based on observed possibilities, constraints and anticipated human-robot interactions. The findings will inform the development of the MAGICIAN system. D2.2 also identifies key aspects of robotic platform design, including user interaction, system adaptability and integration into manufacturing workflows. The insights will feed into the technical specifications of D2.3 and contribute to broader technical advancements in WP3 (Data Acquisition and Skills Learning) and WP4 (Robotic Platform and Interfaces). Additionally, the initial user requirements will support the evaluation framework in WP5 (Integration and Performance Analysis), particularly regarding user acceptance, trust and satisfaction.

By outlining initial user requirements, this document provides a foundation for the development and validation of the MAGICIAN system that aligns with existing work environments and stakeholder needs. It also presents preliminary ethical and social considerations for future automation and robotisation developments beyond the project's immediate scope.

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ACRONYM	DESCRIPTION
D	Deliverable
EC	European Commission
WP	Work package
T	Work task

1 INTRODUCTION

1.1 NOTES ON THE PROJECT

The MAGICIAN project (iMmersive leArninG for ImperfeCtion detectIon and repAir through human-robot interactioN) explores the intersection of human capability and robotic precision. Rather than simply improving efficiency, MAGICIAN asks how immersive learning, AI-driven robotics and human-centred design can actively shape the relationship between humans and machines in industrial settings.

At its core, the project challenges conventional assumptions about automation, particularly the idea that machines should replace human skills rather than complement them. It foregrounds the role of workers, not as passive operators but as essential contributors to the learning and adaptation of robotic systems. By designing technology with and for people, MAGICIAN seeks to create not only more responsive and reliable industrial processes but also working environments that support well-being, agency and meaningful collaboration.

1.2 SCOPE OF THE DELIVERABLE

This deliverable, D2.2 Initial User Requirements Report, is part of Work Package 2 (WP2), under Task 2.2: User-Centred Design. This report aims to establish the initial user requirements that will inform the design of robotic systems within the MAGICIAN project. Rather than treating these requirements as fixed technical specifications, this report and initial user requirements acknowledge that user needs evolve in response to the realities of human-robot interaction, workplace dynamics and socio-technical contexts.

This deliverable brings together findings from various research activities, which included:

- Desktop research: A literature review on human-robot interaction (HRI), addressing worker satisfaction, trust, privacy, equality and skill development in collaborative robotic environments.
- Field studies at TOFAŞ: Ethnographic observations and interviews with production line workers, managers and developers to assess current working conditions and real-world challenges in defect detection and reworking.
- NASA Task Load Index (NASA-TLX) assessment: A workload analysis to evaluate the cognitive and physical demands imposed by current work processes.
- Gender analysis: Examining the current distribution of roles and responsibilities.

The insights from the research activities define the initial user requirements for robotic defect detection and reworking systems. These initial user requirements will be tested and refined through participatory workshops and demonstrator trials in real working environments and will thereby be iteratively updated based on user feedback.

1.3 RELATION TO OTHER DELIVERABLES

In terms of D2.2's relation to other work packages and tasks, D2.2 builds on D2.1 and summarises the empirical findings from the baseline study and desktop research by laying out the foundations of the MAGICIAN project's human-centred design development.

Deliverable 2.2 defines the initial user requirements for meaningful work in car manufacturing when automation and robots are introduced, considering both technical and non-technical requirements through a user-centred design approach. A core aspect of this deliverable is the integration of a human-in-the-loop perspective, ensuring that automation and robotic systems are designed to complement human skills rather than replacing them.

From a socio-technical perspective, we highlight not only the structural, organisational and technical requirements for future meaningful work in car manufacturing but also identify the initial robotic platform user requirements and architecture (D2.3). D2.2 supports all tasks related to technical developments carried out in WP3 – "Data Acquisition and Skills Learning" – and WP4 – "Robotic Platform and Interfaces". A key focus in D2.2 is on how human operators interact with automated systems, ensuring that knowledge transfer, learning mechanisms and ethical considerations are embedded in system design. Furthermore, D2.2 is directly linked to the test and validation activities conducted in WP5 – "Integration and Performance Analysis", particularly in relation to the evaluation of user acceptance, trust and satisfaction.

1.4 STRUCTURE OF THE DOCUMENT

The remainder of this document is structured as follows:

- Chapter 2 describes the human-centred activities conducted so far in WP2, including desktop research, field studies at the TOFAŞ factory, and a gender analysis of the case organisation. It provides insights into human-robot interaction and its impact on various aspects of the workforce, such as satisfaction, trust, privacy, equality, and skill development.
- Chapter 3 introduces personas and user journeys based on a user-centred design approach. It presents different user profiles, including production line workers, managers, and developers, capturing their experiences, needs, and interactions with automation and robotics in the workplace.
- Chapter 4 compiles the initial user requirements derived from the research findings. It details specific requirements related to worker satisfaction, trust, privacy, skill development and gender-sensitive design to guide the development of the MAGICIAN system.

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- Chapter 5 concludes this deliverable by presenting final remarks and key findings.

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2 DESCRIPTION OF ACTIVITIES

2.1 DESKTOP RESEARCH

To inform this section, literature reviews were conducted with regard to the experiences humans currently have with robots and AI, highlighting a range of key ethical dimensions.

2.1.1 HUMAN ROBOT INTERACTION AND IMPACT ON WORKERS' SATISFACTION

The reviews found that HRI in work settings has a mixed impact on worker satisfaction. Notably, the research shows that collaborative robots (co-bots), or 'robot colleagues' appear to mostly satisfy workers if they have some particular flaws and failures that workers then can intersect with and contribute to. This has been found across different work contexts, such as AI-tool supported knowledge work in healthcare [13] and social work [67], or robotic process automation in banking [3, 19]. In industrial settings, research has shown how workers are satisfied with co-bots if these fit neatly into their working routines, such as allocating to them the tasks of repair and maintenance [6].

On the other hand, workers are less satisfied if they need to re-organise their many routines [22], if the robot threatens their job professional scope in the sense of being capable of being replaced [59], or if it adds additional work pressures and burdens for workers to take care and attend to the robot [90, 69, 19]. In platform work settings, robotic applications are shown to lead to enhanced uncertainties due to lacking transparencies about the decision-making processes by the company management and the increasing absence of 'human' relationships [37, 73, 109]. At the same time, research has shown that robots are also appreciated in work settings if they benefit workers by freeing up time [16, 3] and reducing exposure to dangerous touch [6, 7]. A study that evaluated workers' preferences in human-robot interaction in industrial assembly systems settings concluded that workers appreciate if they can classify, divide and assign tasks, thus deciding themselves which tasks they allocate to the robot colleague and which they will perform themselves. This increases their satisfaction as well as perception of control and competence [97].

In sum, the literature review illustrates that HRI in work setting is ambiguously related to worker satisfaction, bearing the potential of both enhancing wellbeing and safety, while also posing risks of threatening worker's identities, adding invisible work and unnecessary stress.

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2.1.2 HUMAN ROBOT INTERACTION AND IMPACT ON TRUST/COMFORT

Trust and comfort are key ethical dimensions also frequently mentioned in the EU framework for AI ethics [42] and its recent legal action to turn into policy a range of core societal concerns with the rapid advancement of AI and robotics [39]. At the same time, literature is unclear about the precise nature of what is meant by 'trustworthy', including associations with reliability [62], democracy [29] and the ensuing relationship between co-bot and humans [102]. As an example, the AI framework for 'trustworthy AI' hierarchically positions all other ethical principles as sub-dimensions of trustworthiness [39].

In the context of robotic applications in work settings, then, the literature review indicates that newly introduced robotic devices usually pass through stages, similar to the domestication process [101], where initially they are met with suspicion, people then put significant effort to make sense of the robot, and later on become more intrinsic to a newly re-organised work setting. For example, newly introduced robotic solutions, like for example the Da Vinci robot into surgery, are shown to re-organise established working routines, re-distributing new work accountabilities and responsibilities among nurses, residents, and surgeons themselves [22, 100]. Studies show that this requires first the establishment of new trusting relationships and attunements across different work settings [121], often requiring several rounds of engagement [54], which human workers may experience as rather uncomfortable, time-consuming and tiring [77, 90, 24].

Along this process, workers may also become accountable for new choices and resolving robot-related ethical dilemmas. Care workers, for example, are shown to frequently make choices now of whether and to what degree to engage robots with older care recipients [81], hence experiencing emotional burdens. Studies show how these issues are transferable across contexts, with collaborative robots across a range of settings creating new moral dilemmas, ranging from janitors keeping airports safe with collaborative cleaning robots [59] over customer service personnel dealing with ethical issues induced by AI chatbot recommendations for building advise to bank customers [19], to healthcare professionals collaborating with machine-learning tools [106]. In that regard, it should be noted that plenty of research appears to point to the direction that a lack of transparency is a key issue, creating anxieties and uncertainties among workers [87, 8, 55, 119].

Especially in the manufacturing context, trust is seen as an underlying and enabling factor for the successful collaboration with robots [23, 96, 98]. Communication plays an important role for building trust, both on an organisational level (communication around introduction, processes, protocols and procedures regarding co-bots) and on a practical task level (information exchange between worker and co-bot to achieve tasks) [20, 98]. Transparency and training that covers aspects related to the potential benefits and limitations of co-bots can contribute to a deepened understanding and positive outlook of human co-workers [33]. Several studies highlighted the collaboration benefits from a functioning communication between worker and co-bot, which means that the worker can easily read and understand the current status and intention of the co-bot while the co-bot can sense and adapt to the workers' actions and behaviour [4, 76, 98, 120].

Generally, studies show that robots are trusted more if their functions are clear and transparent [57, 45, 86], while comfort is greater if robots actually enhance working routines rather than adding added work pressures. Enhancing working routines, though, not only means functional enhancement, but also a seamless fit with work, and no added work responsibilities on workers for the robots functioning [6, 7] – key aspects that are relevant also to the management introducing co-bots.

It is important to acknowledge that several studies addressed that the lack of trust and comfort can result in the risk of creating a negative impact on motivation and performance that can potentially lead to avoiding robots and their potential altogether [76, 120].

2.1.3 HUMAN ROBOT INTERACTION AND IMPACT ON PRIVACY

Generally, HRI has a negative impact on the workers' privacy. Plenty of studies show how, for their functioning, data gathering and processing is essential for robots to engage and respond in their interaction with humans [28, 105, 86]. Due to the technical make-up of robotic solutions, hence, it is clear that there will be an infringement of privacy.

At the same time, the review indicates that there is a huge potential for moderation. That is to say, privacy impacts can be reduced through a range of measures, such as anonymising data, having responsible data management mechanisms and otherwise allocating agency to workers to have a say and choice in making informed privacy decisions. Namely, the review indicates that workers are willing to 'trade' with their privacy if they are receiving enhanced agency, transparency and other work-related benefits [88, 94]. Studies show that privacy concerns appear most prominently to humans when they experience a lack of transparency on the robot's functioning [78, 54]. Across a range of settings of everyday life, on the contrary, studies show how humans are generally open to giving up some personal data in exchange for improved work process efficiency [25], support [103], networking [99] and comfort [74].

In other words, privacy concerns can well be alleviated by means of first, providing workers with transparent information about the functioning of the robot that clearly describes the type of data that is collected, without overburdening them, and second, offering workers a choice regarding the type of data that they are willing to share in exchange for certain benefits.

2.1.4 HUMAN ROBOT INTERACTION AND IMPACT ON EQUALITY

A few studies show that robotic solutions can have a negative impact on equality. For example, the application of AI-powered language tools and chatbots in learning settings has been related to a reduced justice and potentials for discrimination, wherein the applicability of chatbots can be delimited to certain groups of individuals, risking to exclude people from certain societal groups with other language proficiencies or cultural

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backgrounds [57]. Certain robotic applications can also signify societal stigmata by means of their sometimes limiting or patronizing design [69, 1]. Such issues can also lead to issues with democracy and justice, such as in the case of applying robotic software for citizen surveillance [83]. The issue here can be that there may be implicit biases in AI-powered systems, based on potential stereotypes by its designers, thereby raising issues of diversity and the avoidance of discrimination in that regard [84]. A notable remark in this regard is that if discrimination occurs, then research shows that such effects are often much more implicit rather than explicit [108], again suggesting link between discrimination and transparency aspects.

An aspect related to equality is democracy, which research shows can also be negatively impacted by HRI. This is mostly related to aspects of work hierarchy and organization, where plenty of studies show how workers are constituted as relatively powerless when dealing with new robotic solutions and devices [22, 100, 73, 109]. Robots introduced into work settings from top management can cause more unequal power relations, which leaves workers with no other option but to reconcile the ensuing power imbalances [3, 6, 7, 67]. Research shows that workers may also feel de-humanized through certain robotic ways of governance [119]. Robots may also encourage workers themselves to become less moral, or more patronizing, such as in the case of care settings [24], or banking [19]. Liu and Graham [68] furthermore show how this is again linked to a lack of transparency, which can lead to sustained surveillance, heightened control and thereby a threat to democracy.

In summary, when introducing co-bots into work-settings, it is pivotal for management to be mindful of its impact on equality and work hierarchies. There is a real risk that collaborative robots may enforce less democratic and non-participative modes of working due to their tendency of being imposing and materially deterministic. To remedy this and ensure that equality is maintained, any co-bot introduced should be accompanied with a practical opportunity for worker participation and choice, as well as clear communication from management and involvement both from management and worker unions.

2.1.5 HUMAN ROBOT INTERACTION AND IMPACT ON SKILLS DEVELOPMENT

The literature shows that skills development is a necessary component of any robot being introduced into work settings [5]. As mentioned before, plenty of studies reveal the intricate ways in which humans need to put in effort to adjust their routines and form meaningful relations with their new robotic partners [22, 3, 45, 54, 67, 93]. It may thus be said that at the very least, robotic applications appear to motivate new work arrangements and skills adjustments [6, 59, 7].

The introduction of co-bots in manufacturing settings can increase automation and influence the daily activities and tasks carried out by workers and thus affect their required skills. One possible effect is related to the replacement or downgrading of skills which means that some of the tasks are either entirely taken over by a co-bot or that they become less advanced and varied. Another possible effect is related to upskilling and the enhancement of tasks and job responsibilities, which means that human workers' capabilities are expanded and become more varied. Potentially, this can lead to more autonomy and increase job satisfaction [36].

A crucial caution here though is that it is not necessarily the robot itself that facilitates learning. Rather, humans themselves have to seek out new ways of engagement and adjust their routines [22, 100, 13]. Often, separate programs have to be made for workers to learn new ways of engaging with the robots [100, 106], causing added work on the parts of human workers [90, 54]. The literature thus indicates that HRI is at best indirectly related to skills development, making it somewhat necessary, but not in itself being sufficient for that skills development occurring. A more concerning aspect is that most skills development appears to occur only in response to fears about being replaced in the current job [3, 19]. That is to say that it is only out of a negative feeling, of the threat of being made redundant, that workers then sometimes desperately try to re-define and re-delineate their professional identities [22, 8, 19].

In sum, hence, HRI appears to indirectly entangle skills development, albeit not in a necessarily positive fashion. Rather, literature indicates how HRI may make skills development necessary, which is then more often than not extra work performed by the human workers, to get attuned to, become responsible of, and more knowledgeable than, the newly introduced robotic solutions. Companies and management thus have to be careful when introducing collaborative robots, to communicate requirements for skills development in an empathetic way, to show understanding for worker concerns and be accommodating of them, by allowing for sufficient time for workers to be re-trained. This also implies the benefits of investing in workers' development rather than resorting to cost-cutting measures and lay-offs, to make use of the workers' tacit knowledge and build on it, rather than to replace them purely based on current functionalities.

2.2 CONCLUSION: DESKTOP RESEARCH

In summary, the desk research involving a comprehensive review of previous empirical research highlights a range of considerations and concerns regarding the impact of human-robot interaction on worker satisfaction, trust and comfort, privacy, equality and skills development. In doing so, it emphasises both benefits and obstacles, as well as key experiential aspects to consider when introducing collaborative robots into work settings – both for management and policy. In particular, we summarise the following five core action points for user requirements based on our critical review of existing literature:

- Counteract threats linked to fears about job replacement by means of adequate co-bot design as supportive roles, and transparent communication about the future vision for workers
- Ensure collaborative robots fit with work routines, reduce any necessary re-work,

and compensate workers in case added labour is expected to adjust working routines and responsibilities; added responsibilities should be clearly defined and acknowledged

- Inform workers about the types of data that can be collected, and offer them a choice for which data they are comfortable with being collected in exchange for particular benefits
- Involve workers in the process of co-bot introduction, provide them with a democratic voice and say, and ensure transparency about the purpose and function of the co-bots
- Accompany introduction of co-bots with empathetic communication, training programs, and a constructive outlook on advancing worker skills

2.3 INSIGHTS FROM FIELD STUDIES AT TOFAŞ FACTORY

A combination of qualitative and quantitative methods was employed to analyse the error detection process at the TOFAŞ factory systematically. This study encompassed direct observational studies to capture real-time human behaviour, interviews with production line workers, managers, and developers to gain deeper contextual insights, and NASA-TLX questionnaires to assess the cognitive workload associated with defect detection. By combining these methods, we aimed to understand how production line workers perceive, classify, and prioritise defects and the strategies they employ to optimise their workflow within the strict timing constraints of the production cycle. This multi-faceted approach helped to understand human factors in defect detection, which is critical for developing robotic solutions that align with human cognitive and perceptual capabilities.

2.3.1 OBSERVATIONS STUDIES

The observations were conducted to study the production line workers' work processes in real-time, to observe production line workers' behaviour, their interaction with materials, and how they maintained workflow during a work cycle.

2.3.1.1 OBSERVATION PROCEDURE

The observations were conducted through direct oversight of the production line workers' work environment (See Figure 1). The observer was always at a safe distance to minimise interference while ensuring detailed observation. A structured notes template was used to collect data and organise the findings. The observations included both quantitative and qualitative data, documenting the number of personnel, work roles, and specific tasks performed.

A total of eight individuals participated in the observations, including three females. The study included observations of two production line workers for approximately three hours during the morning shift (1st shift) at the Bodyshop and two production line workers for about 1.5 hours in the afternoon shift (2nd shift) at the same location. Additionally, two production line workers were observed for approximately two hours at the Press in the morning and another two production line workers for about one hour at the Press in the afternoon.

Figure 1. Image showing during observations.

2.3.1.1.1 WORK ROLES AND TASKS AT THE BODYSHOP DELIBERRA

The production line workers were responsible for inspecting the vehicle's body structure in the Bodyshop, focusing on detecting defects in the sheet metal. Their inspection process combined visual examination with manual manipulation to identify any irregularities. A mirror was used to check ceiling details that were otherwise difficult to see.

One production line worker was responsible for inspecting the vehicle's hood and the front side areas near the wheels. This production line worker also recorded all detected defects, which were verbally communicated by the other two production line workers during the inspection. The documentation was carried out on paper and digitally, ensuring accurate tracking of any identified issues.

The work was performed quickly and efficiently, with a clear division of tasks among the production line workers. Each team member had a defined role, contributing to a structured, streamlined process. Inspection tasks relied heavily on the production line workers' senses, particularly vision and touch, to identify potential defects.

All inspections were conducted rapidly, with the production line workers using both their hands and eyes in a coordinated manner. The hands could move independently to feel for defects while the eyes focused elsewhere, allowing for a more efficient assessment. Additionally, a mirror was used to inspect the ceiling areas, ensuring a comprehensive examination of the entire body structure. The workers' ability to detect irregularities through experience and trained perception was crucial to ensuring high-quality standards in the production process.

Each production line worker carried a marking pen and a stone, which were essential tools in the defect detection process. If a production line worker was uncertain about a potential defect, they lightly sanded the area with the stone to reveal any irregularities more clearly. Once a defect was confirmed, it was marked and coded using the pen. The defect was then verbally announced to ensure that all team members were aware and that it was properly documented and addressed.

The vehicle remained stationary for approximately 50 to 60 seconds during the inspection. If the production line workers completed their tasks ahead of time, the hood-responsible production line worker manually advanced the vehicle to optimise the workflow efficiency. Additionally, a safety system was in place to prevent accidental vehicle movement. If someone stood in front of or behind the vehicle, a designated area with a rubber mat and an integrated sensor detected their presence, preventing the vehicle from moving forward.

During the inspection, doors were also checked, including interior and exterior metal surfaces. The process was carried out with complete focus—no unnecessary conversation occurred, and production line workers only reported their findings. A logbook followed each vehicle, ensuring that all defects and actions were properly recorded.

When a new vehicle model was introduced, a female production line worker initially handled the stamping process. However, it was later clarified that this was a natural task reassignment. The hood-responsible production line worker had identified and conducted a more thorough inspection, which required additional assistance, leading to the role adjustment.

From an outsider's perspective, defect reports often seemed mumbled. They could be announced at any moment, raising the question of how the report-responsible production line worker managed to hear and remember them. When asked about this, the response was that experience played a crucial role. Production line workers immediately recognized the type of defect based on the way it was reported, and depending on who announced it, they instinctively knew its location. Many of these defects were recurring, making processing the information more efficient, what they said were mainly codes.

For van models, a metal rod was installed to lift and reinforce the door, preventing it from being compressed during the painting process. This task was always performed by the production line worker responsible for the left rear section of the vehicle.

2.3.1.1.2 WORK ROLES AND TASKS AT THE BODYSHOP REPAIR

Three production line workers were responsible for repairing the defects identified in the previous inspection stages. Unlike the inspection process, no women were involved in this stage, as repair work was considered physically demanding, leading most to prefer inspection roles instead.

All production line workers wore protective gear, including safety glasses, gloves, long pants, long-sleeved shirts, and arm protection. However, no hearing protection was used in this area.

The repair process involved a variety of tools, including hammers, grinders, screwdrivers, nut-tighteners, and metal plates for bending. Before addressing reported defects, production line workers quickly checked using their hands and eyes to verify the issue. Repairs were conducted within the main workflow, with at least two empty stations left between sections to create space for the repair team. In cases where more significant defects were detected, the vehicle could be moved to the side for more extensive work.

Production line workers also had to assess tool wear during the process. For example, they relied on experience to determine when sandpaper was worn out and replaced it “on the fly” without disrupting their workflow.

2.3.1.1.3 WORK ROLES AND TASKS AT THE QUALITY CONTROL PRESS (LARGER PARTS)

Two production line workers perform inspections, holding sandpaper in one hand and running with the other hand over the surface to detect defects. One production line worker rotates the part while inspecting.

There are six control points, and after inspection, the larger parts are hung on racks. For larger parts, two production line workers are required for handling, whereas smaller parts can be managed by one person.

Every 200th part is examined more thoroughly, which means that one dedicated worker is responsible for conducting thorough quality control, counting all holes, checking if they are correctly placed, and careful inspections focus on detecting damages along the edges and other critical areas. The tools used include a stone, a marking pen, and sandpaper. These detailed inspections take approximately 10 minutes per part.

2.3.1.1.4 WORK ROLES AND TASKS AT THE QUALITY CONTROL PRESS (SMALLER PARTS)

The inspection team consists of one female and two male production line workers. A camera captures images of the parts as part of the quality control process.

Two production line workers handle the control process, with one responsible for hanging the parts. Additional control is performed every 200th part, like the larger parts, with the inspector moving between two identical machines.

No tools are used in this section. Once a batch is completed, a forklift picks up the finished parts. Production line workers visually inspect the parts as a final check.

Extra inspections focus on counting holes, which takes approximately three minutes per part. A proposed improvement is to use the computer vision module of the MAGICIAN co-bot to automate the hole-counting process, which could be applied both on large and small parts.

2.3.1.1.5 WORK ROLES AND TASKS AT THE REPAIR AREA PRESS

Two male production line workers are responsible for repairing defects found in the press stage.

The work environment is calm, with multiple sanding machines hanging in place, allowing production line workers to access them from any position easily. The defects are often repetitive, meaning the same type of issue can occur across multiple parts in a batch.

Various tools are used in the repair process, including hammers, support stones, planers, sandpaper, sanding machines, and manual inspection using fingers or gloves to detect irregularities.

Production line workers wear protective equipment, including gloves, long sleeves, arm guards, and safety glasses. In areas around the Press, hearing protection is mandatory due to high noise levels.

Different grades of sandpaper are used depending on the task. 600-grit sandpaper helps identify defects, while 100-grit sandpaper is used for machine-assisted repairs, as manual use of this coarse sandpaper can cause damage.

There are 6-7 different sanding machines in operation, spread across four workstations to maximize efficiency. If an adjustment is needed at one station, the work can be transferred to the next available table.

2.3.1.2 KEY TAKE-AWAYS FROM OBSERVATIONS

The production line workers' work processes were well-defined and efficiently executed.

Clear task delegation and the use of tools such as mirrors contributed to maintaining quality and precision.

Observing from a distance allowed the natural workflow to be documented without interference.

2.3.1.2.1 COLLABORATIVE YET SPECIALIZED ROLES

Each production line worker and team member is assigned distinct roles, focusing on specific parts of the vehicle or tasks. Example of assigned roles are:

- Roles at bodyshop
    - Left side, top, back

  - Right side, top, back
  - Front, and reporting
- Roles at bodyshop repair
  - Repair worker 1, take on half of the defects
  - Repair worker 2, take on half of the defects
- Roles at press large parts
  - Quality controllers, six persons
  - One responsible to conduct quality control every 200th part
  - Last two persons carry the parts in pairs
- Roles at press small parts
  - Quality controllers, four persons
  - One responsible to conduct quality control every 200th part
  - Last two persons carry the parts
- Roles at press repair
  - Repair worker 1, take on defect of the arrived parts usually the same error is on the same pack
  - Repair worker 2, take on defect of the arrived parts usually the same error is on the same pack
  - Occasionally workers provide help at the bodyshop if needed

This specialization ensures efficiency, but collaboration occurs through fluid communication albeit often subtle, like calling out errors aloud. For example, the production line worker responsible for the hood finishes first and moves on to document and stamp the control process, ensuring that the workflow remains smooth.

The workflow is highly structured, with set timings for shifts, breaks, and quality control checks. There are clear procedures for moving cars through the process, with built-in safety features like sensors on rubber mats to prevent accidental vehicle movement.

However, flexibility is built into the system for tasks like larger repairs or unexpected delays.

2.3.1.2.2 VISUAL AND TACTILE INSPECTIONS

A common methodology across the teams involves a combination of quick visual and tactile inspections, supplemented by tools like stones and sandpaper to highlight and fix errors. Production line workers rely heavily on their hands and eyes, moving them along different paths to identify issues, such as scratches or imperfections in paint or bodywork. There is a mirror which is used to quickly glance at the top of the car. The production line workers showed a high level of pride for their work.

2.3.2 INTERVIEWS

To understand how production line workers, developers, and managers perceive automation and robotics, a series of interviews were conducted. The goal was to try to understand their thoughts, experiences, and attitudes toward these technologies in their respective roles.

A total of 31 individuals were interviewed (five females): twelve production line workers (three females), nine managers and ten developers (two females, five of the developers were from Altinay). The overall average age of the participants was M = 34.8 (SD = 6.08).

The average age and standard deviation for each group were calculated:

- Production line workers: Mean age = 34.5, SD = 5.13
- Managers: Mean age = 40.2, SD = 3.77
- Developers: Mean age = 30.2, SD = 5.03

Prior to the interviews, a set of structured questions was prepared, which can be found in the appendix. These questions were reviewed and approved by TOFAŞ to ensure relevance and appropriateness.

2.3.2.1 INTERVIEW PROCEDURE

The interviews were conducted in a comfortable setting equipped with air conditioning to ensure a relaxed environment for the participants (See Figure 2). Prior to each interview, participants signed a consent form, confirming their voluntary participation and understanding of the interview process.

All interviews were audio-recorded to ensure the accuracy of the data collected. The recordings were then transcribed into Turkish and subsequently translated into English. A researcher with expertise in the subject matter reviewed the translations to ensure accuracy and consistency.

The transcribed data was analysed using an inductive approach to identify common themes and patterns. Initially, researchers from LU independently reviewed the transcripts to identify potential themes. This was followed by collaborative sessions where the researchers discussed and refined these themes to ensure consistency and depth in the analysis. The results of the interviews are summarised and presented under separate headings for production line workers, managers, and developers, highlighting the unique perspectives and insights from each group.

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Figure 2. Example of a location in which interviews were conducted.

2.3.2.2 SUMMARY FROM INTERVIEW WITH THE PRODUCTION LINE WORKERS

The interviews conducted with production line workers at TOFAŞ reveal several recurring themes regarding their experiences with automation and robotics in the workplace. These themes highlight the interplay between technology, human skills, work conditions, and social dynamics. The following eight themes emerged by first going through the transcribed data individually, and then three researchers from LU discussed and combined some of the themes into new ones.

1. **Impact of Automation on Work Environment and Job Roles**

Automation has significantly transformed the work environment. Production line workers observed improvements such as better lighting, enhanced ventilation, and ergonomically designed tools, contributing to higher productivity, better safety, and well-being.

Example of quotes from the interviewed participants regarding the **environmental improvements**: *"Eight years ago, we didn't have such good lighting or a nice working environment. Now we have fans, better lighting, and even a cafeteria renovation."* The improved workplace conditions have made the factory more comfortable. Another example regarding **health and safety services**: *"There's a health service. It's really good. They treat everything. There's even a fire department here."* Workers have access to a wide range of health and safety services

2. **Efficiency and Quality**

Robots are seen as beneficial for increasing efficiency, reducing errors, and ensuring consistent product quality. They detect defects without missing critical points, improving production speed and reliability. However, some production line workers believe robots are slower in specific tasks compared to humans, for example, one of the co-bots which is used for gap measurements between doors. Importantly, while automation supports production, production line workers remain responsible for oversight, defect management, and complex problem-solving, emphasising the irreplaceable role of human judgment.

Example of quotes from the interviewed participants regarding efficiency: *"I used to work with a master doing door measurements and profile adjustments. Then they brought in robots. Now robots do that job."* This shows how human labour is gradually being replaced by robots in certain tasks, emphasising efficiency.

Regarding quality and reducing human errors: "*Robots are faster than humans in my opinion. They increase production efficiency and speed up the process. Also, people can forget things, but robots generally don't have that issue*."

3. **Job replacement**

Automation has reduced physical workloads, especially in spot welding and part-handling tasks. However, it has also raised concerns about job security. Many production line workers expressed fear of job displacement as robots increasingly take over repetitive tasks, reducing the need for manual labour.

Example of comments from the interviewed participants regarding job replacement: "*The disadvantage is that it takes away our jobs. If you replace me with a robot, I'll be removed*." Despite the advantages of automation, there is a persistent fear of job losses.

4. **Skill Development and Learning**

Workers undergo training, both formal (certifications) and informal (on-the-job learning), particularly in defect detection. Over time, they develop a tactile sense of identifying issues, emphasising the importance of hands-on learning. New technologies and tools, such as sensors and automated systems, require constant skill adaptation. Workers expressed the challenge of learning to use new tools while maintaining the craftsmanship needed for quality inspection. The reliance on informal learning and peer guidance underscores the importance of tacit knowledge in maintaining operational quality.

Example of comments from the interviewed participants regarding formal training: "*We get certifications, and those who don't have the authority can't work here. We take exams and go through extensive training because it's hard to develop that touch sensitivity.*" Workers undergo rigorous training to develop the necessary skills for quality control.

Example of quote from the interviewed participants regarding knowledge transfer between workers: "*We learned from our old master who retired. Now, I show these things to the new workers*." Senior workers pass down their expertise to new employees, ensuring the knowledge stays within the company.

Example of quote regarding "learning by doing": "*Over time, as you keep touching the same spot, you get used to it. Eventually, you can tell when something is different.*" This shows how tactile learning is a critical skill developed through experience. It should be noted that the production line workers took great pride in their expertise, demonstrating an impressive ability to quickly identify even the smallest defects simply by feeling the surface with their hands. Their pride shines through their body language and facial expressions, however, some production line workers gave examples:

Example of quote regarding "pride": "*Friends ask how I see things they can't. But my eyes always catch those defects. Even my older son sometimes says, "Mom, please don't look at the cars like you do at TOFAŞ. It's all about hand skills and observation*."

5. **Workplace Collaboration and Social Dynamics**

Despite technological advancements, human collaboration remains vital. Production line workers frequently engage in teamwork to address defects, share knowledge, and support each other during complex tasks. Strong social bonds and team spirit contribute to a sense of belonging, with many describing their colleagues as an extended family. This collaborative environment helps balance the impersonal nature of automation.

Example of quote regarding teamwork in defect detection: "*We work with two colleagues, one on the right and one on the left side of the engine hood. When a defect comes up, we collaborate to solve it.*" Teamwork ensures that no defects go unnoticed.

Example of quote regarding use of digital communication tools: "*We have WhatsApp groups where they send us pictures of previous defects. We see them, and our supervisor informs us about the defects*." This illustrates how digital tools streamline defect reporting between different groups and teams.

Example of quote regarding support from supervisors: "*Onur is very supportive. When we report something, he gives feedback and provides information*." The role of supervisors in providing real-time feedback and support is crucial to maintaining quality standards.

6. **Gender Dynamics and Diversity**

Interviews highlighted gender imbalances, with men predominantly occupying physically demanding roles. While female participation has increased over the years, traditional gender roles persist, influencing job assignments. Women are often assigned tasks perceived as less physically demanding, reflecting normative assumptions about gender and physical capabilities. However, some female production line workers have successfully challenged these norms, performing tasks traditionally held by men.

Example of quote regarding female participation in male-dominated roles: "*I was one of the first women here, and it was challenging at first. But over time, we got used to each other, and now it's normal.*" Women have gradually integrated into different roles within the company.

Example of quote regarding gender-specific tasks: "*Across the factory, the workload given to women is naturally lighter. That's why there are some complaints from the men*." Physical strength remains a factor in task assignments.

Example of quote regarding support systems for women: "*TOFAŞ offers daycare support for mothers and provides maternity leave, milk money, and four months of paid leave.*" These support systems help balance work and personal responsibilities for female workers.

7. Job Satisfaction and Recognition

Recognition of expertise plays a crucial role in job satisfaction. Workers expressed satisfaction when their expertise was recognized, especially when detecting difficult-to-spot defects. Small acts of recognition, such as immediate feedback and rewards for good work, increased motivation. While automation reduces physical strain, the emotional aspect of feeling valued remains central to employee well-being. Structured work environments, financial stability, and consistent feedback further enhance job satisfaction.

Example of quote regarding job stability: "*At least here, my working hours are set, and I get paid on time. Outside, there are many problematic workplaces. I have no complaints here.*" The sense of stability and structured work life is valued highly.

Example of quote regarding job satisfaction: "*I genuinely enjoy my work. I even analyse cars outside of work. My friends tell me, please, do not look at my car.*" This reflects how personal passion and job satisfaction intertwine for some workers.

Example of quote regarding recognition and rewards: "*But, if I see something wrong, like a missing weld or a misalignment, they give me immediate recognition and rewards as motivation.*"

8. Challenges and Risks of Automation

While automation improves efficiency and safety and reduces human error, it also introduces new challenges that impact workers' experiences on the production line. One of the primary concerns is job security, as workers fear potential job displacement due to robots taking over manual tasks. Although automation aims to support workers rather than replacing them, the outcome usually leads to job displacement or replacement.

Example of quote regarding job displacement: "*The disadvantage is that it takes away our jobs. If you replace me with a robot, I'll be removed.*" Additionally, automation leads to increased operational complexity. While it reduces physical workload, it introduces new cognitive demands, requiring workers to monitor automated processes, troubleshoot errors, and adapt to evolving workflows.

Example of quote regarding complex errors: "*Errors can be good sometimes, but when there's a lot of pressure, it can be difficult. We end up working harder and facing more challenges.*" Workers also emphasised the importance of tacit knowledge and experience in maintaining production quality. Automation does not fully replace the nuanced skills required in defect detection and repair.

"*When you see a defect, you need to know how to address it and communicate it.*" The integration of automated inspection systems should therefore complement, rather than override, human expertise.

2.3.2.2.1 KEY TAKE-AWAYS

These themes suggest that while automation and technology continue to play a pivotal role in improving efficiency, human interaction remains essential, particularly in quality control and learning. The integration of automation at TOFAŞ has created a dual reality for production line workers. On the one hand, it has improved safety and efficiency and reduced physical strain. On the other hand, it has led to concerns about job security and a growing reliance on informal learning.

Despite these challenges, human collaboration, tacit knowledge, and social support systems continue to play a critical role in maintaining workplace resilience and operational excellence. Workers' great pride in their expertise, regarding being able to identify the smallest defects quickly, should be emphasised with the ongoing demonstrator. Collaboration between the workers and the developed co-bot is important.

2.3.2.3 SUMMARY FROM INTERVIEW WITH MANAGERS

The interviews conducted with managers at TOFAŞ provide insights into how automation and robotics are shaping strategic decisions, workforce dynamics, and the future of manufacturing. Several recurring themes emerged, reflecting the complexity of integrating advanced technologies into production environments.

1. **The role of Data and AI in Automation**

While automation adoption is advanced, the use of artificial intelligence (AI) remains in its early stages. Managers highlighted the importance of data-driven decision-making for optimizing production processes. Data from sensors is continuously collected and analysed to enhance efficiency and predict maintenance needs. Projects leveraging AI, such as predictive maintenance systems and automated reporting tools, are underway, though their scope is still limited.

Examples of quotes from managers regarding AI in automation: "*We get data from all kinds of sensors and evaluate that data. We try to create value for that data.*" "*Our robot usage rate has increased from 3 robots to 800 robots over the years. In the field of artificial intelligence, we don't have much serious work yet.*" "*Instead of spending 1-2 hours to prepare a data for excel, the data automatically flows to you and is shared to the workers via e-mail.*" "*We are doing an interface. The ChatGPT communicates. It tells us the steps needed for a solution.*"

2. **Decision-Making in Automation**

Decision-making around automation is heavily influenced by **cost-benefit analyses**. Managers emphasised that **cost reduction** is the primary driver of automation investments. While automation offers efficiency gains, managers acknowledge that it is not always the most cost-effective solution, especially in countries with low labour costs. As such, a balance must be struck between automation and manual labour, depending on economic conditions.

Examples of quotes from managers regarding Decision-making in automation: "*Everything is about the cost. Cost, cost, cost.*" "*We cannot say that automation is always a complete solution for our country because we are a low-budget country. Because our labour costs are low, sometimes there is an optimal level of automation. We need to establish that balance.*"

3. **Advancements in AI and Robotics**

The evolution of robotics within TOFAŞ has been significant, with the number of robots increasing from just a few to over 1,000. Managers expressed optimism about the potential of AI to improve product quality and efficiency. However, there are doubts about the reliability of AI systems in complex manufacturing tasks. The integration of robotics has also led to new forms of collaboration between humans and machines, with robots handling repetitive tasks and humans focusing on oversight and problem-solving.

Examples of quotes from managers regarding advancements in AI and Robotics: "*I am very positive about product quality, but I have doubts about efficiency.*" "*In the last 20 years, from electric technicians to electric and electronic engineers, from there to computer engineers.*"

4. Impact of Automation on the Workforce

Automation has transformed the workforce by reducing the need for manual labour while increasing the demand for technical expertise. Managers noted that while automation reduces physical strain, it also leads to job replacements and, in some respects, deskilling. Workers are often transitioned into roles requiring less hands-on involvement, with a growing emphasis on upskilling in data analysis and system maintenance. Despite these shifts, human expertise remains critical, especially in troubleshooting and quality assurance.

Examples of quotes from managers regarding the impact of automation on the workforce: "*We will probably have more people equipped with technical knowledge and fewer people doing physical work.*" "*Instead of spending 1-2 hours to prepare a data for Excel, the data automatically is sent and is shared to the workers via e-mail.*" "*In terms of product quality, it has more impact on certain aspects, such as welding points and placement, as it works more consistently than a human, providing us with better quality.*" "*If you add up/sum up, it should be workers of 3,000 people (since there are 1,000 robots), in the factory or in the body workshop. But now this number is 1,000.*"

5. Challenges in Automation Implementation

The implementation of automation at TOFAŞ presents several challenges that go beyond technical complexities, affecting both operational efficiency and organizational dynamics. One of the primary difficulties lies in system integration. As automation technologies evolve, integrating diverse systems ranging from robotics to AI-driven analytics has proven complex. These systems often originate from different vendors, operate on varying platforms, and require specialized protocols to communicate effectively. This lack of seamless integration can lead to inefficiencies, data silos, and difficulties in maintaining consistent production workflows.

Another significant challenge is the complexity of maintenance. While automation reduces the need for manual labour, it introduces a new layer of technical demands. Robots and automated systems require regular maintenance and specialized troubleshooting, necessitating a workforce with advanced technical skills. This shift places pressure on organizations to invest in continuous training and ensure that technical staff are equipped to manage routine upkeep and unexpected system failures.

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The reliance on specialized knowledge also increases operational risks, as downtime can be prolonged if the required expertise is not immediately available.

Additionally, employee concerns about job security and role changes present a key challenge in automation adoption. Workers, particularly those whose tasks are directly impacted by automation, often express uncertainty about how these changes will affect their responsibilities and long-term employment prospects. Addressing these concerns requires transparent communication, inclusive change management strategies, and opportunities such as education and training for employees to familiarize themselves with and adapt to new technologies in a way that reinforces their expertise and involvement in the process.

These challenges highlight that automation is a technical endeavour and an organizational transformation. Success in implementing automation relies not only on the technology itself but also on the ability to address human factors, foster a culture of adaptability, and create systems resilient to technical and social disruptions.

Examples of quotes regarding challenges in automation implementation: “*One of the biggest dangers in automation systems is diversity. Everyone has a different system, and sustainability is ruined.*” “*The part that artificial intelligence is not predictable and the form of application is variable, I think the bosses who bring money to us are afraid of this business.*” “*We already have an education institution called TOFAŞ Academy. They organise trainings, seminars, participations, etc. It goes to everyone.*”

6. Worker Involvement and Benefits

Although strategic decisions regarding automation are primarily made at the management level, workers’ insights are actively considered, particularly in process optimization and quality improvement initiatives. Various mechanisms exist to encourage worker participation, from daily feedback loops to structured innovation programs. Some managers reported the existence of patent systems and structured suggestion programs where employees can contribute ideas, even outside their primary field of expertise. Moreover, worker engagement is encouraged through reward mechanisms. Employees who propose valuable ideas or patents related to automation improvements receive formal recognition, reinforcing a culture of innovation.

Examples of quotes from managers regarding worker involvement and benefits: ”*For this, there are patent systems. Anyway, there are these kinds of systems. In these systems, our colleagues can work on these ideas by giving suggestions even outside their own field.*” “*Of course, we ask the workers for their opinions. Every morning, we ask the workers about their work areas and their feedback. They are the ones who know the area best.*” “*We make reward mechanisms so that they can continue this kind of work. The reward mechanism is like this. We support our employees who make a lot of money or bring patents.*” “*The entrepreneurship ecosystem was actually a project to include innovative technologies, image processing, artificial intelligence and similar technologies from different companies.*”

7. Future Trends in Automation

Managers foresee a future where automation will become even more pervasive, with concepts like "dark factories", fully automated production sites with minimal human intervention gaining traction. There is also an expectation of increased collaboration with **local and international AI companies** to drive innovation. However, the success of these initiatives will depend on overcoming technical, economic, and organizational barriers.

Examples of quotes from managers regarding future trends in automation: "*We see and hear that dark factory applications are being carried out. Of course, these are experimental studies, but these experimental studies will probably lead to results.*" "*Local startups, local technology companies, or foreign companies. Therefore, these will be more and more in our lives in the near future.*" "*We are doing an interface. The ChatGPT communicates. It tells us the steps needed for a solution.*"

2.3.2.3.1 KEY TAKE-AWAYS

The interviews with managers at TOFAŞ provided valuable insights into how automation and robotics are shaping strategic decisions, workforce dynamics, and the company's vision for the future. Several key themes emerged, reflecting both the opportunities and challenges associated with automation in a large-scale manufacturing environment.

Automation at TOFAŞ is evolving, with a strong emphasis on data collection and analysis. While AI usage is still in its early stages, there are ongoing projects aimed at enhancing production efficiency and predictive maintenance.

Cost reduction is a primary factor influencing automation decisions. Managers recognize the need to find a balance between automation and manual labour, especially in regions with low labour costs.

Automation is reshaping the workforce, diminishing the need for manual labour while boosting the demand for technical skills. Upskilling in data analysis and system maintenance is becoming increasingly important.

Integrating diverse automation systems poses significant challenges, including system compatibility and maintenance complexities. Efficient communication and operation between different technologies are critical for successful implementation.

2.3.2.4 SUMMARY FROM INTERVIEW WITH DEVELOPERS

The interviews with developers at TOFAŞ (five from TOFAŞ) and Altinay (five from Altinay) provide a view of how automation and AI are reshaping not only manufacturing processes but also organizational structures and work dynamics. Several recurring themes emerged, reflecting both the technological ambitions, safety and risks, and the ethical complexities surrounding automation.

1. **Challenges in automation projects**

Developers emphasised the multifaceted challenges involved in automation and robotics projects, particularly concerning safety, system adaptability, and technological integration. Ensuring that automated systems operate safely alongside human workers remains a primary concern, requiring rigorous testing, compliance with evolving safety standards, and developing fail-safe mechanisms. Additionally, keeping pace with rapidly advancing technologies presents an ongoing challenge as new hardware, software, and AI-driven solutions continuously reshape industry expectations.

Beyond safety and technological shifts, developers also navigate complex system integration issues, ensuring that automation aligns as seamlessly as possible with existing manufacturing processes without disrupting the workflows.

Examples of quotes regarding challenges in automation projects: "*The main challenge, especially with these AI projects, is that the industry is still new globally. Since it's being implemented for the first time, certain aspects of artificial intelligence and vision systems present challenges.*" "*The main challenge is that technology changes very quickly. Sometimes you have to abandon a project midway and fork off to a new direction. For example, I've been working with artificial intelligence since the beginning of the year, and it has changed drastically since then.*" "*If there were a "digital twin" system where I could just point and click on a sensor or object to control it.*"

2. The role of AI in enhancing production and decision-making

AI plays a crucial role in improving predictive maintenance, quality control, and process optimization. Developers are actively working on projects that use AI for image processing, defect detection, and decision support systems. These systems help predict equipment failures, detect production anomalies, and optimise workflows without human intervention. AI's ability to operate independently of human input is viewed as one of its greatest strengths. Developers believe that automation supported by AI not only increases productivity but also reduces costs by minimizing the need for human oversight. However, this reliance on AI introduces new risks, such as cybersecurity threats and system failures, especially when AI systems malfunction in critical operations.

Examples of quotes regarding the role of AI in enhancing production and decision-making: "*I'm really impressed, especially with what's being done in collaborative robotics. Look at how those machines work without needing to change motors they work perfectly alongside humans.*" "*Without automation and robots, it wouldn't be possible to mass-produce at such affordable prices. If we relied on human labour alone, costs would increase significantly.*" "*I follow Boston Dynamics a little bit. Since we are in the field of robotics. Their humanoid robot project Atlas interests me. There's also something else, Feston has a project where they try to imitate the human muscular system with pneumatics. That was nice. So, for me, studies in the field of robotics that are aimed at humanisation seem nice.*"

3. Collaboration and teamwork

Despite the technical focus, developers acknowledged the importance of collaboration and teamwork. Working in cross-functional teams is seen as essential for problem-solving and knowledge sharing. Specifically, developers at Altinay emphasised a core element for problem-solving and a positive working environment is to have a more relaxed, non-hierarchal feeling, a frequently mentioned quote was "campus feeling."

Interestingly, while developers view themselves as problem solvers and innovators, there is a tendency to perceive production line workers as passive recipients of technology.

Examples of quotes regarding collaboration and teamwork: "*We are at a level where we can communicate immediately. If something happens, we immediately turn around and ask. We talk at that moment.*" "*Our working environment is enjoyable, like a university setting; it's fun.*"

4. Ethical considerations and job displacement

Ethical concerns surrounding automation, particularly related to job displacement, are acknowledged but often treated as secondary to the pursuit of efficiency and productivity. Developers recognize that automation reduces the need for human labour, leading to significant workforce reductions. Some expressed mixed feelings about this, acknowledging the social implications while emphasising that job losses are an inevitable consequence of technological progress.

Examples of quotes regarding ethical considerations and job displacement: "*The main ethical concern people have is that it will take jobs away from humans.*"

5. The future of automation: Smart, Autonomous Systems

Looking ahead, developers envision a future dominated by smart factories and autonomous systems. Concepts like "dark factories," fully automated production facilities with minimal human intervention, are not just theoretical but are actively being explored. Developers are particularly interested in advancements such as digital twins, robotic process automation (RPA), and cloud-based factory management systems.

Examples of quotes regarding the future of automation: "*In other words, they are taking over a lot, and now, with Industry 4.0, this dark factory that we call will be something completely different. We are waiting with excitement.*"

6. Safety and risk management in automated environments

As automation becomes more integrated into manufacturing processes, safety remains a critical concern. Developers highlighted the importance of risk management systems, including AI-driven tools that can detect hazardous conditions and trigger automatic shutdowns to prevent accidents. Technologies such as proximity sensors and digital twins are used to enhance workplace safety and reduce the likelihood of human error. However, developers also acknowledged that no system is foolproof. The increasing complexity of automated systems introduces new risks, such as software vulnerabilities, system malfunctions, and cybersecurity threats. Ensuring the reliability and security of these systems requires ongoing vigilance and robust safety protocols.

Examples of quotes regarding safety and risk management: "*The main risk is related to safety. If something goes wrong with the software, it could be dangerous, especially with heavy machinery. By taking additional safety measures and using systems that can detect when a person is in the area and stop the machines automatically. But cannot assure 100%.*" "*Our other key priority is safety. We've implemented several AI tools for safety, such as the Smart Crane, which stops if a person is detected.*" "*We use digital twins to identify risks during design, improving safety and reducing commissioning issues.*"

2.3.2.4.1 KEY TAKE-AWAYS

One of the most significant challenges developers face is the rapid pace of technological change. AI and automation technologies evolve quickly, requiring constant adaptation and continuous learning. Projects often shift direction mid-way due to emerging technologies or changes in strategic priorities. This dynamic environment demands flexibility, resilience, and a willingness to embrace new tools and methodologies.

While developers are optimistic about the potential of AI and robotics to revolutionize manufacturing, their views also reflect the tensions inherent in balancing technological progress with social responsibility.

Automation is not just a technical transformation, it is a cultural and ethical shift that redefines work, alters power dynamics, and reshapes the relationship between humans and machines. Understanding these complexities is essential for navigating the future of work in an increasingly automated world.

2.3.3 NASA TASK LOAD INDEX QUESTIONNAIRE

Besides the observations and interviews, workers from the Bodyshop and the press filled out the NASA Task Load Index (TLX) questionnaire[1]. In an attempt to understand and analyse the users' perceived workload, NASA TLX was used as an assessment tool. It is commonly used to evaluate the perceived workload for a specific task. It uses an ordinal scale on six subscales (mental demand, physical demand, temporal demand, performance, effort, and frustration). A second part of the NASA TLX created an individual weighting of the subscales by letting the participant compare them pairwise based on their perceived importance. However, as Hart [49] reported, using the second part of the NASA TLX might decrease experimental validity. For this reason, it was not used in this experiment. The NASA TLX was utilized in this study to gain an understanding of the contributing factors that determined the task workload.

A total of 27 participants took part in the study. The average age of the participants was M = 35.8 years, with a standard deviation of SD = 5.76 years. The group consisted of 21 males and six females. Participants were distributed across two workplace sections: 10 participants worked in the Press section, while 17 participants were from the Bodyshop section. The average age of the participants from the Press section was M = 34.3, with a standard deviation of SD = 6.68, while the average age of the participants from the Bodyshop section was M = 36.7, with a standard deviation of SD = 5.14. There were three females from each section. The NASA TLX scores are illustrated in Figure 3, the mean NASA TLX score M = 41.9, SD = 6.51.

[1] NASA TLX: *https://humansystems.arc.nasa.gov/groups/TLX/downloads/TLXScale.pdf*.

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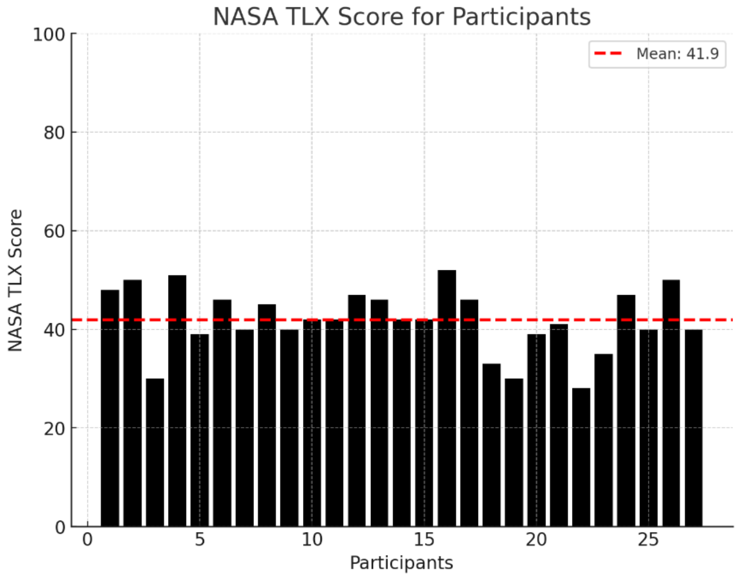

Figure 3. NASA-TLX Total score.

The Temporal Demand and Effort sub-scores had the largest median MD = 8.0 (see Figure 4). The performance sub-score had the lowest value, MD = 6.0. While the Mental Demand, Physical Demand, and Frustration had MD = 7.0. These values are considered to be high values, thus indicating a high perceived workload.

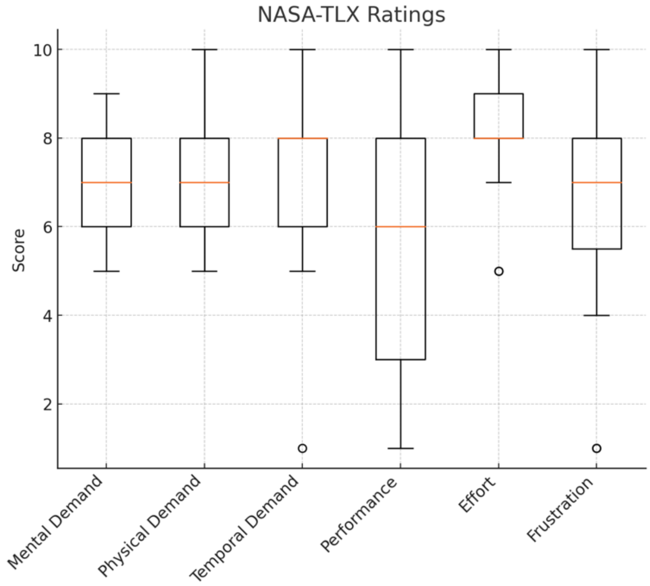

Figure 4. Total NASA-TLX subscore.

The highest sub-score at the Press section had Performance and Effort with a median value of MD = 8.5 (see Figure 5). The second highest value was Frustration, with a median value of MD = 7.0. The third highest value had Mental Demand and Temporal Demand with a median value of MD = 6.5. While the lowest median value of MD = 6.0, was Physical Demand.

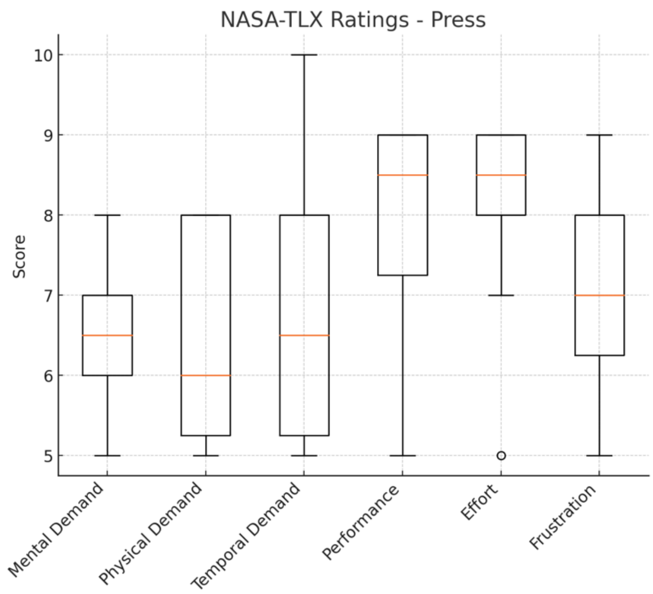

Figure 5. NASA-TLX subscore for the Press section.

The highest sub-score at the Bodyshop section had Physical Demand, Temporal Demand and Effort with a median value of MD = 8.0 (see Figure 6). The second highest value was Mental Demand and Frustration, with a median value of MD = 7.0. While the lowest median value of MD = 3.0, was Performance.

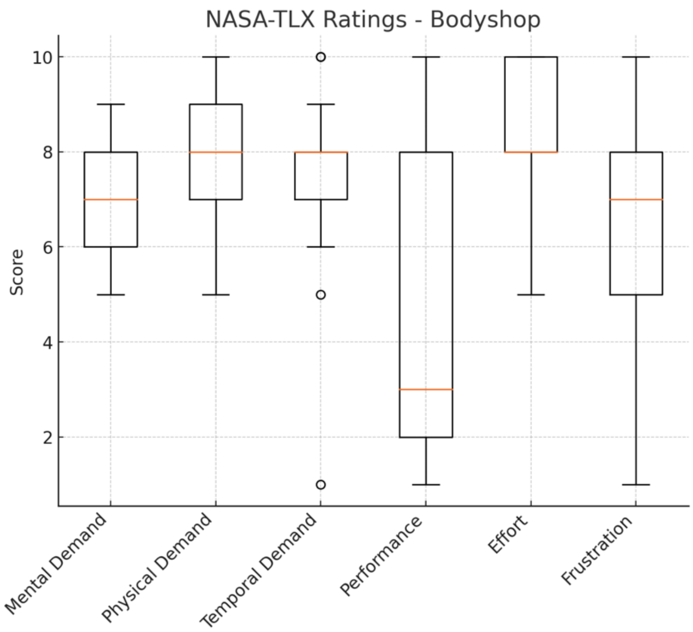

Figure 6. NASA-TLX subscore for the Bodyshop section.

The NASA-TLX sub-score indicates a higher perceived workload at the Bodyshop than the Press section. The biggest difference was on the Performance sub-score in which the Bodyshop had a very low value of MD = 3.0 while the Press section had MD = 8.5. This value is strange, and it might be that the Bodyshop workers misunderstood that a low value of Performance is considered “bad”. Other relatively high differences are Physical Demand, Temporal Demand, and Effort, which are higher than the Press. This indicates and can be confirmed from the observations as well, that the Bodyshop production line workers have a more physically demanding workplace.

2.4 CONCLUSION FIELD STUDIES

The field studies conducted at TOFAŞ provided a comprehensive understanding of the current work processes, human factors, and challenges faced by production line workers, developers, and managers in an increasingly automated production environment. Through direct observations, interviews, and workload assessments (NASA-TLX), we gained valuable insights into how workers interact with automation, the impact of technological change on job roles, and the opportunities and challenges associated with integrating robotic solutions.

Structured and Efficient Workflows

Observations revealed that production line workers follow highly structured workflows, relying on visual and tactile inspections to identify defects efficiently. The division of labour is thoroughly defined, with specialized roles ensuring that tasks such as defect detection, documentation, and repairs are executed smoothly. Despite the introduction of automation, human expertise remains central, particularly in defect detection, where production line workers demonstrate a high degree of tactile sensitivity and experience-driven intuition.

Automation's Role in Productivity and Job Security Concerns

While automation has increased efficiency and reduced physical strain, interviews highlighted concerns about job security and the changing nature of work. Production line workers expressed pride in their ability to identify defects, emphasising that robotic systems should support, rather than replace, human expertise. Developers and managers, on the other hand, viewed automation as a cost-saving measure, though they acknowledged the organizational challenges related to system integration, training, and worker acceptance.

Cognitive and Physical Workload Variations

The NASA-TLX results indicated that production line workers in the Bodyshop experienced a higher overall workload than those in the Press section. The physical and temporal demands were particularly high in the Bodyshop, aligning with observations of manual defect detection and intensive quality control procedures. Interestingly, performance scores varied significantly, suggesting differences in perceptions of efficiency and effectiveness between the two sections.

These insights provide a baseline for future automation strategies, emphasising the importance of user-centred design, workforce engagement, and ethical considerations in the ongoing transition toward smart manufacturing.

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2.5 GENDER ANALYSIS

In recent years, the car manufacturing industry has experienced significant developments in automation and robotisation, drawing considerable attention and investment [14, 50, 56, 65]. Automation and robotics are often imagined and portrayed as superior to human labour; robots are seen as faster, more consistent, precise and unburdened by the human need for rest or wages [107]. For companies in the highly competitive field of car manufacturing, automation and robotics hold attractive promises of optimised production and enhanced efficiency. Mainstream narratives frequently frame automation as an inevitable progression, envisioning a future where robots seamlessly replace human labour and sparking ideas about the "end of work" or paradigm shifts such as the Second Machine Age [14] Industry 4.0 and "dark factories" [58]. However, while these perspectives resonate with the innovation discourse and technical determinism, they sometimes overlook the complexities of sociotechnical change [10, 70 92], framing technology as an unstoppable, neutral force. Such deterministic views risk to oversimplify the ways in which automation interweaves with human experience, obscuring the nuanced, often unpredictable dynamics that emerge as technology and society interrelate [66, 117].

Historically, we know that technology rarely follows a straightforward or purely technical path [71]. Instead, technological changes are typically shaped by cultural, organisational and social factors. Furthermore, past developments suggest that technology has often been constructed based on male norms and values (whether intentionally or unintentionally) resulting in situations where women have been marginalised or where certain technical solutions fail to align with women's expectations, needs or identities [27, 40, 79 ,112]. Against this background, a focus on gender in the context of automation in car manufacturing is essential and our analysis seeks to ask: How is automation shaping gender roles and women's opportunities in car manufacturing?

To investigate this question, we conducted a case study with a specific car manufacturing organisation located at the intersection of Europe and western Asia, referred to throughout this report as the 'case organisation.' To maintain confidentiality, we have chosen to keep the identity of the case organisation anonymous. The case organisation employs approximately 5,000 workers and has a production capacity of 400,000 cars per year, manufacturing both passenger and light commercial vehicles. It hosts one of the main R&D centres of its group and exports globally, with Europe as its primary target. The production facilities include nearly 1,000 robots, primarily in body in white, stamping and painting shop. The case organisation provided us with statistics on workforce gender distribution, gender representation across organisational levels, gender disparities across departments, and information on parental leave and gender distribution in training and education. Specifically, we sought data on: How many men and women work within the organisation? What types of roles and tasks are most commonly associated with each gender? Are there notable differences between male- and female-dominated roles in terms of departmental distribution, parental leave, or admission to training and education?

The data provided by the case organisation were interpreted through the lens of feminist theory and gender studies, enabling us to consider how technology intersects with gender. To contextualise our case study gender analysis within a broader framework, we also explored the academic literature and public reports on the global car manufacturing industry. The approach allowed us to compare whether the patterns observed within the case organisation reflected wider industry trends or revealed unique organisational dynamics shaped by local practices or specific choices made by the organisation itself. Through this analysis, we hope to prompt reflection on how automation may influence not only the structure of the car manufacturing industry but also the gendered realities within it.

2.5.1 GENDER DISTRIBUTION AT THE CASE ORGANISATION

Our interpretive analysis reveals a significant gender imbalance, with approximately 88.3% of the workforce being male and only 11.7% female. This disparity not only reflects the current organisational structure but also resonates with historical and cultural forces that continue to shape traditionally male-dominated industries [30]. From a feminist perspective, this imbalance can be seen as indicative of entrenched structural and cultural barriers that extend beyond mere numbers, highlighting persistent patterns that limit women's representation in car manufacturing [104].

2.5.2 GENDER REPRESENTATION ACROSS ORGANISATIONAL LEVELS

Within the organisational hierarchy of the case study, female representation declines significantly with increasing seniority. Women are most prominent in white-collar "expert-leader" roles, accounting for 27.1%, yet are drastically underrepresented in top-tier positions, such as directors (5.9%) and managers (10.1%). This pattern invites reflection on the complex, gendered dynamics that may shape career progression within the organisation. Studies in gender theory suggest that organisational structures and leadership roles often embody traits traditionally associated with masculinity, such as assertiveness, decisiveness and competitiveness [2, 52]. These characteristics may unconsciously align with assumptions about effective leadership in the car manufacturing sector, possibly creating barriers to women's advancement [91]. Furthermore, gender studies indicate that access to mentorship, influential networks and visible role models in senior roles plays a critical role in shaping career trajectories [52, 53]. In contexts where these support structures are male-dominated, women may feel less encouraged or adequately supported to pursue higher positions, reinforcing patterns of gender inequality [9].

Another contributing factor may be societal expectations around family responsibilities, household duties and childcare, which disproportionately affect women and limit their availability for roles that demand extensive hours or additional commitments. Gender research has highlighted how the expectation that work should be prioritised above personal responsibilities may conflict with societal norms urging women to prioritise family, creating a situation where some women may be less inclined or feel socially discouraged, to pursue these high-demand roles [15, 33, 115]. This self-perpetuating cycle subtly reinforces male dominance in leadership, shaping an organisational culture that may discourage or hinder women from advancing to directorship roles [26, 63].

2.5.3 GENDER DISPARITIES ACROSS DEPARTMENTS

Our analysis of gender distribution across departments within the case organisation illustrates a diverse pattern. In the R&D department, women constitute 18% of the workforce, contrasting with an 82% male majority. Gender imbalance is also observed in other technical departments, such as IT and Quality, where women account for only 17.9% and 11.2% of the workforce, respectively. The figures indicate a pronounced gender gap in roles typically associated with technical expertise and development. A similar pattern is evident in the Supply Chain department, where women comprise merely 9.4% of the workforce. The most significant gender disparity appears in the Production department, where women represent just 7%, compared to 93% men, stressing substantial male dominance in this area.

In contrast, the gender distribution in the HR department exhibits a more balanced composition, with women constituting 47.3% and men 52.7% of the workforce. A comparable distribution is noted in the Finance department, where women represent 48.6% and men 51.4%. The statistics suggest that HR and Finance roles are accessible and attractive to both genders. The Sales department similarly shows a moderate balance, with women comprising 41.5% of the workforce. Interestingly, women are in the majority in the CEO department (Communication and External Relations) where they make up 62.9% of the workforce. The findings implies that women in the car manufacturing sector are more likely to be engaged in roles with administrative, relational or communicative purposes.

Interpreting these statistics implies that gendered norms, biases and organisational structures may play a role in shaping gender distribution and role allocation [2, 113, 114]. The statistics reveals that men predominantly occupy positions associated with technical expertise and development, while women are more often found in roles linked to relational or administrative functions. The underrepresentation of women in R&D, IT, Quality, Supply Chain, and Production departments reflects broader trends of gender disparity in STEM fields [21], where technical expertise is frequently aligned with masculine norms and values [41, 111]. In contrast, roles that involve relational, administrative or communicative functions are often seen as "feminised," potentially reinforcing occupational segregation and contributing to the relative undervaluation of 'soft' skills compared to 'hard' technical skills [27, 48, 114]. The statistics from the case organisation align with broader trends, with men predominantly occupying technical and leadership roles while women are more frequently represented in administrative or relational positions [114]. Within feminist theory, the concepts of the "glass ceiling" and "glass walls" are often used to describe how women encounter structural barriers that restrict them to particular roles within organisations, thus limiting their advancement opportunities [2, 91, 114].

2.5.4 SALARIES, BONUSES AND SALARY PROGRESSION

According to the case organisation, average salaries for men and women across various organisational levels do not differ based on gender, as they endorse equal pay for equal work. However, due to the lack of detailed salary data by department, we cannot verify the statement of "equal pay for equal work". Specifically, it remains unclear whether departments like R&D, IT, Quality, and Supply Chain, which are predominantly male, have higher average salaries than areas such as the CEO office, where the majority of employees are female.

However, the statistics that we have received clearly show that women are more frequently represented in white-collar "expert-leader" roles but are less prevalent in top-tier positions, such as directors and managers. This distribution suggests that, on average, women may have lower salaries than men, as higher-level positions, which typically come with higher pay, are occupied by fewer women. Prior research indicates that women, especially in male-dominated industries like manufacturing, often earn less overall, partly due to underrepresentation in roles that offer greater compensation [11, 12, 44].

The case organisation also reported that bonuses, incentives and other forms of compensation are distributed without gender-based differences. However, due to women's underrepresentation in leadership positions, they may receive fewer bonuses, given that rewards are typically associated with senior roles. Past studies imply that even when bonus policies are formally gender-neutral, women receive fewer performance-based incentives due to their lower representation in high-ranking or "performance-critical" roles [116]. Thus, while the case organisation's policies align with equality principles, structural underrepresentation in senior positions may limit women's access to these rewards, reflecting trends documented in the literature.

The case organisation also reported that salary progression over time is equal across genders, with no discernible gender-based differences. The information about equal salary progression contrasts with previous research, which indicates that women often face "sticky floors" that hinder upward salary progression, particularly in fields where men dominate in higher-paid technical roles [11, 12, 44, 116].

2.5.5 PARENTAL LEAVE

The parental leave policy at the case study organisation, which aligns with the country's policy, highlights a significant gender disparity, with women eligible for up to 16 weeks of paid leave, whereas men have the right to five days. While this policy may intend to support women's work-life balance, feminist theory suggests it could inadvertently reinforce traditional gender roles, positioning women as primary caregivers and shaping their career trajectories in ways that align with societal expectations rather than individual preferences [80, 115].

The provision of 16 weeks of paid leave for women reflects a "maternalist" approach, which can implicitly reinforce the expectation that women will assume primary responsibility for childcare, potentially placing additional pressure on them to prioritise family obligations over career ambitions [72]. Past research shows that these dual expectations, balancing caregiving with career responsibilities, can lead to slowed career progression for women, as extended leave periods may impact their visibility and advancement opportunities within the workplace [82].

Furthermore, the limited paternity leave granted to men reinforces the perception of caregiving as a predominantly female role and aligns with traditional norms of men as primary financial providers [82]. This in turn, marginalises men who wish to engage more actively in family life and perpetuates an organisational culture that does not fully support men's caregiving roles [18]. Consequently, the policy may hinder both men and women in pursuing balanced career and family lives, with men constrained in their caregiving involvement and women potentially facing a slower career trajectory due to extended time away from the workplace.

On the flipside, the case organisation's policy provision of 16 weeks of paid leave for women signals a progressive approach to supporting women's roles as both workers and mothers. Past research indicates that paid maternity leave can reduce the immediate financial strain of childbirth and provide essential time for recovery and bonding with the child, contributing to improved physical and mental health outcomes for both mother and child [72]. By offering paid leave, the case organisation may support stronger workforce attachment for women, potentially mitigating some of the long-term career penalties often associated with maternal leave [46, 51].

Additionally, the five-day paternity leave for men, although limited, demonstrates an acknowledgment of fathers' roles in early childcare. While only five days, it may reflect a shift from traditional, gendered workplace expectations, where men historically had no entitlement to family leave. Previous research indicates that even short paternity leaves can positively impact father-child bonding and may encourage men to take a more active role in caregiving [85, 118].

2.5.6 TRAINING AND PROFESSIONAL DEVELOPMENT

The statistics from the case study organisation show that in 2022, 676 women participated in training programs offered by the organisation, completing a total of 724 individual training sessions. In contrast, 5,513 men participated in training programs, with a total of 5,624 individual training sessions completed. In 2023, the number of women participating in training programs increased to 822, although the number of individual sessions completed by women decreased slightly, in total 712. Meanwhile, male participation rose marginally to 5,557, with men completing 5,248 individual training sessions.

In both 2022 and 2023, women's participation rates in training programs were proportionally higher than their representation in the workforce (676 women out of 671 in 2022 and 822 women out of 671 in 2023). This could be interpreted as an indication of the organisation's commitment to supporting women's professional development. However, it also raises questions about the content and structure of the training programs. If the training primarily focuses on soft skills, such as communication or administration, it may inadvertently reinforce gendered skill divides by positioning women in supportive roles rather than equipping them for leadership or roles requiring technical expertise in automated processes.

Past research implies that for training programs to empower women, they should provide opportunities to develop technical, strategic and leadership-focused skills that support career advancement and personal development [21, 34, 60, 114]. Without these elements, training risks perpetuating occupational segregation by confining women to roles with lower status and authority. The statistics on individual training sessions or "single education" sessions, indicates that men completed significantly more sessions overall. This may reflect a stronger emphasis on technical skill-building in male-dominated areas, such as R&D and Production.

2.5.6.1 PUTTING THE CASE STUDY INTO A BROADER CONTEXT

In analysing the statistics obtained from the case organisation, a significant gender imbalance was observed, with approximately 88.3% of the workforce being male and only 11.7% female. This imbalance is notably higher than in most other countries with established automotive industries, highlighting the extent of gender disparity in this specific context. For instance, a report by Deloitte, "Women at the Wheel" [35], reveals women make up about 25% of the automotive workforce worldwide [35]. Similar to the findings in our case study, Deloitte's report highlights that female representation is especially low in technical and blue-collar roles. According to the Deloitte report, aspects deterring women from entering and staying in automotive manufacturing include limited flexibility in work arrangements and a workplace culture that is predominantly male-oriented. This finding is consistent with prior research, such as Acker's [2] work on "gendered organisations," which suggests that traditional gender norms and hierarchies are reinforced within organisational structures, creating barriers that persist even in the presence of diversity initiatives [2].

The report "A manufactured gender imbalance" provides further insight into gender disparities within the manufacturing sector [64]. While approximately 30% of the manufacturing workforce in the United States is female, countries with well-established automotive industries, such as Germany, Austria, and Switzerland, account even lower female representation, around 20%, particularly in manufacturing roles. This disparity is attributed to cultural expectations surrounding traditional gender roles, which influence hiring practices, workplace dynamics and retention. The report also notes that initiatives to increase female leadership encounter cultural challenges, including subtle forms of discrimination such as implicit bias [64]. These findings align with studies on how cultural expectations shape gender roles in the workplace, which often limit women's

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access to opportunities in male-dominated industries like automotive manufacturing [38]. Furthermore, studies on gender in workplaces stress how workplace biases often work against women, especially in male-dominated fields [110]. The “A manufactured gender imbalance” report concludes that reaching a critical mass of women in the automotive manufacturing sector is essential to fostering a more inclusive environment [64]. In accordance to the critical mass theory, women must make up a sufficient representation within an organization to positively impact the workplace culture and reduce gendered biases [32, 95].

The 2024 Global Gender Gap Report by the World Economic Forum underscores persistent challenges, such as gender disparities in leadership and technical roles, as common across the automotive industry worldwide [43]. The report highlights the potential of gender-inclusive strategies, not only as ethical imperatives but also as opportunities to enhance productivity and innovation. These insights align with research suggesting that diversity is positively associated with organisational performance and can drive innovation and adaptability in an increasingly competitive global market [61].

2.6 CONCLUSION GENDER ANALYSIS

In conclusion, the gender analysis identifies a range of initial user requirements, covering both structural and technical elements, to inform the future development of robots and automation in the automotive industry. The structural requirements address organisational objectives such as diversity, equity, and inclusion:

- Develop recruitment strategies to increase the representation of women in technical and leadership roles in departments of research and development, information technology, and production.
- Establish structured mentorship programmes to support career advancement for women into senior positions. Mentorship initiatives should incorporate leadership development to prepare women for managerial responsibilities.
- Design technical training programmes tailored to women to enhance skills in automation, robotics, and STEM-related fields. Female participation ought to lead to opportunities for career progression into senior technical and leadership roles.

The technical requirements address objectives such as accessibility, ergonomics, functionality and usability in robotic and automated systems:

- Develop human-machine interfaces (HMIs) with adjustable controls that accommodate differences in physical characteristics such as height, strength, reach, and dexterity.
- Employ modular design principles to enable systems to adapt to individual user needs.
- Utilise advanced technologies such as virtual reality (VR) and augmented reality (AR) to provide accessible training simulations for individuals new to automated systems. The training resources ought to be designed to minimise cognitive and physical barriers to learning.

- Implement continuous feedback mechanisms in automated workflows to collect user input, enhance usability and ensure fair task distribution.

Reflecting on these requirements highlights the nuanced relationship between organisational priorities and technological capabilities. The emphasis on diversity and inclusivity opens avenues for exploration, yet the process of transforming these ideals into tangible outcomes invites critical examination. It warrants iterative testing cycles where diverse users evaluate prototypes to assess user trust in the system and its perceived fairness, particularly among women in male-dominated roles.

3 PERSONAS AND USER JOURNEY BASED ON THE USER-CENTRED DESIGN (LU/TOFAS/ALT/CRF)

Personas and user journeys serve as tools to bridge the gap between technological advancements and human factors [31, 75]. Personas provide a structured way to represent different user groups based on the collected empirical data through field studies, observations and interviews. They embody the objectives, challenges, desires, and necessities of users [89]. By creating personas for workers, developers, and managers, we aim to capture the diverse perspectives within TOFAŞ and highlight their unique interactions with automation.

User journeys further enhance this approach by mapping out the typical workflows, pain points, and interactions of these personas within the production environment [47, 17]. These visual representations illustrate the step-by-step processes involved in defect detection, quality control, and automation integration, helping to identify opportunities for improvement.

3.1 PERSONAS

Personas were developed to better understand the needs, challenges, and perspectives of workers, managers and developers in the defect detection process at TOFAŞ. The primary reason for using personas is to ensure that automation solutions align with real-world user needs, rather than being developed in isolation from the people who will interact with them. Research has shown that personas improve empathy, support user-centred decision-making, and help teams prioritize features based on user goals [75].

3.1.1 PERSONAS FOR WORKERS

The personas for workers were selected based on common themes that emerged from the interviews. They represent key roles within the defect detection line and quality control line. Moreover, they highlight different levels of experience, technical adaptability, and engagement with automation technologies. Two production line workers, Figure 7 and Figure 8, one manager Figure 9, and two developers Figure 10 and

Figure 11 were developed.

1. Ahmet – The Experienced Production line worker

Figure 7. Persona called Ahmed, the image is generated using ChatGPT.

- **Age:** 38
- **Role:** Bodyshop Production line worker
- **Goals:** Ensure defect-free production, maintain personal safety, and uphold quality standards.
- **Frustrations:** Fear of job insecurity, i.e. will robots replace the production line worker.
- **Motivations:** Pride in detecting small, hard-to-spot defects; values hands-on craftsmanship.
- **Needs:** A system that complements his tacit knowledge, offering insights without replacing his expertise.

2. Fatma – The Adaptable Newcomer

Figure 8. Persona called Fatma, the image is generated using ChatGPT.

- **Age:** 29
- **Role:** Press Line Production line worker

- **Goals:** Learn quickly, adapt to new technologies, and gain recognition for her contributions.
- **Frustrations:** Lack of formal training for advanced automation systems.
- **Motivations:** Career growth and mastering both manual and automated inspection techniques. Pride in detecting hard-to-spot defects.
- **Needs:** Tools that reduce repetitive work but still require critical thinking and expertise.

3.1.2 PERSONAS FOR MANAGERS

The manager persona was created based on insights from the interviews to capture the perspectives of those responsible for strategic decision-making at TOFAŞ. Managers play a crucial role in balancing automation adoption with operational efficiency, worker well-being, and business objectives.

The persona reflects a manager who needs to balance priorities, challenges, and expectations regarding automation. While they recognize the benefits of increased efficiency and cost reduction, they also face organizational resistance, training gaps, and ethical concerns about automation's impact on the workforce.

Emre – The Strategic Leader

Figure 9. Persona called Emre, the image is generated using ChatGPT.

- **Age:** 45
- **Role:** Operations manager
- **Goals:** Improve productivity, reduce costs, and achieve high operational efficiency.
- **Frustration:** Support employee development, manage change effectively during automation rollouts.
- **Motivations:** Empowering employees to thrive in an automated environment.
- **Needs:** Training modules that bridge the gap between traditional workflows and AI based automated systems.

3.1.3 PERSONAS FOR DEVELOPERS

The developer personas were created based on insights from our interview data to capture the perspectives of those responsible for designing, implementing, and optimizing automation technologies at TOFAŞ and Altinay. These individuals are crucial in shaping how AI, robotics, and digital tools can be integrated into manufacturing workflows. The personas reflect different technical expertise and responsibilities, focusing in particular on safety and cybersecurity.

1. **Can – The Automation Enthusiast**

Figure 10. Persona called Can, the image is generated using ChatGPT.

- **Age:** 31
- **Role:** Software Developer
- **Goals:** Create efficient, scalable automation systems that reduce human error.
- **Frustrations:** Limited understanding of on-the-ground production line worker workflows; difficulties in aligning AI capabilities with real-world needs.
- **Motivations:** Pushing the boundaries of AI in manufacturing.
- **Needs:** Direct feedback from production line workers to improve system usability and relevance.

2. **Zeynep – The Safety-Focused Developer**

Figure 11. Persona called Zeynep, the image is generated using ChatGPT.

- **Age: 29**
- **Role:** Safety Engineer in Robotics and Automation
- **Goals:** Ensure that robotic systems operate safely around human workers. Develop real-time monitoring solutions to prevent accidents. Design fail-safe mechanisms to stop robotic operations in emergencies.
- **Frustrations:** Difficulty in aligning safety standards with rapid automation changes.
- **Motivations:** Passionate about human-robot collaboration and accident prevention. Driven to build a workplace where automation enhances worker safety rather than increasing risks. Inspired by advances in sensor-based safety systems and AI-driven risk detection.
- **Needs:** Access to real-time robotics performance data for safety monitoring. Increased collaboration between developers, production line workers, and safety experts to create human-friendly automation.

While personas provide insights into user goals, challenges, and motivations, analysing how they perform their tasks in the production environment is equally important. To complement our personas, we have attempted to visualize the current workflow to map out the key steps and decision points in defect detection and quality control.

3.2 USER JOURNEY

This section presents user journey visualizations by creating a workflow chart from the workers' and managers' perspectives. Understanding the current defect detection workflow for designing effective and user-centred AI-driven solutions. This workflow visualization was developed to map out the manual processes, identify possibly points to improve, and highlight areas where automation could provide meaningful support without disrupting well-established expertise-driven practices. By documenting the step-by-step process workers follow to inspect and identify defects, we gain insights into:

- Critical decision points that impact efficiency and accuracy.

- Human expertise and tacit knowledge that cannot easily be replaced by automation.
- Bottlenecks and challenges in manual defect detection.

This workflow serves as a baseline for evaluating the impact of automation and ensuring that new technologies like the MAGICIAN robotic solutions are designed to complement, rather than replace, the skills, intuition, and craftsmanship that workers bring to the production process.

Workers – working flow – prior MAGICIAN

The current defect detection process (see Figure 12) at TOFAŞ relies on production line worker expertise and structured reporting systems. The workflow follows a systematic approach, where operators visually and physically inspect the vehicle body, identify defects, document findings, and direct affected units to repair stations.

Step-by-Step Process (see Figure 12):

1. Initial Inspection
    a. Operators begin by conducting a thorough visual and tactile inspection of the vehicle body.
    b. They use their hands and sandpaper to detect surface irregularities that may not be visible to the naked eye.
2. Decision Point: Is the Body Clean?
    a. If no defects are found, the vehicle proceeds to the next stage of production.
    b. If a defect is detected, the operator documents the issue and decides on the appropriate corrective action.
3. Defect Documentation
    a. Defects are marked directly on the vehicle using pens or other indicators.
    b. The operator records detailed defect information in a logbook and digital system to track recurring issues and ensure proper handling.
4. Escalation and Repair Process
    a. If a defect requires rework, the vehicle is redirected to a repair station for further inspection and correction.
    b. Specialized operators at the repair station re-evaluate and resolve the defect before allowing the vehicle to continue in the production line.

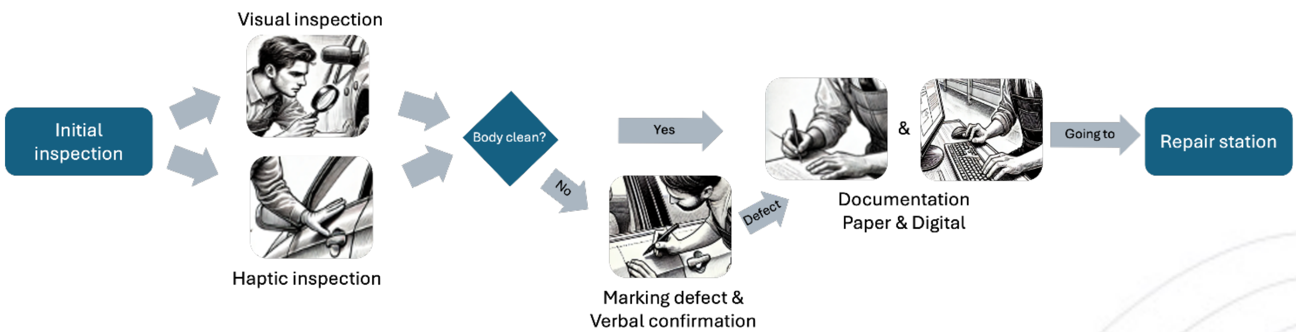

Figure 12. Defect detection process before MAGICIAN.

Key observations from user journey

- Reliance on Human Expertise: Operators use tacit knowledge and experience to detect issues, making the process highly dependent on individual skill levels.
- Time-Consuming and Repetitive: Manual inspections can be labour-intensive and may slow down production cycles when multiple defects require attention.
- Documentation Challenges: Defects are recorded manually, which can sometimes lead to delayed or inconsistent reporting.
- Potential for Undetected Errors: Due to human limitations and production pressures, some defects may go unnoticed or be misclassified.

With the introduction of MAGICIAN co-bot and AI-driven automation, the defect detection process can be enhanced by:

- Real-time digital documentation to minimise errors in defect tracking.
- Co-bot-assisted scanning to supplement human inspections and improve detection accuracy.
- Predictive defect analysis, where AI can identify patterns in defect occurrences and suggest preventative measures.
- Co-bots for seamless reporting: A co-bot could listen to workers' defect reports in real time and automatically input them into the system, eliminating the need for manual documentation while reducing the cognitive load on operators.

This workflow serves as a baseline for evaluating the impact of automation, ensuring that future AI-driven solutions integrate seamlessly with existing worker expertise rather than replacing their role in quality control.

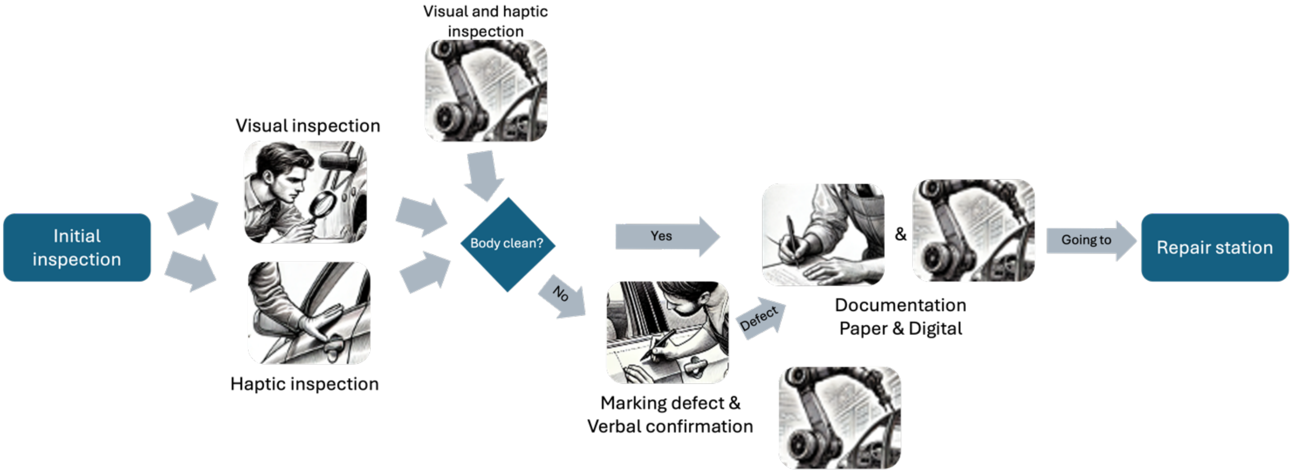

Figure 13. Worklflow with COBOT as a complement to workers.

Managers at TOFAŞ play a pivotal role in evaluating and implementing process optimisations derived from data-driven insights and operational feedback. Their responsibilities include assessing efficiency metrics, considering cost implications, and overseeing implementation strategies for automation and production improvements.

Step-by-Step Process (see Figure 14):

1. Gathering Insights and Optimisation Proposals
    a. Managers receive data-driven reports from automated monitoring systems. These reports provide real-time analytics on production efficiency, defect rates, and system performance.
    b. Feedback is also gathered from cross-functional discussions between engineers, operators, and team leads. These discussions highlight challenges, bottlenecks, and potential areas for optimization.
2. Manager decision-making
    a. Managers analyse whether the proposed optimisations align with cost-effectiveness and efficiency improvements.
    b. If the proposal meets strategic goals, the decision is made to proceed with implementation
    c. If the cost-benefit analysis does not support the proposed changes, the manager may request further refinement, additional testing or alternative solutions or no action.
3. Implementation of changes
    a. Approved changes are implemented within the production line. These may include automating specific processes and modifying workflow.
    b. Managers continue to monitor the impact of the changes using updated data reports and operational feedback to ensure effectiveness.

Key observations from user journey

- Reliance on data and expert input: Decision-making is based on a combination of real-time production data and expert insights from developer engineers and production line workers.
- Cost and efficiency constraints: The feasibility of automation changes is primarily evaluated based on economic impact and productivity gains.
- Iterative Process: Not all changes are implemented immediately, some require additional refinements based on further assessments.

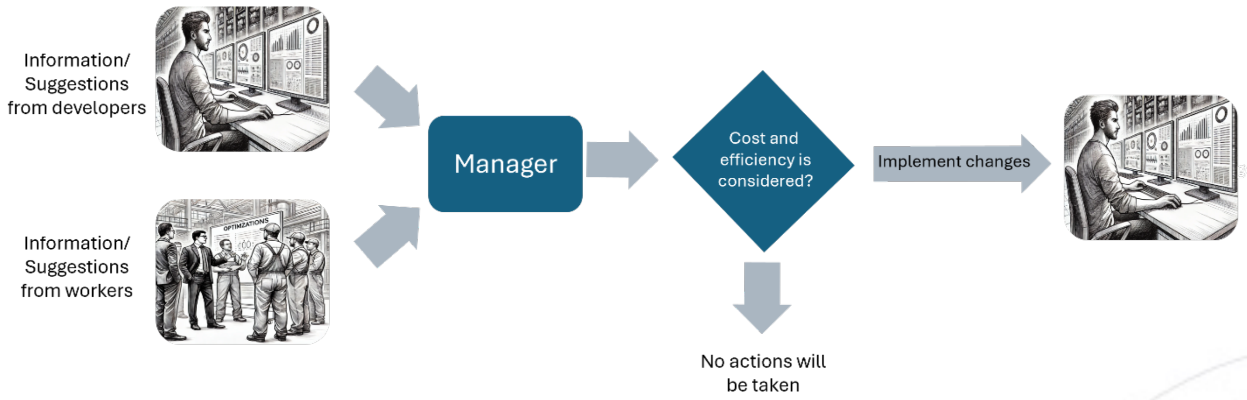

Figure 14. The current workflow for new implementations or optimizations. Images in the workflow have been generated with ChatGPT.

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With the introduction of MAGICIAN co-bot and AI predictive analytics, this workflow can be further optimised (see Figure 15):

- Automated cost-benefit simulations that help managers make quicker, data-backed decisions.
- Real-time AI-driven performance alerts to identify optimization opportunities proactively.
- Enhanced collaboration between MAGICIAN co-bot and human expertise, ensuring managers receive both quantitative insights and qualitative input from production line workers.
- Enhanced collaboration between developers and production line workers.

This manager decision-making workflow serves as a foundation for evaluating how AI-driven automation can enhance efficiency, reduce manual assessments, and streamline real-time process improvements.

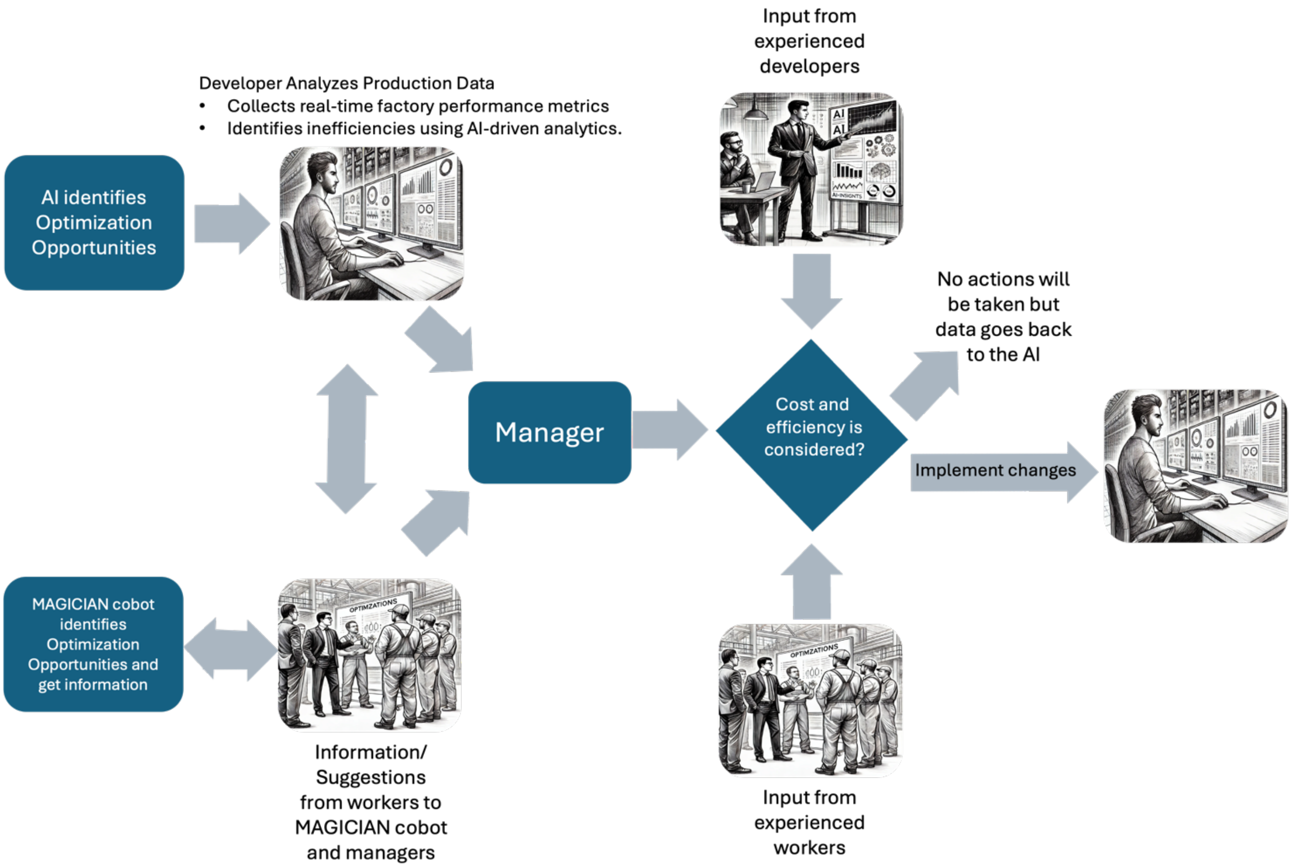

Figure 15. Workflow for new implementations or optimizations with MAGICIAN. Images in the workflow have been generated with ChatGPT.

3.3 CONCLUSIONS FROM PERSONAS AND USER JOURNEY

Using personas and user journeys to understand the interactions of workers, managers, and developers within the defect detection process at TOFAŞ is essential for fostering a user-centred approach to automation. By developing detailed personas, we gain valuable insights into different stakeholders' diverse needs, motivations, and frustrations.

The worker personas reveal the importance of balancing automation with the preservation of essential skills and the sense of craftsmanship, while the manager personas highlight the need for strategic decision-making that considers operational efficiency and employee well-being. Furthermore, the developer personas underscore the necessity for collaboration and feedback between technical teams and end-users to ensure that technological advancements are relevant and effective in the production environment.

The User Journey tries to map and identify pain points in defect detection and workflow of integrating new machines or software to enhance efficiency and worker well-being. The analysis of both the defect detection workflow and the workflow to implement or optimise new machines or software at TOFAŞ highlights the balance between human expertise, data-driven insights, and automation in production environments. The defect detection workflow underscores the critical role of production line workers in ensuring quality through manual inspection, tactile assessment, and intuitive defect classification. The integration of co-bots and AI assistance could offer an opportunity to streamline documentation and improve defect detection accuracy while preserving the workers' expertise.

The workflow to implement or optimise new machines or software workflow reveals a structured, data-informed approach where managers rely on real-time analytics and expert feedback to assess potential process optimisations. However, cost considerations and efficiency constraints are important in determining which automation improvements are implemented. The current workflow is iterative, requiring continuous refinements before fully adopting changes. AI-driven predictive analytics, automated cost-benefit assessments, and real-time performance tracking could enhance decision-making efficiency and accelerate implementation cycles.

These insights will continue to inform future design iterations and user requirements assessments as the MAGICIAN project progresses. The user-centred approach reinforces that successful automation is not solely about technological efficiency but about fostering seamless integration between human expertise and machine intelligence.

4 TABLES OF INITIAL USER REQUIREMENTS BASED ON THE USER-CENTRED DESIGN

This section presents user requirements derived from interviews, observations, field studies and desktop research. The requirements are structured into tables, categorised by key themes identified through the research findings and labelled with user requirement IDs for reference.

Our studies emphasise the following key aspects:

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- Workflow integration – Workers' perspectives indicate that workflow integration is a fundamental factor in the successful adoption of robotic systems.
- Customisation – Workers articulated a preference for automation that is adaptable to individual working styles.
- Cognitive and physical assistance – Workers reported experiencing high cognitive load and task-related stress.
- Transparency, feedback and predictability – Workers are more likely to engage positively with automation when they have access to clear explanations of system decisions, accessible error reporting and consistent system behaviour.
- Job security and participation – There was a clear desire to be involved in decisions surrounding automation.
- Privacy and data collection – Workers expressed a preference for systems that limit data collection to task-relevant information, ensuring that personal or unnecessary tracking does not contribute to feelings of surveillance or loss of autonomy.
- Skills development – Workers were not only concerned with how automation assists current tasks but also with how it supports skill enhancement rather than deskilling.
- Gender-sensitive lens – The findings revealed differences in safety concerns, workload distribution, and training preferences.

The tables below outline specific user requirements for each of these themes, connecting research findings to actionable requirements.

4.1 THE INITIAL USER REQUIREMENTS FOR WORKER SATISFACTION IN HUMAN-ROBOT INTERACTION AND AUTOMATION

The analysis indicated that worker satisfaction is shaped by the extent to which robots integrate into daily work routines, the level of control workers can exercise over automation and whether automation alleviates or amplifies their workload.

Table 1. Initial user requirements for worker satisfaction in human-robot interaction.

Key Aspects	Research findings	Requirement description	ID
Workflow	Workers expressed satisfaction when robotic systems blended seamlessly into their established workflows, minimising	If workers perform manual inspections and corrections, the MAGICIAN system should assist in this process without requiring them to stop or relocate	Workflow_1

	disruptions rather than imposing new patterns of work. (Interviews, observations)	tasks to a different station.	
		If workers visually inspect parts for defects, the MAGICIAN system should enhance this process by providing automated suggestions or augmented vision rather than replacing the entire workflow.	Workflow_2
		If workers perform two-handed operations and require tools in a specific order, the MAGICIAN system should be able to anticipate their needs, handing over tools or assisting without forcing a new working posture.	Workflow_3
		If workers already use a digital system to log inspections or incidents, the MAGICIAN system should integrate with that system instead of requiring a new interface.	Workflow_4
Customisation	Workers saw value in robotic systems that could be adjusted to their preferences rather than imposing fixed parameters. (Desktop research,	The MAGICIAN system shall allow workers to configure and adjust the response speed and precision according to their input	Customisation_1

	interview, observations)	The MAGICIAN system shall allow workers to configure the level of autonomy in robotic assistance according to their preference.	Customisation_2
Assistance	Initial studies revealed that high cognitive load and frustration were prevalent before the introduction of robots. Rather than merely assisting with physical tasks, automation was seen as most effective when it alleviated cognitive strain and reduced task-related stress. (NASA-TLX)	The MAGICIAN system should use AI-driven defect detection to reduce the cognitive load on workers performing visual inspections, allowing them to focus on complex decision-making rather than repetitive analysis.	Assistance 1
		The MAGICIAN system shall provide real-time guidance and decision support in workflow execution, reducing stress from high-tempo work processes and facilitating coordination between human and automated tasks.	Assistance_2
Job security	Concerns about automation displacing workers rather than supporting them were evident across interviews. While some recognised its potential benefits, many voiced	Provide internal newsletters, meetings and training sessions that explain how the MAGICIAN system is integrated into the workforce strategy.	Job security_1

	apprehensions about long-term job security (desktop research, interviews)	Allow workers to provide feedback on how the MAGICIAN system is integrated into their workflows.	Job Security_2
Workload recognition	Workers reported that automation systems often introduce additional maintenance, monitoring and repair tasks that are not officially recognised, leading to increased workload without compensation or acknowledgment. (Desktop research)	Ensure that any additional work required from workers to operate, maintain or repair the system is formally acknowledged and integrated into work responsibilities for appropriate recognition and workload considerations.	Job Security_3

4.2 THE INITIAL USER REQUIREMENTS FOR TRUST IN HUMAN-ROBOT INTERACTION AND AUTOMATION

The analysis suggests that trust in human-robot collaboration is shaped not only by the reliability and transparency of automated systems but also by how effectively they communicate their decisions. Workers and users develop confidence in automation when they can make sense of system behaviour through clear, explainable feedback, reinforcing their role as active participants rather than passive production line workers.

Table 2. Initial user requirements for trust in human robot interaction.

Key aspect	Research findings	Requirement description	ID
Transparency	Workers trust robots more when they understand its decision-making processes. (Desktop research, field studies)	The MAGICIAN system shall display real-time status updates on a screen or through auditory notifications to inform workers of decision-making processes and task execution.	Transparency_1

		The MAGICIAN system shall provide an accessible history of actions taken, with explanations for each decision, to help workers verify system outputs.	Transparency_2
		When an error occurs, the MAGICIAN system should generate a detailed but easy-to-understand explanation of what went wrong and suggest corrective actions.	Transparency_3
		The MAGICIAN system shall allow workers to adjust the level of detail provided about its decision-making processes based on their expertise and role.	Transparency_4
		The MAGICIAN system shall ensure decision traceability by clearly documenting and displaying which system component or human operator is accountable for specific failures or functions	Transparency_5
Feedback	Clear feedback mechanisms improve trust in robots. (Interviews)	The MAGICIAN system shall provide regular feedback through an interface displaying ongoing tasks, system alerts, and explanations for adjustments.	Feedback_1
Predictability	Predictability in robot behaviour	The MAGICIAN system shall ensure	Predictability_1

	improves worker comfort (Desktop research, observations)	predictable movement patterns, task execution timelines and clear notifications when deviations occur.	
Participation	Workers feel more comfortable when involved in automation decisions. (Interviews)	Workers should be involved in the introduction of the MAGICIAN system through participatory decision-making.	Partcipation_1

4.3 THE INITIAL USER REQUIREMENTS FOR PRIVACY CONCERNS IN HUMAN-ROBOT INTERACTION

The analysis reveals that privacy concerns arise not only from data collection practices but also from the broader anxieties associated with surveillance and the potential loss of autonomy in human-automation interactions.

Table 3. Initial user requirements for privacy concerns in human-robot interaction.

Key aspect	Research findings	Requirement description	ID
Data minimisation	Privacy concerns increase when robots collect unnecessary data. (Desktop research)	The MAGICIAN system shall collect only task-relevant data, avoiding unnecessary tracking of worker movements or biometric details.	Data minimisation_1
		The MAGICIAN system shall process only de-identified information for analytics and performance tracking.	Data minimisation_2

Transparency	Transparency in data collection was seen as a key trust-building measure. (Desktop research)	Workers should be informed about what data the MAGICIAN system is collecting, how it is used and how long it will be stored.	Transparency_6 (see table 2 for Transparency_1,_2, _3, _4 and _5)
Consent	Workers prefer opt-in mechanisms for data sharing. (Desktop research)	Workers should be able to enable or disable certain types of data collection, such as performance tracking or location monitoring.	Consent_1
Real-time access	Real-time transparency builds trust. (desktop research, observations)	Workers should have access to logs showing who has accessed their data and when	Real-time access_1

4.4 THE INITIAL USER REQUIREMENTS FOR SKILLS DEVELOPMENT

The analysis suggests that training, upskilling, and co-development may shape how workers and users experience automation. The analysis revealed that workers not only want to develop new skills but also value opportunities to navigate change, feel included and make sense of evolving work practices.

Table 4. Initial user requirements for skills development.

Key aspect	Research findings	Requirement description	ID
Training	Training preferences varied widely, but immersive, hands-on experiences were consistently favoured over static instructional materials. Workers reported greater confidence when learning was integrated into real-	The MAGICIAN system shall provide step-by-step guidance during real work tasks, ensuring workers learn by doing rather than passive instruction.	Training_1
		AR glasses or screen-based guides to provide	Training_2

	world tasks rather than abstracted into manuals. (Desktop research, interviews, observations, field studies)	interactive instructions layered onto the real-world workspace.	
		Workers can choose between text-based, video, audio or hands-on interactive guidance depending on their preferred learning style.	Training_3
Upskilling	Concerns about deskilling were raised (Interviews, desktop research)	The MAGICIAN system shall support gradual skill enhancement, helping workers progress from basic operation to advanced troubleshooting rather than making their tasks obsolete.	Upskilling_1
Co-development	Workers expressed a higher sense of ownership and confidence when they were actively involved in refining and adapting the system's functionalities based on their expertise and experiences. (Desktop research, Interviews)	Workers should be able to co-develop and refine the MAGICIAN system's functionalities based on their expertise.	Co-development_1

4.5 THE INITIAL USER REQUIREMENTS FOR GENDER-SENSITIVE DESIGN

The analysis reveals that expectations and experiences of automation are shaped by various factors, including workplace roles, expectations and past experiences, which can differ by gender.

Table 5. Initial user requirements for skills development.

Key aspect	Research findings	Requirement description	ID
Safety consideration	Women reported higher concerns about proximity-based safety measures, particularly in collaborative environments. (Desktop research, interviews, observations)	The MAGICIAN system should include adaptive safety zones and customizable safety alerts to enhance user confidence.	Safety considerations_1
Workload distribution	Gender disparities were observed in physically demanding tasks, with men more frequently assigned lifting and endurance-based activities. (Observations)	The MAGICIAN system should assist in equalising workload distribution rather than reinforcing existing labour divisions.	Workload distribution_1
Training approaches	Learning preferences are often shaped by gendered experiences. Women are more likely to seek collaborative, guided training while men prefer trial-and-error approaches. (Desktop research, interviews)	Training programs should incorporate both structured learning modules and experiential training to cater to different learning styles.	Training approaches_1

5 CONCLUSION

This deliverable presents the first iteration of T2.2 activities, covering the period from M1 to M18 and provides the initial user requirements for the MAGICIAN system. It not only identifies preliminary considerations for the MAGICIAN system but also reflects on broader automation requirements that may extend beyond the project's immediate scope. The initial user requirements are derived from desktop research, field studies (i.e., interviews and observations) at TOFAŞ and a gender analysis of the case organisation.

By outlining initial user requirements, this report establishes the groundwork for the iterative refinement of solutions within the MAGICIAN project, particularly in relation to usability, trust, skill development, gender-sensitive design and worker satisfaction. Additionally, the personas and user journeys presented in this deliverable highlight the diverse needs of production line workers, managers and developers. The insights will inform the next phases of the project, feeding into technical specifications (D2.3) and contributing to advancements in WP3 (Data Acquisition and Skills Learning) and WP4 (Robotic Platform and Interfaces). Furthermore, the initial user requirements will support the evaluation framework in WP5 (Integration and Performance Analysis), particularly in assessing user acceptance, trust and overall system performance.

This deliverable serves as a stepping stone towards a human-centred approach to automation in car manufacturing, ensuring that the MAGICIAN system aligns with real-world work environments and stakeholder needs. Future iterations will refine and expand upon these initial user requirements, validating them through demonstrator trials and further stakeholder co-design workshops.

6 BIBLIOGRAPHY

[1] Abendschein, B., A. Edwards and C. Edwards (2022). Novelty Experience in Prolonged Interaction: A Qualitative Study of Socially-Isolated College Students' In-Home Use of a Robot Companion Animal. Frontiers in Robotics and AI. 9: 1-19.

[2] Acker, J. (1990). Hierarchies, jobs, bodies: A theory of gendered organizations. Gender & society, 4(2), 139-158.

[3] Ågnes, J. S. (2022). Gaining and Training a Digital Colleague: Employee Responses to Robotization. Journal of Applied Behavioral Science. 58: 29-64.

[4] Alenljung, B., Lindblom, J., Zaragoza-Sundqvist, M., & Hanna, A. (2023). Towards a Framework of Human-Robot Interaction Strategies from an Operator 5.0 Perspective. Advances in Transdisciplinary Engineering, 10.3233/ATDE230905

[5] Bankins, S. and P. Formosa (2023). The Ethical Implications of Artificial Intelligence (AI) For Meaningful Work. Journal of Business Ethics, Springer Netherlands. 185: 725-740.

[6] Barker, N. and C. Jewitt (2022). Filtering Touch: An Ethnography of Dirt, Danger, and Industrial Robots. Journal of Contemporary Ethnography. 51: 103-130.

[7] Barker, N. and C. Jewitt (2023). Collaborative Robots and Tangled Passages of Tactile- Affects. ACM Transactions on Interactive Intelligent Systems. 12.

[8] Bellesia, F., E. Mattarelli and F. Bertolotti (2023). Algorithms and their Affordances: How Crowdworkers Manage Algorithmic Scores in Online Labour Markets. Journal of Management Studies. 60: 1-37.

[9] Berry, P., & Franks, T. J. (2010). Women in the World of Corporate Business: Looking at the Glass Ceiling. Contemporary Issues in Education Research, 3(2), 1-10.

Co-funded by the European Union

[10] Bijker, W. E., Huges, T. P., & Trevor, P. (2012). Social construction of technological systems. MIT Press.
[11] Blau, F. D., & Kahn, L. M. (2000). Gender differences in pay. Journal of Economic perspectives, 14(4), 75-100.
[12] Blau, F. D., & Kahn, L. M. (2017). The gender wage gap: Extent, trends, and explanations. Journal of economic literature, 55(3), 789-865.
[13] Bossen, C. and K. H. Pine (2023). Batman and Robin in Healthcare Knowledge Work: Human-AI Collaboration by Clinical Documentation Integrity Specialists. ACM Transactions on Computer-Human Interaction. 30.
[14] Brynjolfsson, E., & McAfee, A. (2014). The second machine age: Work, progress, and prosperity in a time of brilliant technologies. WW Norton & company.
[15] Busch, F. (2020). Gender segregation, occupational sorting, and growth of wage disparities between women. Demography, 57(3), 1063-1088.
[16] Butchart, J., R. Harrison, J. Ritchie, F. Martí, C. McCarthy, S. Knight and A. Scheinberg (2021). Child and parent perceptions of acceptability and therapeutic value of a socially assistive robot used during pediatric rehabilitation. Disability and Rehabilitation, Taylor & Francis. 43: 163-170.
[17] Buxton, B. (2010). Sketching user experiences: getting the design right and the right design. Morgan kaufmann.
[18] Cannito, M. (2020). The influence of partners on fathers' decision-making about parental leave in Italy: Rethinking maternal gatekeeping. Current Sociology, 68(6), 832-849.
[19] Carreri, A., G. Gosetti and N. Masiero (2023). Digitalization of relational space in the service triangle: The case study of retail banking. Frontiers in Sociology. 8.
[20] Charalambous, G., Fletcher, S., & Webb, P. (2016). Development of a human factors roadmap for the successful implementation of industrial human-robot collaboration. Advances in Intelligent Systems and Computing,
[21] Charles, M., & Bradley, K. (2009). Indulging our gendered selves? Sex segregation by field of study in 44 countries. American journal of sociology, 114(4), 924-976.
[22] Cheatle, A., H. Pelikan, M. Jung and S. Jackson (2019). Sensing (Co)operations: Articulation and compensation in the robotic operating room. Proceedings of the ACM on Human-Computer Interaction. 3.
[23] Chen, J. Y. C., & Barnes, M. J. (2014). Human - Agent teaming for multirobot control: A review of human factors issues [Article]. IEEE Transactions on Human-Machine Systems, 44(1), 13-29, Article 6697830.
[24] Chevallier, M. (2023). Staging Paro: The care of making robot(s) care. Social Studies of Science. 53: 635-659.
[25] Chua, W. F., J. Graaf and K. Kraus (2022). Mapping and contesting peer selection in digitalized public sector benchmarking. Financial Accountability and Management. 38: 223-251.
[26] Ciciolla, L., & Luthar, S. S. (2019). Invisible household labour and ramifications for adjustment: Mothers as captains of households. Sex Roles, 81(7), 467-486.
[27] Cockburn, C., & Ormrod, S. (1993). Gender and Technology in the Making. SAGE Publications Ltd.
[28] Coeckelbergh, M. (2010). Health care, capabilities, and AI assistive technologies. Ethical Theory and Moral Practice. 13: 181-190. 16

[29] Coeckelbergh, M. (2023). Democracy, epistemic agency, and AI: political epistemology in times of artificial intelligence. AI and Ethics, Springer International Publishing. 3: 1341-1350.
[30] Corcoran-Nantes, Y., & Roberts, K. (1995). 'We've Got One of Those': The Peripheral Status of Women in Male Dominated Industries. Gender, Work & Organization, 2(1), 21-33.
[31] Cooper, A. (1999). The inmates are running the asylum (pp. 17-17). Vieweg+ Teubner Verlag.
[32] Dahlerup, D. (2006). The story of the theory of critical mass. Politics & Gender, 2(4), 511-522.
[33] Daniels, A. K. (1987). Invisible work. Social Problems, 34(5), 403-415.
[34] Day, D. V., Riggio, R. E., Tan, S. J., & Conger, J. A. (2021). Advancing the science of 21st-century leadership development: Theory, research, and practice. In (Vol. 32, pp. 101557): Elsevier.
[35] Deloitte. (2020). Women at the wheel: Diversity in the automotive industry.
[36] Dornelles, J. d. A., Ayala, N. F., & Frank, A. G. (2023). Collaborative or substitutive robots? Effects on workers' skills in manufacturing activities. International Journal of Production Research, 61(22), 7922-7955.
[37] Duggan, J., U. Sherman, R. Carbery and A. McDonnell (2022). Boundaryless careers and algorithmic constraints in the gig economy. International Journal of Human Resource Management, Routledge. 33: 4468-4498.
[38] Ely, R. J., & Meyerson, D. E. (2000). Theories of gender in organizations: A new approach to organizational analysis and change. Research in organizational behavior, 22, 103-151.
[39] EU (2021). Proposal for a Regulation of the European Parliament and of the Council laying down harmonised rules on Artificial Intelligence (Artificial Intelligence Act) and amending certain Union legislative acts, Brussels, Belgium.
[40] Faulkner, W. (2001). The technology question in feminism: A view from feminist technology studies. Women's studies International Forum,
[41] Faulkner, W. (2015). 'Nuts and Bolts and People'Gender Troubled Engineering Identities. Engineering Identities, Epistemologies and Values: Engineering Education and Practice in Context, Volume 2, 23-40.
[42] Floridi, L., J. Cowls, M. Beltrametti, R. Chatila, P. Chazerand, V. Dignum, C. Luetge, R. Madelin, U. Pagallo, F. Rossi, B. Schafer, P. Valcke and E. Vayena (2018). AI4People—An Ethical Framework for a Good AI Society: Opportunities, Risks, Principles, and Recommendations. Minds and Machines, Springer Netherlands. 28: 689-707.
[43] Forum, W. E. (2024). Global Gender Gap Report 2024.
[44] Fry, R., Kennedy, B., & Funk, C. (2021). STEM jobs see uneven progress in increasing gender, racial and ethnic diversity. Pew Research Center, 1.
[45] Gkinko, L. and A. Elbanna (2022). Hope, tolerance and empathy: employees' emotions when using an AI-enabled chatbot in a digitalised workplace. Information Technology and People. 35: 1714-1743.
[46] Gornick, J. C., & Heron, A. (2020). The regulation of working time as work-family reconciliation policy: Comparing Europe, Japan, and the United States. In Policy Sectors in Comparative Policy Analysis Studies (pp. 239-256). Routledge.

[47] Gothelf, J. (2013). Lean UX: Applying lean principles to improve user experience. " O'Reilly Media, Inc.".
[48] Harding, S. (1991). Whose science? Whose knowledge?: Thinking from women's lives. Cornell University Press.
[49] Hart, S. G. (2006, October). NASA-task load index (NASA-TLX); 20 years later. In Proceedings of the human factors and ergonomics society annual meeting (Vol. 50, No. 9, pp. 904-908). Sage CA: Los Angeles, CA: Sage publications.
[50] Hentout, A., Aouache, M., Maoudj, A., & Akli, I. (2019). Human–robot interaction in industrial collaborative robotics: a literature review of the decade 2008–2017. Advanced Robotics, 33(15-16), 764-799.
[51] Heshmati, A., Honkaniemi, H., & Juárez, S. P. (2023). The effect of parental leave on parents' mental health: a systematic review. The Lancet Public Health, 8(1), e57-e75.
[52] Holgersson, C. (2013). Recruiting managing directors: Doing homosociality. Gender, Work & Organization, 20(4), 454-466.
[53] Ibarra, H. (1992). Homophily and differential returns: Sex differences in network structure and access in an advertising firm. Administrative science quarterly, 422-447.
[54] Islam, M. U. and B. M. Chaudhry (2023). A Framework to Enhance User Experience of Older Adults With Speech-Based Intelligent Personal Assistants. IEEE Access, IEEE. 11: 16683-16699.
[55] James, A. (2023). Platform work-lives in the gig economy: Recentering work–family research. Gender, Work and Organization: 1-22.
[56] Javaid, M., Haleem, A., Singh, R. P., & Suman, R. (2021). Substantial capabilities of robotics in enhancing industry 4.0 implementation. Cognitive Robotics, 1, 58-75.
[57] Jeon, J. (2021). Exploring AI chatbot affordances in the EFL classroom: young learners' experiences and perspectives. Computer Assisted Language Learning, Routledge. 37: 1- 26.
[58] Kablan, A. (2020). Dark Factories from an Industry 4.0 Perspective: Its Effects on Cost Accounting and Managerial Accounting. Digital Business Strategies in Blockchain Ecosystems: Transformational Design and Future of Global Business, 503-518.
[59] Kang, E. Y. and S. E. Fox (2022). Stories from the Frontline: Recuperating Essential Worker Accounts of AI Integration. DIS 2022 - Proceedings of the 2022 ACM Designing Interactive Systems Conference: Digital Wellbeing: 58-70.
[60] Karyotaki, M., Bakola, L., Drigas, A., & Skianis, C. (2022). Women's Leadership via Digital Technology and Entrepreneurship in business and society. Technium Soc. Sci. J., 28, 246.
[61] Katsardis, A., & Aman, R. (2024). Gender Equality at Work: Tackling Gender Inequality in Senior Leadership in the Automotive Aftermarket Industry. In Automotive Aftermarket: Global and Interdisciplinary Perspectives (pp. 167-192). Springer.
[62] Kaur, D., S. Uslu, K. J. Rittichier and A. Durresi (2023). Trustworthy Artificial Intelligence: A Review. ACM Computing Surveys. 55: 1-38.

[63] Kossek, E. E., Su, R., & Wu, L. (2017). “Opting out” or “pushed out”? Integrating perspectives on women’s career equality for gender inclusion and interventions. Journal of Management, 43(1), 228-254.
[64] Krenz, W. (2022). A Manufactured Gender Imbalance.
[65] Kurzweil, R. (2005). The singularity is near. In Ethics and emerging technologies (pp. 393-406). Springer.
[66] Latour, B., & Porter, C. (1996). Aramis, or, The love of technology (Vol. 1996). Harvard University Press Cambridge, MA.
[67] Lehtiniemi, T. (2023). Contextual social valences for artificial intelligence: anticipation that matters in social work. Information Communication and Society: 1-16.
[68] Liu, C. and R. Graham (2021). Making sense of algorithms: Relational perception of contact tracing and risk assessment during COVID-19. Big Data and Society. 8.
[69] Lusardi, R., S. Tomelleri and J. Wherton (2021). Living With Assistive Robotics: Exploring the Everyday Use of Exoskeleton for Persons With Spinal Cord Injury. Frontiers in Medical Technology. 3: 1-6.
[70] MacKenzie, D., & Wajcman, J. (1999a). The social shaping of technology. Open university press.
[71] MacKenzie, D., & Wajcman, J. (1999b). The social shaping of technology. Open university press.
[72] Misra, J., Budig, M. J., & Moller, S. (2020). Reconciliation policies and the effects of motherhood on employment, earnings and poverty. In Policy Sectors in Comparative Policy Analysis Studies (pp. 204-224). Routledge.
[73] Möhlmann, M., C. Alves de Lima Salge and M. Marabelli (2022). Algorithm Sensemaking: How Platform Workers Make Sense of Algorithmic Management. Journal of the Association for Information Systems. 24: 35-64.
[74] Nimrod, G. and Y. Edan (2022). Technology Domestication in Later Life. International Journal of Human-Computer Interaction, Taylor & Francis. 38: 339-350.
[75] Norman, D. (2013). The design of everyday things: Revised and expanded edition. Basic books.
[76] Obidat, O. and Wang, W., "TELL ME YOUR FEELINGS: Characterization and Analysis of Human Comfort in Human-Robot Collaborative Manufacturing Contexts," 2021 6th International Conference on Control, Robotics and Cybernetics (CRC), Shanghai, China, 2021, pp. 165-169, doi: 10.1109/CRC52766.2021.9620158.
[77] Omoniyi, A., C. Trask, S. Milosavljevic and O. Thamsuwan (2020). Farmers’ perceptions of exoskeleton use on farms: Finding the right tool for the work(er). International Journal of Industrial Ergonomics, Elsevier B.V. 80: 103036.
[78] Ostrowski, A. K., C. Breazeal and H. W. Park (2022). Mixed-Method Long-Term Robot Usage: Older Adults' Lived Experience of Social Robots. ACM/IEEE International Conference on Human-Robot Interaction, IEEE. 2022-March: 33-42.
[79] Oudshoorn, N., & Pinch, T. (2005). How users matter: The co-construction of users and technology. MIT press.
[80] Padavic, I., Ely, R. J., & Reid, E. M. (2020). Explaining the persistence of gender inequality: The work–family narrative as a social defense against the 24/7 work culture. Administrative science quarterly, 65(1), 61-111.

[81] Paluch, R. and C. Müller (2022). "That's Something for Children". Proceedings of the ACM on Human-Computer Interaction. 6: 1-35.
[82] Pepping, A., & Maniam, B. (2020). The Motherhood Penalty. Journal of Business & Behavioral Sciences, 32(2).
[83] Pereira, G. and C. Raetzsch (2022). From Banal Surveillance to Function Creep: Automated License Plate Recognition (ALPR) in Denmark. Surveillance and Society. 20: 265-280.
[84] Perrotta, C., N. Selwyn and C. Ewin (2022). Artificial intelligence and the affective labour of understanding: The intimate moderation of a language model. New Media and Society.
[85] Petts, R. J., & Knoester, C. (2020). Are parental relationships improved if fathers take time off of work after the birth of a child? Social Forces, 98(3), 1223-1256.
[86] Pitardi, V., J. Wirtz, S. Paluch and W. H. Kunz (2022). Service robots, agency and embarrassing service encounters. Journal of Service Management. 33: 389-414.
[87] Popan, C. (2021). Embodied Precariat and Digital Control in the “Gig Economy”: The Mobile Labor of Food Delivery Workers. Journal of Urban Technology. 0: 1-20.
[88] Pridmore, J. and A. Mols (2020). Personal choices and situated data: Privacy negotiations and the acceptance of household Intelligent Personal Assistants. Big Data and Society. 7.
[89] Pruitt, J., & Adlin, T. (2010). The persona lifecycle: keeping people in mind throughout product design. Elsevier.
[90] Read, E., C. Woolsey, C. A. McGibbon and C. O'Connell (2020). Physiotherapists' Experiences Using the Ekso Bionic Exoskeleton with Patients in a Neurological Rehabilitation Hospital: A Qualitative Study. Rehabilitation Research and Practice. 2020.
[91] Ridgeway, C. L. (2001). Gender, status, and leadership. Journal of Social issues, 57(4), 637-655.
[92] Rogers, E. M., Singhal, A., & Quinlan, M. M. (2014). Diffusion of innovations. In An integrated approach to communication theory and research (pp. 432-448). Routledge.
[93] Rudnik, J. and R. Brewer (2023). Care and Coordination in Algorithmic Systems: An Economies of Worth Approach. ACM International Conference Proceeding Series: 627- 638.
[94] Sankaran, S. and P. Markopoulos (2021). "it's like a puppet master": User perceptions of personal autonomy when interacting with intelligent technologies. UMAP 2021 - Proceedings of the 29th ACM Conference on User Modeling, Adaptation and Personalization: 108-118.
[95] Sarah, C., & Mona, L. K. (2008). Critical mass theory and women's political representation. Political studies, 56(3), 725-736.
[96] Sauppé, A., & Mutlu, B. (2015). The Social Impact of a Robot Co-Worker in Industrial Settings.
[97] Schmidbauer, C., Zafari, S., Hader, B., & Schlund, S. (2023). An Empirical Study on Workers' Preferences in Human-Robot Task Assignment in Industrial Assembly Systems [Article]. IEEE Transactions on Human-Machine Systems, 53(2), 293-302.
[98] Schmidtler, J., Knott, V., Hoelzel, C., & Bengler, K. (2015). Human Centred Assistance Applications for the working environment of the future. Occupational Ergonomics, 12, 83-95.

[99] Schwartz, S. A. and M. S. Mahnke (2021). Facebook use as a communicative relation: exploring the relation between Facebook users and the algorithmic news feed. Information Communication and Society. 24: 1041-1056.
[100] Sergeeva, A. V., S. Faraj and M. Huysman (2020). Losing Touch: An embodiment perspective on coordination in robotic surgery. Organization Science. 31: 1248-1271.
[101] Silverstone, R. and E. Hirsch (1992). Consuming Technologies: Media and Information in Domestic Spaces. London, UK, Routledge: 225.
[102] Simone, V. D., V. D. Pasquale, V. Giubileo and S. Miranda (2022). Human-Robot Collaboration: an analysis of worker's performance. Procedia Computer Science, Elsevier B.V. 200: 1540-1549.
[103] Skjuve, M., A. Følstad, K. I. Fostervold and P. B. Brandtzaeg (2021). My Chatbot Companion - a Study of Human-Chatbot Relationships. International Journal of Human Computer Studies. 149.
[104] Smith, L. (2013). Working hard with gender: Gendered labour for women in male dominated occupations of manual trades and information technology (IT). Equality, diversity and inclusion: An international journal, 32(6), 592-603.
[105] Stahl, B. C. and D. Wright (2018). Ethics and Privacy in AI and Big Data: Implementing Responsible Research and Innovation. IEEE Security & Privacy, IEEE. 16: 26-33.
[106] Stevens, M. and A. Beaulieu (2023). A careful approach to artificial intelligence: the struggles with epistemic responsibility of healthcare professionals. Information Communication and Society: 1-16.
[107] Susskind, D. (2020). A world without work: Technology, automation and how we should respond. Penguin UK.
[108] Swart, J. (2021). Experiencing Algorithms: How Young People Understand, Feel About, and Engage With Algorithmic News Selection on Social Media. Social Media and Society. 7.
[109] Tarafdar, M., X. Page and M. Marabelli (2023). Algorithms as co-workers: Human algorithm role interactions in algorithmic work. Information Systems Journal. 33: 232- 267.
[110] Utzeri, M. (2015). The double-edged sword of gender equality programmes a comparative case study at the management of a German and a French auto manufacturer.
[111] Wajcman, J. (2000). Reflections on gender and technology studies: In what state is the art? Social Studies of Science, 30(3), 447-464.
[112] Wajcman, J. (2010). Feminist theories of technology. Cambridge journal of Economics, 34(1), 143-152.
[113] West, C., & Zimmerman, D. H. (1987). Doing gender. Gender & society, 1(2), 125-151.
[114] Williams, C. L., Muller, C., & Kilanski, K. (2012). Gendered organizations in the new economy. Gender & society, 26(4), 549-573.
[115] Williams, J., Boyle, J., Davis, A., Ertman, M., Polikoff, N., Silbaugh, K. B., White, L., Carle, S., & Volpp, L. (2000). Unbending gender: Why work and family conflict and what to do about it. American University Law Review, 49, 943.
[116] Woodhams, C., Trojanowski, G., & Wilkinson, K. (2022). Merit sticks to men: gender pay gaps and (In) equality at UK Russell Group Universities. Sex Roles, 86(9), 544-558.

[117] Woolgar, S., & Cooper, G. (1999). Do Artefacts Have Ambivalence: Moses' Bridges, Winner's Bridges and other Urban Legends in S&TS. Social Studies of Science, 29(3), 433-449.
[118] Wray, D. (2020). Paternity leave and fathers' responsibility: Evidence from a natural experiment in Canada. Journal of Marriage and Family, 82(2), 534-549.
[119] Wu, X., Q. Liu, H. Qu and J. Wang (2023). The effect of algorithmic management and workers' coping behavior: An exploratory qualitative research of Chinese food-delivery platform. Tourism Management, Elsevier Ltd. 96: 104716.
[120] Ye, Y., You, H., & Du, J. (2023). Improved Trust in Human-Robot Collaboration With ChatGPT [Article]. Ieee Access, 11, 55748-55754. https://doi.org/10.1109/ACCESS.2023.328211
[121] Yolgormez, C. and J. Thibodeau (2022). Socially robotic: making useless machines. AI & SOCIETY, Springer London. 37: 565-578

7 APPENDIX

7.1 INTERVIEW QUESTIONS FOR OPERATORS

Interviewees: Production line workers in the automotive industry.

7.1.1 INTRODUCTION

- What is your role on the production line?
- Can you describe your main job responsibilities?
- How long have you been working at this workplace? What are the most significant changes or developments you have observed during your time here?
- What is your employment status? (full-time, part-time, temporary, etc.)

7.1.2 WORK

- Can you describe your work in more detail?
- What does a typical workday look like?
- Do you mostly work alone, or do you collaborate with colleagues?
- Who do you collaborate with to perform your job, and how does this collaboration function?
- Do you generally receive support from your immediate manager at work?
- Can you give an example of a time when this support was particularly helpful?
- Do you feel that your knowledge and skills are valued?
- Can you provide examples where your skills were crucial for your work?
- Do you have opportunities to learn new things in your job?
- Can you provide examples of new things you have recently learned?
- Are there any aspects of your job that you particularly appreciate?
- Have you participated in development activities, such as training or courses, in the past year?
- What training opportunities have been available to you?

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7.1.3 TECHNOLOGY

- Do you use automated systems in your daily work?
- If yes, for what purposes do you use them?
- Can you explain how these systems make your job easier?
- Do you use robots in your daily work?
- If yes, for what purposes do you use them?
- Can you explain how robots impact your workload?
- Can you provide examples of how automation has affected your productivity?
- How interested do you consider yourself in using automated systems? Robots? Artificial Intelligence?
- Can you see specific advantages of these technologies?
- In general, what do you see as the advantages of automation in the automotive industry? Robots? Artificial Intelligence?
- Have you noticed any disadvantages?
- What do you see as the advantages of automation in your specific field? The use of robots? Artificial Intelligence?
- Have you observed any challenges that automation may bring? Robots? Artificial Intelligence?
- In the past year, have you received any specific training to improve your ability to use automated systems? Robots? Artificial Intelligence?
- Can you describe some of the training programs or initiatives you have participated in?

7.1.4 ETHICS AND FUTURE OUTLOOK

- What advantages do you think increased automation can bring to the automotive industry in terms of product quality and efficiency? Artificial Intelligence? Robots?
- How do you think automation will impact employment opportunities in the automotive industry in the short and long term? Artificial Intelligence? Robots?

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- What challenges and risks do you see associated with increased automation in the automotive industry, and how do you think these can be addressed? Artificial Intelligence? Robots?

7.1.5 GENDER AND DIVERSITY

- Can you summarise the gender distribution among employees?
- What are the most common job roles for men and women in the organization?

7.1.6 CONCLUSION

- Is there anything else that comes to mind regarding automation, AI, and robots?

7.2 INTERVIEW QUESTIONS FOR DECISION MAKERS

Interviewees: Decision-makers in the automotive industry regarding automation and robotics (e.g., managers)

7.2.1 INTRODUCTION

- What is your position in the automotive industry, and what is your responsibility in the decision-making process related to automation and robotics?
- As a decision-maker or union representative, can you provide a general overview of your main responsibilities and duties in this context?
- How long have you been in your current position, and what are the most significant changes and advancements in automation, robotics, and AI you have observed during your tenure?
- What type of employment do you have – full-time, part-time, temporary, or other?

7.2.2 WORK

- Can you describe in more detail your role in shaping company strategy and decision-making regarding the use of automation, robotics, and AI in the automotive industry?
- Can you provide information about the decisions and policies that influence the use of automation systems, robotics, and AI?
- How do you ensure the implementation of decisions and track their impacts?
- How do you address issues related to time constraints and workload for employees in the context of automation?
- Can you describe your interactions with colleagues and stakeholders involved in the decision-making process for automation and robotics?
- How do you optimise the use of automation and robotic technology across different departments and stakeholders?
- To what extent do employees participate in decision-making regarding their work tasks and conditions? Can you provide examples?
- What do you think about the impact of automation, robotics, and AI on job flexibility and variety?
- What is your personal perspective on the use of automation systems, robotics, and AI in the automotive industry?
- As a decision-maker or union representative, what are the benefits of these technologies within the organization?
- What do you think about the contribution of automation and robotics to improving product quality and efficiency?
- What potential challenges and risks associated with increasing automation, robotics, and AI have you identified?
    - How do you address these issues?

- What strategies do you think are necessary for a smooth transition to a more automated automotive industry?
- How have you addressed employees' workload and work environment concerning automation, robotics, and AI? Have you initiated discussions on these topics?

7.2.3 CONCLUSION

- Finally, is there anything else you would like to add or consider regarding automation, robotics, and AI in the automotive industry?

7.3 INTERVIEW QUESTIONS FOR DEVELOPERS

Interviewees: Developers and researchers working on automation, robotics, and AI for the automotive industry

7.3.1 INTRODUCTION

- What is your position?
- Can you provide examples of specific projects or tasks you are currently working on?
- What are the specific objectives you are working towards, and what challenges have you encountered?
- How long have you been working in your current field?
- What are the most significant developments or advancements you have observed throughout your career?
- Can you provide examples of how these developments have affected your work and society in general?
- What is your type of employment (e.g., academic, industrial, or another type)?
- Which organizations or companies have you previously worked for?
- How have your previous jobs shaped your current role?

7.3.2 WORK AND TECHNOLOGY

- Can you describe your work in automation, robotics, and artificial intelligence in more detail? What are the most complex technical challenges you have encountered recently?
- What does a typical workday look like for you as a developer or researcher?
- Can you share some specific tasks you focus on and how much time you dedicate to them?
- How are these tasks related to your current project or goals?
- Do you generally have enough time to complete your tasks in your work process?

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- Can you provide examples of situations where time constraints were a challenge?
- How do you manage these challenges?
- Do you collaborate with colleagues or other researchers in your work?
- Can you explain how this collaboration works?
- How does collaboration impact your work process and results?
- What are your thoughts on the impact of automation, robotics, and artificial intelligence on workload and productivity in the automotive industry?
- Can you provide examples of projects where these technologies have made a noticeable difference?
- In general, what do you think are the main advantages of using automation, robotics, and artificial intelligence in the automotive industry?
- What challenges have you encountered related to automation? Robotics? Artificial Intelligence?
- Can you provide examples of situations where automation has improved work processes and/or working conditions?
- Can you provide examples of situations where automation has worsened work processes and/or working conditions?
- How do you assess the practical impact of these technologies on factory/production line work?
- What advantages do you think increased automation and artificial intelligence bring in terms of product quality and efficiency?
- Can you provide examples of projects where these advantages have been particularly evident?
- How do you think automation will affect working conditions in the short and long term?
- What challenges and risks do you associate with increased automation?
- How can these challenges and risks be managed?
- Are you aware of concrete strategies or technical solutions developed to mitigate these risks?

- How do you see the future of automation, robotics, and artificial intelligence in the automotive industry?
- Looking ahead, which specific research or technology areas do you think will be most important?
- Do you have any thoughts on how research and development can support a smooth transition to a more automated future?

7.3.3 CONCLUSION

- Do you have any additional thoughts or ideas related to automation, robotics, and artificial intelligence in your field of work and research?