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COLLABORATIVE ASSESSMENT OF AUTOMATION TECHNOLOGIES FROM THE WORK PERSPECTIVE

Yuri Oliveira de Lima

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Orientador(es): Jano Moreira de Souza

António Brandão Moniz

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Orientadores: Jano Moreira de Souza
António Brandão Moniz

Aprovada por: Prof. Jano Moreira de Souza
Prof. António Brandão Moniz
Profª. Ana Cristina Bicharra Garcia
Profª. Julia Celia Mercedes Strauch
Prof. Carlos Frederico Leão Rocha
Prof. Geraldo Bonorino Xexéo

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AVALIAÇÃO COLABORATIVA DE TECNOLOGIAS DE AUTOMAÇÃO SOB A PERSPECTIVA DO TRABALHO

Yuri Oliveira de Lima

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Orientadores: Jano Moreira de Souza
António Brandão Moniz

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O trabalho é um aspecto central da vida humana, pois é um meio para obter recursos financeiros e relevância social. Tecnologias sempre foram criadas para auxiliar o trabalho humano em tarefas específicas ou torná-las desnecessárias. No longo prazo, as tecnologias impactaram positivamente o trabalho e, em geral, trouxeram benefícios para a sociedade. No entanto, as primeiras gerações de trabalhadores que lidaram com a adoção de novas tecnologias tiveram seus empregos impactados negativamente. Os sistemas de computação podem ser usados não apenas para automatizar o trabalho, mas também para ajudar no processo de adoção responsável da automação. Esta tese propõe o desenvolvimento de um modelo que permite a avaliação colaborativa do impacto das tecnologias de automação no trabalho. Dois modelos são desenvolvidos usando a metodologia Soft Design Science Research. O primeiro usa crowd computing para avaliar o impacto das tecnologias de automação nas ocupações. O segundo usa groupware para avaliar de forma colaborativa o impacto de uma determinada tecnologia em uma ocupação em uma empresa. Os resultados da tese mostram diferentes oportunidades para a aplicação do Trabalho Cooperativo Suportado por Computador em apoio à Avaliação de Tecnologia colaborativa da automação a partir da perspectiva do trabalho.

Abstract of Thesis presented to COPPE/UFRJ as a partial fulfillment of the requirements for the degree of Doctor of Science (D.Sc.)

COLLABORATIVE ASSESSMENT OF AUTOMATION TECHNOLOGIES FROM THE WORK PERSPECTIVE

Yuri Oliveira de Lima

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Advisors: Jano Moreira de Souza
António Brandão Moniz

Department: Computer and Systems Engineering

Work is a central aspect of human life because it is a means to obtain financial resources and social relevance. Technologies have always been created to help human labor with specific tasks or even make them unnecessary. In the long run, technologies positively impacted work and, in general, brought benefits to society. However, the first generations of workers that face the adoption of new technologies had their jobs negatively impacted. Computing systems can be used not only to automate work but also to help in the process of responsibly adopting automation. This thesis proposes the development of a model that allows the collaborative assessment of the impact of automation technologies on work. Two models are developed using the Soft Design Science Research methodology. The first one uses crowd computing to survey the impact of automation technologies on occupations. The second one uses groupware to collaboratively assess the impact of a given technology on an occupation in a company. The results of the thesis show different opportunities for the application of Computer-supported Cooperative Work in support of the collaborative Technology Assessment of automation from the perspective of work.

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List of Abbreviations

AHP	Analytic Hierarchy Process
CAGED	General Register Of Employees and Unemployed
CBO	Brazilian Classification of Occupations
CSCW	Computer-Supported Cooperative Work
DS	Design Science
DSR	Design Science Research
FTA	Future-oriented Technology Analysis
ICT	Information and Computation Technology
ILO	International Labour Organization
IS	Information Systems
MCDM	Multi-Criteria Decision Making
NACS	National Association of Convenience Stores
OTA	Office of Technology Assessment
pTA	Participatory Technology Assessment
RAIS	Annual Report of Social Information
SDSR	Soft Design Science Research
STEM	Science, Technology, Engineering, and Mathematics
TA	Technology Assessment
TRL	Technology Readiness Level

“If it weren’t for the people, the goddamn people” said Finnerty, “always getting tangled up in the machinery. If it weren’t for them, the world would be an engineer’s paradise.”

Kurt Vonnegut – Player Piano

Thou aimest high, Master Lee. Consider *thou* what the invention could do to my poor subjects. It would assuredly bring to them ruin by depriving them of employment, thus making them beggars.

Queen Elizabeth I

"You must have a vast and magnificent estate," said Candide to the Turk.

"I have only twenty acres," replied the old man; "I and my children cultivate them; our labour preserves us from three great evils – weariness, vice, and want."

Voltaire – Candide

1. Introduction

1.1 Background

As we enter the 4th Industrial Revolution, changes to work are expected to intensify. We are already seeing some of these changes as car-hailing companies dispute the industry with taxi drivers, advances in AI and robotics make us question the limits of machines, and *e*-commerce giants make traditional stores file for bankruptcy.

Amidst this turbulence, non-standard employment grows and becomes the new standard in some countries like Brazil. Unions are slow to adapt to the new world of work, and governments follow suit. Workers go through a representation crisis and, even worse, suffer the consequences of the new business models and automation.

In the long-run, economics teaches us we should not worry because technological change is positive for employment, and automation tends to free humans from the burden of lesser activities (AUTOR, 2015). Still, concerns with the short term are genuine and it would be risky to dismiss them as Neo-Luddism.

If we are to build a better society with the help of new technologies, a joint effort from companies, government, unions, and individuals is necessary. Companies are able to discover and responsibly integrate new technologies into their production. Governments can drive the investment in research and innovation while helping workers to adapt to the changes provoked by technology. Unions are being increasingly pressured to reinvent themselves to help to organize workers that are impacted by automation or are subject to questionable "modern" work relations. Finally, workers have to keep themselves informed and educated about new technologies to remain relevant for the labor market.

As can be seen, much work is needed in order to successfully adopt new technologies while bringing benefits to society as a whole and this thesis brings a small contribution to this necessary effort by discussing the impact of automation and proposing models to collaboratively assess the impact of automation technologies on work.

1.2 Relevance

The relevance of this thesis can be seen from three perspectives of the relationship between work and technology: legal, political/economic, and academic.

Article 7 of the Brazilian Constitution establishes the rights of the urban and rural workers, and, among them, in Item XXVII is the right to "protection against automation" (BRAZIL, 2018). Still, as it happens to many constitutional rights in Brazil, the right of a worker to be protected from the introduction of new technologies to production is mainly ignored as there is little to no control over this process, and workers tend to be alienated from the decision process of technology adoption (BRAZIL, 2014).

This protection in the case of automation is highly needed as irresponsible automation can worsen the economic situation in Brazil. A situation already worrisome as the unemployment rate in the trimester ended in July 2020 was 13.8%, the highest rate since the survey began in 2012. The COVID-19 pandemic has been making this scenario even worse as the number of unemployed people raised by 27.6% from 10.1 million in May to 12.9 million in August. Another unprecedented number that was reached during the pandemic was that more than half of the working-age population did not have a job, a group that comprises the unemployed and the population out of the workforce, those that did not seek a job in the 30 days before the survey. The high unemployment is not only an effect of the recent pandemic, as the unemployment rate is above 10% since 2016 (IBGE, 2020).

If the current situation is complicated, the future is equally challenging, as 60% of Brazilian workers have a high risk of automation in the coming decades, as shown in Chapter 4. The Automation Readiness Index, calculated by The Economist Intelligence Unit (2018), which considers the innovation environment, education policies, and labor market policies of 25 countries, gives Brazil a 46.4 score (the average score is 62.1) putting the country in the 19th position. In the innovation environment category, Brazil stands in last place, in education policies, 17th place, and in labor market policies, 13th.

The academy has been making efforts in different research fields to help society to create new jobs and better deal with the adoption of new technologies. Since the dawn of computation, for instance, the consequences of automation are problematized (WIENER, 1960). The challenge of protecting society against the undesirable consequences of technology involves the simultaneous development of our understanding of such technologies and the evolution of the technologies themselves (WIENER, 1960).

Nowadays, this preoccupation is still alive as the IEEE includes in its Guidelines for Ethically Aligned Design, the issue of "Autonomous and Intelligent Systems neglecting the complexities of employment" and the "mismatch between the rate of technological change and workforce (re)training" (IEEE, 2017). Another contemporary example of the preoccupation of the academic community with the impact of technologies, the AI Open Letter – signed by over eight thousand people including researchers such as Stephen Hawking – includes the concern over AI adverse effects such as unemployment (FUTURE OF LIFE INSTITUTE, 2015).

1.3 Goal, Research Question, and Premisses

There is a dispute over several centuries between two economic theses regarding the impact of new technologies on labor (LIMA; SOUZA, 2017; MONIZ, 2013, 2014). The first thesis defends that the adoption of new technologies is likely to cause technological unemployment that is defined by Keynes (2010) as "unemployment due to our ability to find ways to save the use of work be greater than the ability to find new uses for work." Today, this theory has been defended by several authors who believe that the industrial revolution that we are going through is different from the previous ones and will cause an increase in unemployment (STRAWN, 2016).

The second thesis about the impact of new technologies is that, as has happened in recent centuries, introducing new technologies into production will make certain jobs obsolete as new jobs are created, with a given balance between the number of jobs destroyed and generated.

According to a Future Research about work in 2050, carried out by Laboratório do Futuro (2017), the concretization of each of these theses would lead us to different future scenarios. In the pessimistic scenario for the future of work, confident that technological unemployment would not be a problem, the social actors did not prepare themselves properly, causing an increase in unemployment and throwing part of the population into an economically useless class while a small elite owns the technological advances. In the optimistic scenario, the second thesis would be fulfilled because the social actors would recognize the need to retrain a portion of the workers unemployed by the technology to occupy new jobs.

The description of these two scenarios demonstrates that social mobilization to deal with the new technologies and their impacts is essential as unemployment can affect one, two, or more generations depending on how fast the society adapts.

In addition to the impact of the industrial revolution on the quantity and quality of jobs available, there is also an impact on organizations. Thus, understanding how new technologies modify the organization of work is necessary to evaluate their real impact and to make the necessary adaptations to the management and the production process (MONIZ; KRINGS, 2016). It is worth noting that the deployment of technologies such as robotics to production tends to increase the complexity of the productive system, raise productivity, and make any "unexpected event" have a significant impact on productivity (MONIZ, 2015; MONIZ; KRINGS, 2016; PFEIFFER, 2016). In Brazil and other developing countries such as India and China, the impact of new technologies on the production process is even more severe because companies in these countries are worse managed than those in developed countries (BLOOM, 2012).

Therefore, it is essential to carry out the Technological Assessment of these new technologies, which includes scientific research carried out through systematic methods of the consequences of the application of a given technology (GRUNWALD, 2009). This assessment can be used by the various actors capable of engendering social changes so that the technologies can be harnessed in the best way for Brazilian economic and social development. Legislators, entrepreneurs, workers, NGOs, judges are some examples of the actors who can find value in the evaluation of emerging technologies.

Given this context, the **goal** of this thesis is to develop a model that allows the collaborative assessment of the impact of automation technologies on work.

The thesis seeks to answer the following **research question**: can Computer-Supported Cooperative Work (CSCW) be used to help the participatory assessment of work-disruptive technologies?

The thesis is based on the three **premises** below.

1. Work is central to society and individuals;
2. When new technologies are applied to production, workers are the most impacted group;
3. Workers are the main specialists in terms of their own working activities.

1.4 Methodology

In order to achieve this goal, Design Science Research is used as the methodology. More specifically, the Soft Design Science Research approach to Design Science will be applied to generate the models that attend to the research goal.

1.5 Contributions

In summary, the contributions of this thesis are the following.

- A review of the academic literature about the future of work;
- An estimation of the impact of automation in Brazil;
- A proposal of a model supported by a crowdsourcing system to survey the impact of automation technologies on occupations;
- A proposal of a model supported by groupware to collaboratively assess the impact of an automation technology on a given occupation in a company;
- A proposal of an algorithm that calculates professional career pathways for workers considering the data available in Brazil;
- An evaluation of the Self-Checkout technology impact on the Cashier’s work;
- A technology forecasting about the future of convenience stores;
- Two examples of the application of the Soft Design Science Research approach.

1.6 Structure

The remainder of this work is organized as follows.

Chapter 2 presents Design Science Research which is the Methodology used in the thesis.

Chapter 3 presents the Literature Review. First, the Theoretical Background of the thesis that includes Technology Assessment, a discussion about Expertise & Knowledge, and Computer-Supported Cooperative Work is presented. Next, a literature review about the Future of Work is presented including its Social, and Work, and Organizational trends. Finally, recent literature about the impact of automation on work is reviewed.

Chapter 4 presents a study about the Impact of Automation in Brazil.

Chapter 5 discusses the proposal of the thesis and how the two models designed in the following chapters.

Chapters 6 and 7 present the first and second design cycles, respectively, that developed the two models proposed in the thesis.

Chapter 8 presents the contributions of the thesis, limitations of the work, and future work.

2. Methodology

This Chapter presents a discussion about the methodology used in this thesis. It starts with a presentation of the epistemology of Design Science (DS). It then explains the Design Science Research (DSR) paradigm and finishes with the description of different approaches to operationalize the paradigm with a focus on the Soft Design Science Research (SDSR), as summarized in Figure 1.

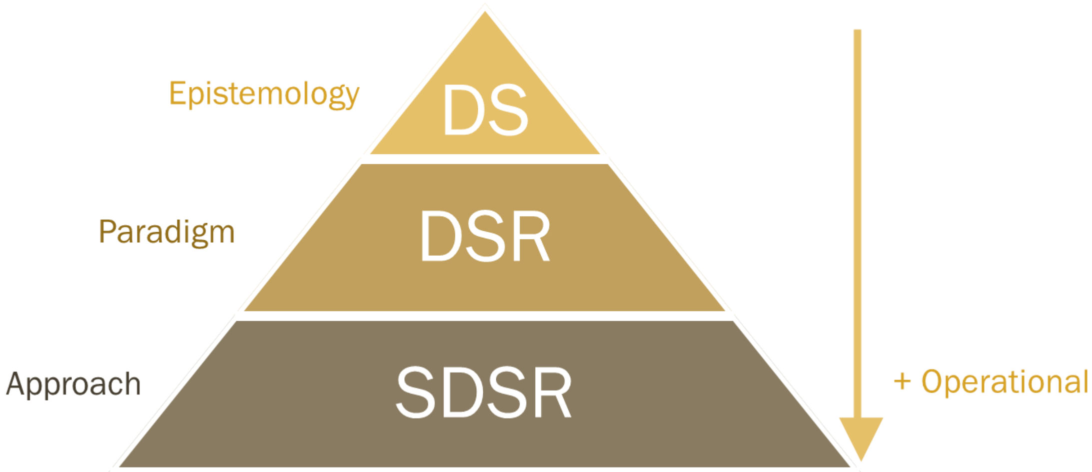

Figure 1: Hierarchy of the Design Science Methodology

2.1 Definition

In order to understand Design Science Research, it is necessary to explore its origins. First published in 1969, Herbert Simon's book titled "The Sciences of the Artificial" put forward the discussion of "the science of the design" that differed from natural and social sciences because of its focus on creating models rather than describing the universe around us (SIMON, 1996). Design Science Research (DSR) comes from this epistemological discussion being the research method applied by those who seek to develop a model to solve a real-world problem (DRESCH; LACERDA; JÚNIOR, 2015; HEVNER; CHATTERJEE, 2010).

According to Hevner & Chatterjee (2010), DSR is a research paradigm in which a researcher seeks to answer questions relevant to human problems by creating an innovative model. Both the designing process and the resulting model must contribute to the academic community.

DSR is a relatively new research paradigm, but it is already well-accepted in Information Systems (IS) being widely used to generate models while having its definition, methods, and evaluation techniques discussed and improved (ALTURKI; GABLE; BANDAR, 2011).

Hevner *et al.* (2004) developed a set of guidelines for using DSR in IS research, that – despite being focused on systems for organizations, which are not the case of this thesis – may present some valuable principles for conducting DSR and are described below.

Guideline 1: Design as a model. The result of DSR in IS must be an IT artifact that can be understood as the constructs, models, and methods used to develop and use the information system. By the end of the design, the artifact is not necessarily ready to be deployed but must be a reliable representation of the problem making the solution easily perceptible. Still, instantiations of the artifact are essential to demonstrate its viability in at least one situation.

Guideline 2: Problem Relevance. The objective of the research must be relevant not only to the academic community but to the end-users, producing changes in their reality that takes them closer to their goals.

Guideline 3: Design Evaluation. Design is an iterative and incremental activity. Evaluating the resulting artifact at the end of each iteration is essential to improve it. In any design cycle, the artifact features must be compared with its requirements being completed only when they are satisfied effectively.

Guideline 4: Research Contributions. A well-executed DSR must provide contributions to either the area of the design model and design methodology. In general, the resulting artifact is the primary research contribution of a DSR, but the design process may also provide relevant contributions to the foundations and methodology of DSR.

Guideline 5: Research Rigor. DSR efforts must use a knowledge base effectively to justify their decisions both of the theoretical foundations of the design and its research methodology that bring about the artifact.

Guideline 6: Design as a Search Process. In essence, the design is a search process for an effective solution that involves utilizing the available means to reach a desirable end while respecting the constraints of the environment. This demands knowledge about the application domain such as the requirements and constraints, and the solution domain which are the technical and organizational aspects of the proposed model. In this process, DSR involves the simplification of a problem and its decomposition in subproblems which will eventually evolve and expand to a more approximate representation of a given reality making the solution increasingly more relevant.

Guideline 7: Communication of Research. The communication of research must be twofold, satisfying both the technical community and the end-user community. The technical community must be provided with enough information about the model and its design process to allow for either repeatability of the research project in other contexts or improvement of the provided model. The end-users must have a clear understanding of the problem that the research was seeking to solve to evaluate if the solution can be implemented in their context.

2.2 Approaches

As DSR is a research paradigm, its principles and guidelines are too high-level to guide practice (ALTURKI; GABLE; BANDAR, 2011; BASKERVILLE; PRIES-HEJE; VENABLE, 2009; PEFFERS et al., 2007). Thus, several approaches have been proposed for DSR, or, as Dresch, Lacerda & Júnior (2015) call them, "methods formalized to operationalize research". Next, four approaches developed specifically for the IS research field will be briefly discussed in chronological order.

The **first** approach is called Information System Design Theory (ISDT) and was proposed by Walls, Widmeyer & El Sawy (1992) to be a predictive theory integrating normative and descriptive theories to design more effective systems.

The authors highlight that "design" is both a noun and a verb meaning that it is a product and a process. Consequently, a design theory must deal with two dependent aspects, one dealing with the product and the other one with the process. Each aspect of the theory is constituted of the following components:

- Design Product:
    1. Meta-requirements: describe the class of goals to which the theory can be applied;
    2. Meta-model: describes the class of models that can meet the meta-requirements;
    3. Kernel theories: the group of theories from natural and social sciences that govern the design requirements;

4. Testable design product hypothesis: the set of hypotheses that can be used to determine if the meta-design meets the meta-requirements of the design.

- Design Process:
  1. Design method: describes the procedures for the construction of the model;
  2. Kernel theories: the group of theories from natural and social sciences that govern the design process;
  3. Testable design process hypothesis: the set of hypotheses that can be used to determine if the design method results in a model consistent with the meta-design.

Walls, Widmeyer & El Sawy (1992) defend that the design process starts right after the problem identification. The design process is composed of several cycles, each involving increasingly detailed decision-making, and terminates when the end-user accepts the system.

Design Science Research Methodology (DSRM) is the **second** approach to DSR to be discussed here. It was put forward by Peffers *et al.* (2007) because they felt a need for a common framework for DSR in IS that constituted a process model for research and a mental model to allow readers and reviewers to identify and evaluate a DSR.

The authors considered that a methodology for DSR should be composed by three parts: a definition of DSR, practice rules, and a process for carrying it out. The last one, the process, was chosen as their focus for being underdeveloped in the literature. Peffers *et al.* (2007) write that the proposed process is not the only way to use DSR as a methodology, but represents a suggestion of an excellent way to undertake it.

By analyzing seven of the most important papers about DSR, Peffers *et al.* (2007) defined that DSRM involves the following activities:

1. *Problem identification and motivation:* define the problem, preferably by atomizing it to allow the solution to capture its complexity. Justify the value of a solution to the problem;
2. *Define the objectives for a solution:* considering the problem defined in the previous activity, determine the objectives that the solution must achieve;

3. *Design and development:* this activity involves the creation of the artifact, be it a construct, model, method, or instantiation;
4. *Demonstration:* here, the artifact must be tested for its capacity to solve one or more instances of the problem, which could be undertaken in several manners such as experimentation, simulation, or case study;
5. *Evaluation:* complementary to the previous activity, this one entails comparing the performance of the artifact in the demonstration with the objectives defined in activity two. If the designer is satisfied with the performance, the next activity can be done. Otherwise, the design process must iterate back to activity three;
6. Communication: the problem and its relevance, the design process, the artifact, and its effectiveness must be communicated to the academic and other interested communities.

Peffers *et al.* (2007) highlight that researchers are not expected to follow each of these activities sequentially and the process could be started at almost any step.

The **third** approach described here is called Soft Design Science Research (SDSR) and was proposed by Baskerville, Pries-Heje & Venable (2009). The authors defend that, despite the iterative character of the DSR paradigm, the DSR has been mostly regarded as episodic. They believe that this happens because Engineering and Computer Science anchor theory to a set of specifications so complex that the construction process of the artifact becomes equally complicated and expensive, making revisions to the artifact after evaluation so costly that they are not undertaken.

In order to make DSR iterative, Baskerville, Pries-Heje & Venable (2009) propose that the design and the artifact "must necessarily be simpler, less complex, and less costly if the process is to be repeated multiple times". Therefore, the authors emphasize the importance of prototyping in SDSR. The simplest form of the prototype being a mock-up prototype that models the physical aspects of the artifact.

The SDSR approach comes from combining the DSR paradigm with the Soft Systems Methodology, which emerged from the combination of Action Research and Systems Science. The authors understand that the Soft Systems Methodology provides a set of critical activities and techniques that come from system thinking that could be adapted for use in DSR. Seven activities compose the proposed approach:

1. The specific problem is identified and delineated;
2. The problem is expressed as a set of specific requirements;
3. In the systems world, the specific requirements are abstracted and translated to a general problem;
4. A general solution is then developed based on a set of general requirements;
5. The general and specific requirements are compared;
6. A search is done for the specific components that will provide an effective instance of a solution to the general requirements;
7. An instance of the specific solution is built and deployed in the social system, thus changing the specific problem, allowing learning to be derived, and starting the cycle again.

The **fourth** and last approach to DSR to be presented here is the DSR Roadmap proposed by Alturki, Gable & Bandar (2011). As the previous creators of DSR approaches discussed, Alturki, Gable & Bandar (2011) also saw a lack of operationalization in the DSR methodology that tends to have a high level of abstraction.

In order to overcome this drawback to DSR application, the authors made a literature review of sixty papers about DSR and proposed the DSR Roadmap based on the literature. The Roadmap involves the following fourteen activities.

1. Document the spark of an idea/problem that can come either from practitioners or the literature;
2. Investigate and evaluate the importance of the problem/idea;
3. Evaluate the new solution feasibility within the timeframe and resources available;
4. Define the initial research scope and goal, which can later be revised as the design progress;
5. Decide whether the research falls under the DS paradigm;
6. Establish if the research is about DS research (creating an artifact) or DS science (evolving DS methodology);
7. Define the theme as being construction, evaluation, or both;
8. Define the necessary skills, tools, and experience required for the design;
9. Define alternative solutions to the problem;
10. Explore the knowledge base for the support of the alternatives;

11. Plan for the construction and evaluation of the artifact;
12. Develop/construct the artifact;
13. Evaluate the artifact;
14. Communicate findings.

As can be seen, the DSR approaches in the field of IS are relatively similar. This is expected as they belong to the same research paradigm. Still, one of these approaches has to be selected to guide the design process. Thus, the remainder of this thesis will follow the SDSR approach proposed by Baskerville, Pries-Heje & Venable (2009). The choice for the SDSR comes from the fact that it is the approach with the most concern for the iterative character of the design and a strong emphasis on the importance of prototyping. As the author of this thesis is not a developer, prototyping is a fundamental activity that enables the construction and evaluation of a model with much less effort than developing a system would demand.

The main drawback of this approach is the evaluation phase which is combined with the last step of the development of the model. Nevertheless, this could be considered a problem with every DSR approach. To solve this lack of discussion about evaluation, literature specifically about evaluation will be considered when performing this important step in the design cycles.

3. Literature Review

This Chapter presents the Literature Review of the thesis and is divided in three parts corresponding to the three subchapters. In the first one, the Theoretical Background of the thesis that includes Technology Assessment, a discussion about Expertise & Knowledge, and Computer-Supported Cooperative Work is presented. In the second one, a literature review about the Future of Work is presented including its Social, and Work, and Organizational trends. Finally, in the third one, recent literature about the impact of automation on work is reviewed.

3.1 Theoretical Background

This subchapter provides an overview of some theories that serve as a background to the development of the models presented on Chapters 6 and 7. It starts with the presentation of Technology Assessment (TA) where its definition, history, and types are discussed. Next, a brief discussion about knowledge and knowledge sharing with a focus on the relationship between experts and laypeople is presented. Finally, the research field of Computer-Supported Cooperative Work (CSCW) is introduced with particular attention to crowd computing and groupware which are used to support the first and second models, respectively.

3.1.1 Technology Assessment

After reviewing the literature about the future of work, I started searching for a way of predicting the impact of technological change on work. This search led me to the research field of Technology Assessment, which will be presented here.

Technology Assessment can be defined as

> The most common collective designation of the systematic methods used to scientifically investigate the conditions for and the consequences of technology and technicising and to denote their societal evaluation. (GRUNWALD, 2009)

The term has been subject to changes and different interpretations since its creation making it necessary to understand its history to observe the diversity of definitions.

During the 60s, the belief that technology would naturally lead humanity to a better world could no longer be sustained. Thus, dealing with the impacts and consequences of technology became a relevant issue for politics, society, and science (GRUNWALD, 1999).

It was during that period that the development of the concept of TA began in the United States of America due to studies from three advisory groups to the Congress: the National Academy of Sciences, the National Academy of Engineering, and the National Academy for Public Administration (COATES, 2016). Another two remarkable efforts were creating the Program of Policy Studies in Science and Technology by the National Aeronautics and Space Administration and the Program of Technology Assessment by the National Science Foundation both at the George Washington University (COATES, 2016).

The culmination of all these efforts was the creation, in 1972, of the Office of Technology Assessment (OTA) by the USA Congress (COATES, 2016; GRUNWALD, 2009; TRAN; DAIM, 2008; VAN DEN ENDE et al., 1998). Several factors motivated the creation of the OTA, including:

- The need of the Congress for an earlier awareness, warning, and understanding of the consequences of the introduction into a society of new technologies or the substantial expansion of existing ones (COATES, 2016; TRAN; DAIM, 2008);
- The asymmetrical access to technically and politically relevant knowledge possessed by the USA executive and legislative bodies was deemed to create a dangerous unbalance between these two powers regarding technology-related issues (GRUNWALD, 1999).

The term "Technology Assessment" itself was coined by the US congressman Emilio Daddario, responsible for introducing the bill that created the OTA (COATES, 2016; GRUNWALD, 2009; TRAN; DAIM, 2008; VAN DEN ENDE et al., 1998). He defined TA as:

> A form of policy research which provides a balanced appraisal to the policymaker. Ideally, it is a system to ask the right questions and obtain correct and timely answers. It identifies policy issues, assesses the impact of alternative courses of action and presents findings. It is a method of analysis that systematically appraises the nature, significance, status, and merit of a technological program (US CONGRESS, 1968).

OTA thrived for almost 20 years before a set of cost-cutting initiatives dismantled it (COATES, 2016).

As it can be devised from the history of the OTA, the concept of TA was created to improve government decision making (TRAN; DAIM, 2008). This was supposed to happen by the establishment of a neutral approach and the promotion of an early awareness of both the course of development and of all the societal consequences of new technologies (VAN DEN ENDE *et al.*, 1998).

In the 70s and 80s, these original assumptions and operating modes of TA became increasingly problematic as unforeseen events such as the oil crisis made many assessments of the period to become worthless (VAN DEN ENDE *et al.*, 1998). Thus, new styles of TA (e.g., Strategic TA and Constructive TA) were created as it became a more strategic and focused tool (VAN DEN ENDE *et al.*, 1998).

Nowadays, TA is widely known in the government, policy, and business communities of the USA where it was created – although currently it is virtually unpracticed there – but its center of activity has switched to Europe (COATES, 2016). There is an international community devoted to TA including institutions and organizations (e.g., the European Parliamentary Technology Assessment Network), networks (e.g., the German-language network TA), disciplinary organizations, and conferences (e.g., the European Association for the Study of Science and Technology, and the Institute of Electrical and Electronics Engineers initiatives concerned with the social implications of technology) (GRUNWALD, 2009).

Speaking of TA types, the Traditional TA (also called Classical TA, Awareness TA, or Early Warning TA) incorporates practices of the OTA. However, it is a later stylization and not a precise historical reconstruction (GRUNWALD, 2009). Its objective is to provide policy options and to raise awareness of future technological developments (VAN DEN ENDE *et al.*, 1998).

The following six elements are considered to be the basis of the traditional TA (GRUNWALD, 2009):

1. *Positivism*: the view that TA should only provide value-free knowledge about technology and its impact while decisions concerning politics are out of its jurisdiction;

2. *Etatism*: Traditional TA is concerned with advising on politics, and it is the responsibility of the State to guide technology advancement with social concerns in mind;
3. *Comprehensiveness*: it was believed that TA should provide complete knowledge of the consequences of the technologies;
4. *Quantification*: in order to reduce the subjectivity of the results of TA, the traditional approach puts excellent expectations in the quantification of the effects of technology;
5. *Prognoticism*: society was seen as a natural system whose laws could be discovered, allowing politicians to know beforehand what could be done to respond to the adverse effects of technology uncovered by TA;
6. *Orientation towards experts*: in Traditional TA, experts had the sole responsibility for providing knowledge to decision-makers.

A different type of TA, called Constructive Technology Assessment (CTA), was developed in the Netherlands and is based on the idea that dealing with the impacts of technologies is a responsibility that starts in the technology design phase because the more you know about the impact of technology the least you can do to influence it (GRUNWALD, 2009). As this style of TA demands, its practitioners are mainly public and academic research institutes that seek to influence the development of technology by aligning it with social demands and expectations (VAN DEN ENDE *et al.*, 1998).

This approach to TA originates from the modern views of the Science and Technology Studies (STS) research field that claims that the very design of technologies is intertwined with societal processes (VAN DEN ENDE *et al.*, 1998).

A third type of TA originated from a desire to increase the participation of more people in the process. As can be seen from the description of the Traditional TA, it was extremely centralized in the hands of two actors: politicians (decisionism) and experts (expertocracy), resulting in demands for more participatory approaches following democratic principles (GRUNWALD, 2009).

Participatory TA (pTA) is one answer to this demand. pTA does so by adding to experts' efforts the views of social groups such as lobbyists, affected citizens, non-experts, and the public in general in the process of analyzing technologies and their impacts (GRUNWALD, 2009).

There is an expectation that the inclusion of a wider group of participants in the TA process will improve the legitimacy of the decisions made concerning the technologies (GRUNWALD, 2009). However, this promise can only be fulfilled in specific conditions (GRUNWALD, 2004).

3.1.2 Expertise & Knowledge

Technological change is not only a technical matter as power disputes play a crucial role in defining who comes out as a winner from this process. Thus, considering that knowledge about new technologies and their impact is a weapon in this battle, before going forward, some thinking has to be dedicated to the struggle concerning knowledge production and sharing. This Chapter presents a brief history of knowledge sharing and then a discussion about the relationship between the Knowledge Society and expertise.

“Human action is knowledge-based” (BÖHME; STEHR, 1986). Several technologies have increased human capacity to acquire, store, and share knowledge. Language can be considered one of the first, as many skills, myths, and prophecies were passed down the generations orally. Writing is one revolutionary technology that allowed the storage of information and facilitated its sharing. The invention of the printing press in 1470 represented a massive step in the sharing of knowledge as can be seen by the explosion in the consumption of printed books from 1454 to 1750 in Western Europe (Figure 2) (BURINGH; VAN ZANDEN, 2009).

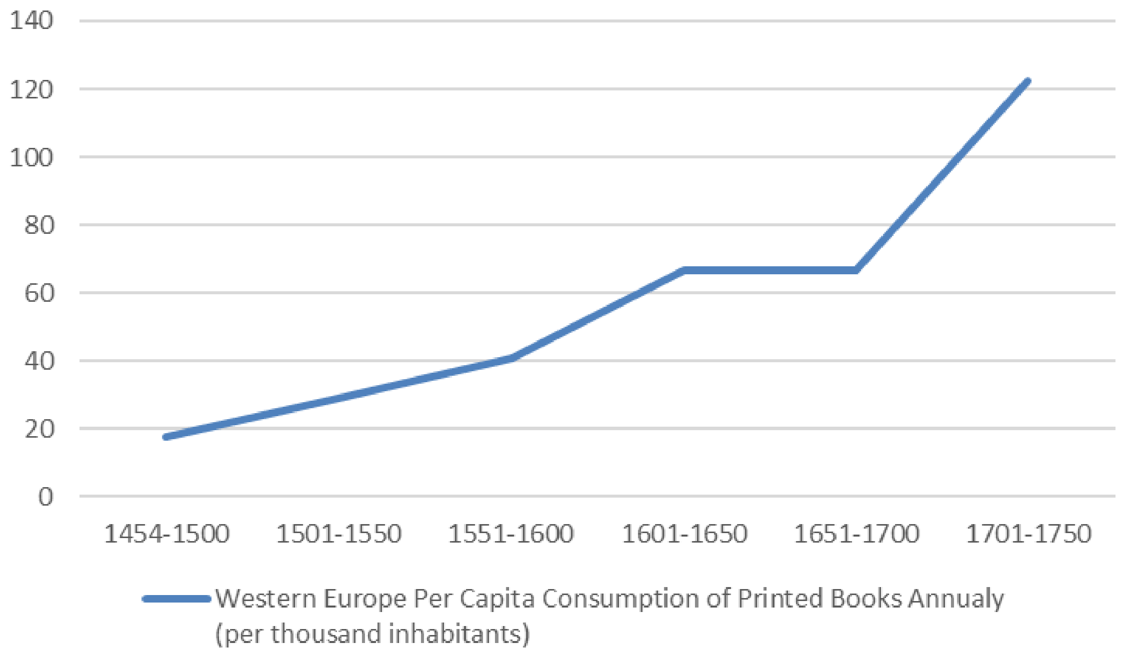

Figure 2: Book consumption between 1454-1750 in Western Europe. Based on Buringh & Van Zanden (2009)

The invention of the computer and, later, the Internet represent another two steps in this long history of evolution in humanity's knowledge sharing capacity. Nowadays, in the Web 2.0 era, vast amounts of data are generated every day. A fact that shows how much data we are creating is that more data was created in 2014 and 2015 than in the entire previous history of the human race (MARR, 2015). We are in the middle of an exponential climb in the production of data, as Figure 3 shows (GANTZ; REINSEL, 2012). That does not mean that we are producing that much knowledge or that we are extremely more intelligent than our ancestors. As the previous knowledge-sharing technologies, ICTs also help the spread of fake news and "fake facts" (PINTO *et al.*, 2019). These phenomena are there to prove that this history represents an evolution in the capacity of sharing knowledge, but not necessarily in the quality of the knowledge that is being shared.

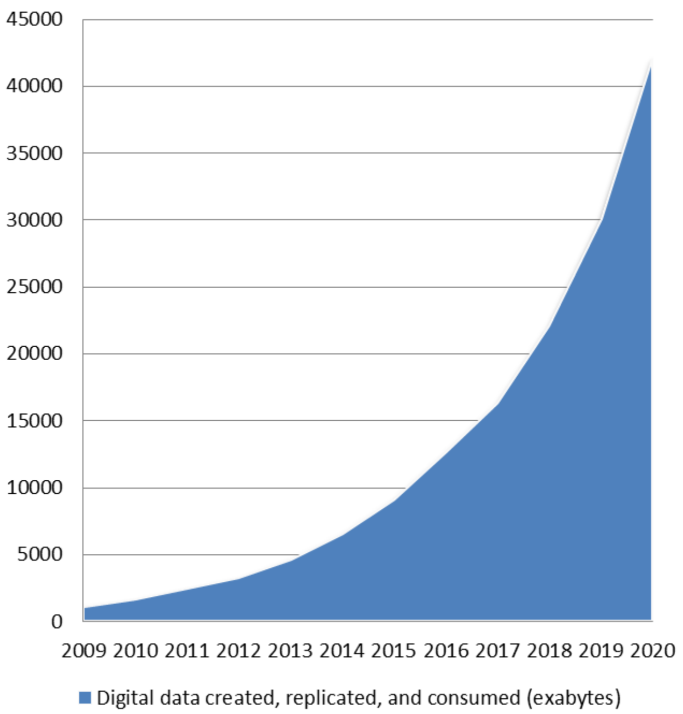

Figure 3: Exponential growth of the digital universe. Based on (GANTZ; REINSEL, 2012).

Along with the history of the relation between humanity and knowledge, another one can be told, the one about experts, those that hold knowledge. As more people can access knowledge nowadays than ever in history, we could infer that experts have lost most of their power. Indeed, if we compare the shaman from ancient history, vested in god-given power, and a modern engineer, we can see an immense difference regarding power but the engineers' relevance cannot be ignored in a society increasingly dependent on (scientific) knowledge.

As early as in the 70s, there were predictions of the coming of a new type of society (BELL, 1974). Since then, several theories have been put forward to describe this new society (BELL, 1974; CASTELLS, 2002; TOFFLER, 1980; TOURAINE, 1971). All these theories share a common trace, the belief in the "profound and apparently irreversible effect that scientific knowledge is having on all social processes in society" (BÖHME; STEHR, 1986).

Contemporary society can be considered a knowledge society given the penetration of scientific knowledge in every sphere of life (BÖHME; STEHR, 1986). Stating that the knowledge society has arrived does not mean, as some may believe, that the whole world is no longer an industrial society. This movement is similar to one of the waves, as several types of societies may coexist around the world and even in a given country (TOFFLER, 1980). Thus, the rise of a new type of society cannot be understood as a revolutionary development but a gradual change of the former society (BÖHME; STEHR, 1986).

In a society dominated by knowledge, expertise is a central concept. A definition of expertise is that it "refers to a widely acknowledged source of reliable knowledge, skill, or technique that is accorded status and authority by the peers of the person who holds it and accepted by members of the larger public" (FISCHER, 2009).

Thus, western society has evolved as a "professional society", dominated by expert disciplines that speak to and regulate all aspects of contemporary life. Professional experts have a high degree of influence in most of the sectors of modern social systems. However, this is not to imply that the professions are a relatively new phenomenon; the traditional professions emerged as part of the legacy of the seventeenth and eighteenth-century Enlightenment in Europe. By the end of the Second World War, professions, as we know them, had emerged (FISCHER, 2009).

The centrality of the professions in our society is one of the main reasons that trust has emerged as a critical sociopolitical issue. Modern life depends fundamentally on trusting experts we do not know who often move in elite circles socially distant to the lives of everyday citizens and speak languages that can be difficult to understand (FISCHER, 2009).

A recent study sheds light on the issue of trust in our society. It shows that people are more likely to trust search engines (59%) than human editors (41%). The study also reveals that a person's peers (such as friends and family) are considered as credible as technical or academic experts (EDELMAN, 2017).

Even if people trust the internet more than other people, there is a difference between being an expert and just having access to a pool of knowledge, even if it allows you to take action. This is not a new issue, as the following passage from Aristotle shows:

> "It is possible to do something that is in accordance with the laws of grammar, either by chance or at the suggestion of another. A man will be a grammarian, then, only when he has done something grammatical and done it grammatically; and this means doing it in accordance with the grammatical knowledge in himself" (ARISTOTLE, 1999).

Besides this difference between having the knowledge and just using it, professionals set themselves apart from laypeople in modern societies because they are entrusted with the right of using and guarding a given body of knowledge by their peers, government, and society as a whole (PARSONS, 1975). That is, they enjoy a different social status.

If leaving it to experts to solve social problems is increasingly being questioned, the solution seems to be bringing citizens to weigh in decisions that will impact their own lives. However, by looking at Brazil's state in this aspect, we can see that this is not a trivial task. As the Democracy Index shows, despite having a high grade in two variables of the index, Electoral Process and Pluralism (9.58 out of 10), and Civil Liberties (8.24), Brazil has a bad evaluation of the other relevant variables, namely Political Participation (6.11), Functioning of Government (5.36), and Political Culture (5.00) (THE ECONOMIST INTELLIGENCE UNIT, 2018).

We could then derive from this situation that the involvement of citizens in the participatory/democratic in Brazil initiatives is a challenging task. Still, it is by creating opportunities for participation in decisions impacting society that the political culture will evolve in Brazil.

3.1.3 Computer-Supported Cooperative Work

Computer systems have become an important and ubiquitous tool for collaboration that can be used in participative Technology Assessment. It has been successfully applied to support collaboration in different situations such as politics, science, and business. This Chapter presents the research area of CSCW that is concerned with the development of such systems. The Chapter is divided into two parts, the first one provides an overview of the CSCW research field, and the second one shows some of its diverse applications.

The phrase Computer-Supported Cooperative Work was coined in 1984 by Irene Greif and Paul Cashman during a workshop that was discussing the role of technology in the work environment (NICOLACI-DA-COSTA; PIMENTEL, 2012). The authors created the phrase to refer to a set of concerns regarding the support of a group of individuals working together with computer systems. As such, the area of CSCW is expansive (BANNON; SCHMIDT, 1989), even more, today as computer systems are used everywhere.

The term Groupware is used to define “computer-based systems that support groups of people engaged in a common task and that provide an interface to a shared environment” (ELLIS; GIBBS; REIN, 1991). What differentiates computer systems in general and groupware is that the latter is concerned with three key areas: communication, collaboration, and coordination (ELLIS; GIBBS; REIN, 1991). This division in three areas inspired the creation of the 3C Model that considers the activities related to communication, cooperation (instead of collaboration), and coordination as the basis for the collaboration of a group (FUKS *et al.*, 2012). The 3C Model helps to classify groupware according to the degree to which each system supports each one of the C’s (FUKS *et al.*, 2012).

As the Internet progressed, new possibilities appeared for CSCW and new applications of groupware appeared that were concerned with an expanded group of people that resembled a crowd given the number of people involved. One of the most prominent applications of groupware to this new era of the internet is crowdsourcing.

Crowdsourcing was first discussed by Jeff Howe in a Wired magazine article back in 2006 (MORAES *et al.*, 2014; SCHNEIDER; DE SOUZA; MORAES, 2011). Howe was interested in showing how different industries such as the pharmaceuticals and television were tapping into the potential of a crowd through the internet; he called this process crowdsourcing. This crowd participation was not always free but could cost companies much less than hiring and paying employees (HOWE, 2006).

The basic process of crowdsourcing involves the submission by a requester of a certain task to be executed to an intermediation platform where a provider (worker) can analyze the task, accept it, and then post the result in the same platform to receive his payment upon the approval of the result by the requester (ZHAO; ZHU, 2014).

In the past years, crowdsourcing grew, and its possibilities diversified. One possible classification of Crowdsourcing systems is given in Figure 4 where the systems are divided into four quadrants according to the heterogeneity of the tasks and of the individual or collective characteristic of the work (GEIGER; ROSEMANN; FIELT, 2011).

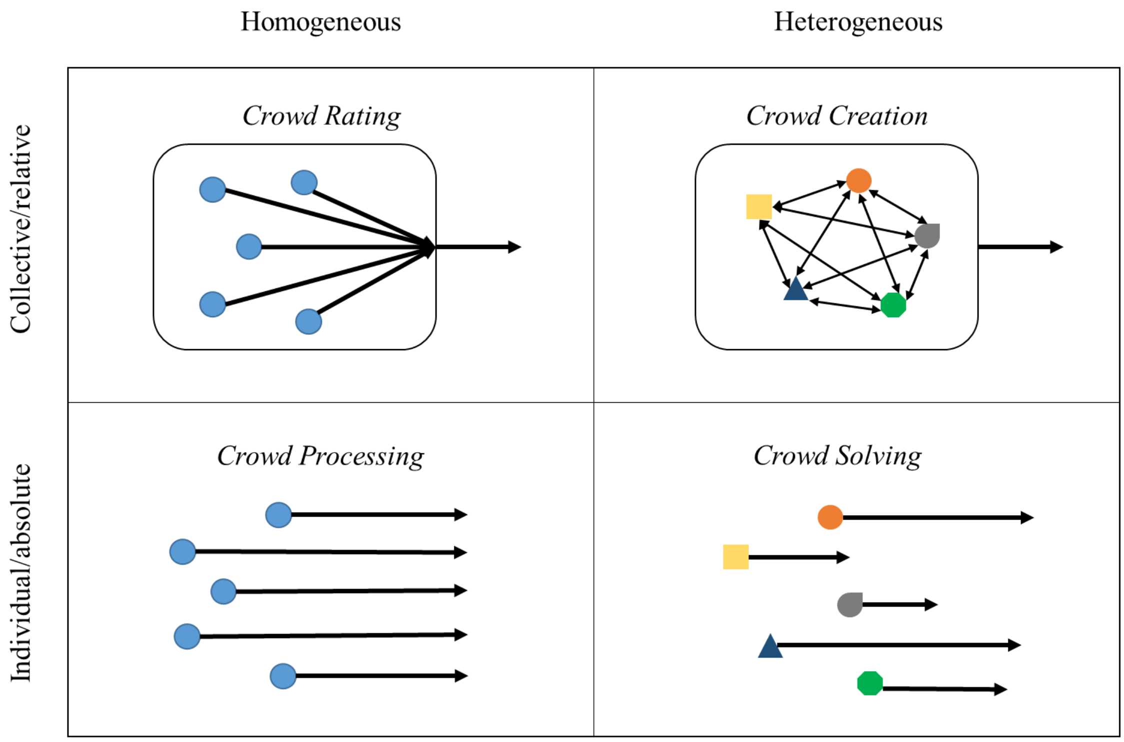

Figure 4: Classification of crowdsourcing systems (GEIGER; ROSEMANN; FIELT, 2011)

Crowd rating systems seek to aggregate the collective opinion or assessment of a crowd and have no *a priori* right or wrong result from each contribution. Statistic procedures are usually applied to aggregate the results. *Crowd processing systems* also aggregate individual homogeneous contributions but they can be evaluated individually and objectively. *Crowd creation systems* involve the execution of heterogeneous tasks by the crowd to create a common result that has to be evaluated as the full result of the efforts of the individuals. Finally, *crowd solving systems* are similar to crowd processing, but there are different possible solutions to a given problem, and, as such, the tasks executed by the individuals are heterogeneous. In this case, the final result is the best solution given by the individual efforts of the crowd.

As the plurality of CSCW shows, there has been a significant advancement in the field during the more than three decades since its creation and its applications nowadays are everywhere to be seen.

In terms of laypeople participation, a specific interest of this thesis, Natural Sciences are already making good use of CSCW systems as projects in citizen science shows. The movement is answering social desires such as people's thirst for data and a push to improve the transparency and accessibility of science (IRWIN, 2018). We can highlight successful experiences in the field of citizen science such as EteRNA – a massive open laboratory that allowed a crowd of laypeople to test RNA structure designs (LEE *et al.*, 2014; TREUILLE; DAS, 2014) – and Fast Science – a Brazilian platform that allows experts to set up experiments and recruit the crowd to participate (ESTEVES, 2016). Recruiting the crowd is a strategy that has also been applied in another Brazilian case that uses humans as sensors as in CrowdView, a system that allows citizens to identify and report problems in their city (SILVA, 2017).

In the field of Future-oriented Technology Analysis (FTA), which Technology Assessment is a part of, some computational systems could be classified as groupware such as Autobox, Forecast Pro, and SAS Forcast Server. Still, these systems are focused on Technology Forecasting, not Technology Assessment (BARBOSA, 2018). As such, there is an opportunity for recruiting the crowd or creating groupware to help in Technology Assessment.

Thus, we propose in Chapter 6, a system to leverage the power of crowd computing to enable lay people to act as experts. This will be accomplished not only by breaking bigger and complex tasks into smaller ones and distributing them to a crowd, as crowd computing advocates but also by subverting the expert logic when considering that worker’s knowledge about their own job activities is so rich that they can be considered experts when asked to do tasks that involve analyzing their work.

In Chapter 7, the proposed system is groupware, as it focuses on the collaboration of a smaller number of participants. Still, similarly to the previous one, this system is also grounded on the idea of leveraging workers’ knowledge for Technology Assessment.

3.2 Future of Work

A broad perspective about the future of work is an essential first step towards the development of models that are effective in helping society to cope with new technologies. Furthermore, the very choice of a problem to dwell on depends on knowing the challenges ahead.

This Chapter seeks to provide a glimpse into the future of work. In the first part, a brief history of work is told which helps to situate the current changes in a historical landscape whilst the second part presents a literature review about the future of work.

Work has a central role in society for centuries now, but it has not always been like that as the idea of work changed several times. As an example, the meaning of the words used in the Latin languages for "work", such as "*trabalho"* in Portuguese or "*travail"* in French, is multiple and changed throughout history. Etymologically, its origins go back to the Latin word "*tripalium*" which means a torture device, and hints at the fact that the wide recognition of work as being fundamental as we have today was not shared by our ancestors (ALBORNOZ, 1988).

In Greek society, only slaves or second-class citizens used to work as it was mainly a physical activity considered undesirable by the upper-class people (DE MASI, 2000). Work remained an activity reserved for the unfortunate in the Medieval Period as it was considered something to be avoided by the members of the Catholic Church and the nobles (LAFARGUE, 2013).

The ethics of the religious denominations that derived from the Protestant Reformation went in direct opposition with the Catholic view of work by viewing it as a means to salvation (WEBER, 1930). This change in the meaning of work was extremely important for the Industrial Revolution that was to follow, for it provided the cultural and moral justification to keep people working for 16+ hours per day.

The industrial revolutions deserve special consideration in the history of work as they represent "profound changes in the means of production" (LANDES, 1969). In these periods, work went relatively quickly through severe changes. The **1st Industrial Revolution** – which took place in the XVIII century – represented the shift from artisanal production to the factory mode of production boosted by the new steam-powered machines (LANDES, 1969). Several intellectuals perceived the changes happening in this period and – even though their accounts differed in several ways – there are some points of convergence. Both Adam Smith and Karl Marx saw how the work that was done by the artisans was being replaced by a highly specialized work that brought several adverse effects to the workers as well as positive economic results (MARX, 1887; SMITH, 2009).

Another period in which work has changed rapidly was during the **2nd Industrial Revolution** when electricity was invented and applied in the production (LANDES, 1969). The characteristics of the factory system were further intensified by the works of entrepreneurs such as Frederick Taylor that brought the scientific administration to the factories, and Henry Ford, that seek to intensify the division and specialization of work by the creation of the production lines. The electrification of production meant that machines substituted some of the work done by the people. Around that time, Jules Fayol's work helped to organize companies as the white-collar work was increasing.

The invention of Information and Computation Technologies (ICTs) and their application on business around the 1970s represent the main event of the **3rd Industrial Revolution** (CASTELLS, 1996). With the ICTs came new industries and new types of jobs, the main product of several companies became information, and the third sector of the economy (Services sector) represented – for the first time in history – the largest share of GDP of various developed countries.

Robotics, Artificial Intelligence, bio, and nanotechnology are considered the tip of the iceberg of what might be called the **4th Industrial Revolution** (SCHWAB, 2016). As these technologies are further developed and used, usually in combination, we will see even more changes to work.

The literature review presented here aims to show some of the trends indicated in the literature that will help to shape work in the upcoming decades. What follows is a description of how this research was undertaken.

On November 10th, 2016, a search was made on both the ISI Web of Science and Scopus databases for journal and conference papers in English containing the specific phrase "future of work (or employment or jobs)" on the fields "Title", "Abstract", or "Keywords". This search resulted in 148 papers relevant to this literature review. Two conclusions can be drawn from the distribution of papers published by the year presented in Figure 5. First, since 1956 there are records of papers published on the subject which shows that the academic interest in predicting the future of work is an old one. Second, from 1991 to 2016, at least one paper on the future of work was published which shows a continuous academic effort to explore it.

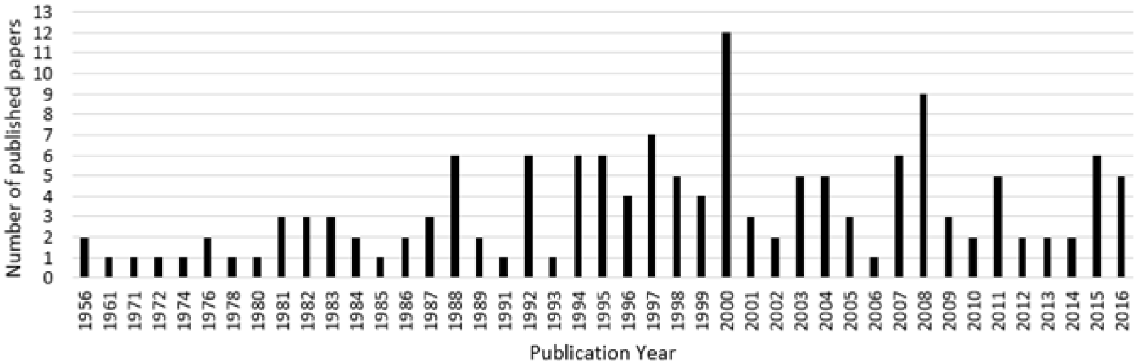

Figure 5: Distribution of papers about the future of work by publication year

In order to make predictions about the future of work, authors tend to rely on their knowledge about the past and the present of work, technology, society, and economy. Taking that into account, papers published before 2010 were not considered to maintain the relevance of the review.

Considering the papers published from 2010 to 2016 that were found in the original search, the literature review followed the steps shown in Table 1. From a total of 102 papers that resulted from the search, 24 duplicates were removed. After the inspectional reading (which considers only the paper title, abstract and a quick reading of its parts) (ADLER; VAN DOREN, 2014) of the remaining 78 papers, 20 were selected for syntopical reading (comparative reading of multiple papers on the same subject) (ADLER; VAN DOREN, 2014).

Table 1: Summary of literature review stages.

Literature review stage	**# of papers**
Search on ISI Web of Science	37
Search on Scopus	65
Total	102
Duplicates	24
Total - Duplicates	78
Approved upon inspectional reading	24
Document unavailable	4
Approved to analytical reading	20

The papers reviewed – except (FINKEL, 2015; GRATTON, 2010; HODGSON, 2016; PETRIE, 2015) – are concerned with the future of specific subjects that are intertwined with the future of work. The main subjects explored by the authors are work-life fit (GALINSKY; MATOS, 2011; KHALLASH; KRUSE, 2012), education and skills (WILSON, 2013), automation (ADAMSON, 2015), crowdsourcing (HOBFELD; HIRTH; TRAN-GIA, 2011), economy (KUBIK, 2013), artificial intelligence (BRUNDAGE, 2015), flexicurity (ZHANG et al., 2015), employment (MORTENSEN; VILELLA-VILA, 2012; STRAWN, 2016), retirement (MAXIN; DELLER, 2011), volunteer work (CROWSTON, 2011), work as play (SMITH, 2011), future of work narratives (FORLANO; HALPERN, 2015), the International Labour Organization (MOORE, 2016), and online collaboration (RYDER, 2015).

This multiplicity of subjects demonstrates that instead of creating competing scenarios for the future of work, articles on the subject are concerned with how multiple aspects of the future society and work will behave in the next decades. Thus, it is necessary to build the puzzle of the future of work using the several pieces that compose it and that are given by the reviewed literature. Some of these pieces compete to fill the same space meaning that sometimes authors will diverge in their views about some aspects of the future. This difference is expected since the future is unknown and authors may use different methods to predict it, possibly yielding divergent conclusions.

The trends henceforth presented are divided into two main groups: the first comprises trends related to social topics (e.g., economy, education, and employment), while the second is concerned with trends specific to work and its organization.

The introduction of the social trends is paramount to exploring the future of work, since there is no work isolated from society and vice-versa. As such, social changes might help to explain or even anticipate some shifts to work.

3.2.1 Social trends

Automation

In the 1st Industrial Revolution, some activities that demanded human physical labor were replaced by machine power of various sorts. During the current industrial revolution, moderately repetitive or predictable tasks executed by intellectual and skilled workers are expected to be automated. This automation is neither necessarily bad nor good, but it is a significant driver of the future of work (ADAMSON, 2015).

Automation is one of the forces changing our conceptions of job, career and task uniformity as organizations' continuous oversight and bureaucracy are giving way to improvisation, innovation, and networking (KUBIK, 2013). There is a belief that humans will remain working because of our creativity (KUBIK, 2013), intuition, and sophisticated judgment (HODGSON, 2016).

Employment

The trends found in the reviewed literature regarding employment are quite diverse. Some of them are divergent and cannot happen in the same future scenario, while others could be thought of as belonging to the same future scenario.

Two major lines of thought that can be considered as competing with each other are: we will see increasing unemployment in the future (RYDER, 2015; STRAWN, 2016) or there will be no unemployment but job displacement (ADAMSON, 2015; BRUNDAGE, 2015; FINKEL, 2015; HODGSON, 2016).

Still, some authors give different perspectives on the future of employment. Kubik (2013) defends that there will be an increased need for educated workers while the need for lower-level skills shall cease to exist. Wilson (2013) takes on a different approach and considers that technology can make some jobs redundant or obsolete. However, unemployment can be avoided since there is no limit to what humans can do, regardless of their skills. Wilson (2013) then poses the question as to whether these activities that humans can perform better than the machines will generate viable incomes.

Petrie (2015) writes that the workforce will become more self-employed in the future while Khallash & Kruse (2012) says that labor mobility is increasing and will follow this trend. Gratton (2010) considers that globalization will allow talent to be tapped wherever they are while those that are not connected to the global market or do not have the required skills will be excluded. Galinsky & Matos (2011), Maxin & Deller (2011), and Mortensen & Vilella-Vila (2012) point to the increase of older employees as being the most substantial projected growth in the labor force.

Education

Education should accompany the skills required by work as it becomes more knowledge-intensive (HODGSON, 2016; MOORE, 2016). Also, the democratization of education in this future society turns into an obligation if we wish to stop a social divide that is likely to happen (or to intensify) between those ready for the work of the future and the rest of the population (HODGSON, 2016).

Some authors highlight the importance of education to account for the skills required in the trends of the future of work that they layout. Training people for self-employment (FINKEL, 2015) and the importance of Science, Technology, Engineering, and Mathematics (STEM) formation (WILSON, 2013) are the projected requirements for education in the reviewed literature.

Trends for education include the increasing importance of technology as a tool for changing education (BRUNDAGE, 2015; KUBIK, 2013; WILSON, 2013). Particularly, AI would have an "ethical obligation" of improving education because – partly due to the automation potential of AI – people will spend more time on education activities rather than working and might need retraining to transition to new careers (BRUNDAGE, 2015). Another noteworthy application for technology would be "silicon-based apprenticeships" which involve the combination of humans, smart models, and smart environments wherein systems provide master-apprenticeship functions that fuse learning and practice into a single process. These apprenticeships would have the capacity to close the learning-performing gap caused by current education and training models (KUBIK, 2013).

Social welfare

The thematic of the future of work tends to closely relate to social welfare as observed in the reviewed literature. Concerns toward future trends regarding welfare gravitate around two main topics: retirement (GRATTON, 2010; MAXIN; DELLER, 2011) and work contract flexibilization (MORTENSEN; VILELLA-VILA, 2012).

The increase in the retirement age, in the number of workers that keep on working beyond the statutory retirement age, and in the life expectancy are challenges to current social welfare that are being debated in the developed countries such as Germany (MAXIN; DELLER, 2011). These challenges can be expected to turn into global problems in the upcoming decades (GRATTON, 2010).

As work contracts become more flexible, due to increases in the use of practices such as outsourcing, crowdsourcing, and part-time jobs, there is a growing concern about the impact of these new types of work contracts on the social welfare system since they defy traditional jobs definitions and worker's legal rights (MORTENSEN; VILELLA-VILA, 2012).

Universal Basic Income is one of the proposed solutions for the problems that social welfare is facing (HODGSON, 2016; STRAWN, 2016). Despite resistance from some countries to the idea, that may sound like a socialist approach to the problem, there are developed nations such as Switzerland considering the adoption of the Universal Basic Income (STRAWN, 2016).

Economy

Trends in the future of the economy are taken into account in most of the reviewed literature (ADAMSON, 2015; BRUNDAGE, 2015; GALINSKY; MATOS, 2011; GRATTON, 2010; HODGSON, 2016; HOBFELD; HIRTH; TRAN-GIA, 2011; KUBIK, 2013; MAXIN; DELLER, 2011; MOORE, 2016; MORTENSEN; VILELLA-VILA, 2012; WILSON, 2013).

The emerging economy – labeled Knowledge or Borderless Economy – has some features that distinguishes it from previous economies (HODGSON, 2016; KUBIK, 2013; MOORE, 2016; MORTENSEN; VILELLA-VILA, 2012; WILSON, 2013). Production is becoming increasingly complex and information-intensive, rather than involving the processing of materials and things as it used to be the case in the previous Industrial Economy (HODGSON, 2016; MOORE, 2016).

Furthermore, there is a change in the means of production. Knowledge workers are the main assets of the companies in this new economy as the production goes from being capital-intensive to become more knowledge-intensive. (HODGSON, 2016; MOORE, 2016).

Other characteristics of the emerging economy are: it functions unlike previous economic systems based on scarcity; it is participative as it allows consumers and stakeholders to have increased choice and involvement in the market, as enterprises turn to open access and peer production to involve more prosumer minds; it is technologically rooted because it is driven by a variety of digital technologies in diverse e-commerce and social configurations; and, finally, it is global as it involves more significant percentages of the global population (KUBIK, 2013).

Regarding technology, three economic trends are indicated. The first of them is about the potential that AI may have on the socio-economic impact of intelligence and wealth in life, depending on its accessibility and usability to/by a broad population (BRUNDAGE, 2015). The second one is that we may be about to experience an information technology productivity avalanche as the productivity gains of the past seven decades arrive in a few years if the answer to the productivity paradox is that early benefits are "spent" on further development until a technology achieves maturity (ADAMSON, 2015). Finally, crowdsourcing (the outsourcing of activities to a crowd, usually through computer systems) is following the path left by outsourcing in regards to the delegation of work from countries with high wages and Human Development Indexes to poor or developing economies (HOBFELD; HIRTH; TRAN-GIA, 2011).

The rise of the new economy is believed to shape work and life to allow people to reconnect with what makes them happy and create a high-quality experience rather than using quantitative indicators to measure consumption (GRATTON, 2010). Also, it allows the work-life issue to be played in different ways (GALINSKY; MATOS, 2011).

Socio-economical challenges

Besides providing trends for the future of society and economy, the reviewed literature also put forward some challenges that we are likely to face in the future.

The challenges we are going to be facing are divided into two groups. The first group concerns, mostly, companies. This group of challenges comprises the global war for talents (KUBIK, 2013), managing an aging workforce and dealing with a demand of greater work-life flexibility from employees of all ages (GALINSKY; MATOS, 2011), solving the problem of the power imbalance between agency (outsourced) and company workers (ZHANG et al., 2015), and managing and leading high-performing virtual teams (GRATTON, 2010; MOORE, 2016).

In the second group of challenges are those that involve society as a whole: consolidation of workers' legal rights; mainly for the most recent work contract types (e.g. agency and crowdsourcing workers) (HODGSON, 2016; ZHANG *et al.*, 2015); trade unions importance (FORLANO; HALPERN, 2015; HODGSON, 2016), information ownership (HODGSON, 2016); advanced education and training for everyone (HODGSON, 2016); growing inequality (HODGSON, 2016; RYDER, 2015); gender equality (RYDER, 2015); need for new regulatory frameworks to manage new technologies (FINKEL, 2015) such as artificial intelligence (BRUNDAGE, 2015) or, more specifically, the ones resulting from the combined use of artificial intelligence and robots (e.g. Killing Autonomous Machines) (ADAMSON, 2015); changes in the welfare state required to accompany trends as the ageing of the workforce (GALINSKY; MATOS, 2011); rise of a global instead of a local workforce (KUBIK, 2013); work contracts flexibility (ZHANG *et al.*, 2015); and the threat of unemployment due to automation (STRAWN, 2016).

3.2.2 Work and organizational trends

After presenting the social trends, we can move forward to analyze the trends of the future of work highlighted in the reviewed literature. The trends presented here are divided into the following parts: workplace and working time, work contract, skills, and work organization.

Workplace and working time

The changing nature of society and economy showed above helps to change (the opposite also happens) the workplace and working time creating a different work in the future than the one we have nowadays.

There is a growing acceptance of the flexibilization of the workplace as employees are allowed to perform more and more work out of the office (GALINSKY; MATOS, 2011; GRATTON, 2010; HODGSON, 2016; KHALLASH; KRUSE, 2012; WILSON, 2013). This trend can be viewed as a return to the pre-industrial mode of working where you live (KHALLASH; KRUSE, 2012). This change is happening because it allows for better work-life flexibility (GALINSKY; MATOS, 2011; HODGSON, 2016; KHALLASH; KRUSE, 2012) – which is an increasing demand from employees – and because ICT is getting ever cheaper making telework an opportunity for companies to save money (GALINSKY; MATOS, 2011; KHALLASH; KRUSE, 2012; WILSON, 2013).

Work can change in two ways to allow the workplace to change from the office to anywhere. Workers can have more autonomy and freedom (GRATTON, 2010;

HODGSON, 2016), or they can be given smaller and repetitive tasks that require little to no coordination with colleagues (HOBFELD; HIRTH; TRAN-GIA, 2011).

"Time-based" work will also come into question in the future as employees increasingly see time as a currency that is more or just as important as money (GALINSKY; MATOS, 2011). According to the reviewed literature, this happens for three reasons: ICT allows employees to work anytime and anywhere (or "every time" and everywhere) (GALINSKY; MATOS, 2011), the rise in part-time work (MORTENSEN; VILELLA-VILA, 2012), and the increasing number of workers on the group of above legal retiring age that put family and health as priorities above work (CROWSTON, 2011).

Work contract

One of the characteristics of the future of work will be the plurality of types of work contracts. Workers might become increasingly detached from individual companies and organize themselves in groups defined by specific skills resembling guilds from the pre-industrial era (MAXIN; DELLER, 2011).

Another type of work contract that appears as an increasing component of the work landscape is the agency work (ZHANG *et al.*, 2015). The use of outsourcing and crowdsourcing platforms with the purpose of outsourcing work represents yet another kind of work contract that appears as a trend (HOBFELD; HIRTH; TRAN-GIA, 2011). In these platforms, since the tasks (microtasks) might be executed in hours or even in minutes, there can be no work contract (HOBFELD; HIRTH; TRAN-GIA, 2011).

Voluntary work, like the one used to develop or improve open source software, is also a type of work contract that is expected to increase in the future (CROWSTON, 2011).

Finally, all the previous forms of work contract described here and even the usual bilateral conventional work contract between a single company and a worker may fall into or resemble the broader category of self-employment in the future. That happens because – even in traditional work contracts – employees are being given more control and autonomy over/on their work as owners of part of the intangible means of production. This trend is typical of the knowledge economy and makes employees more independent from their bosses while allowing for easier change of company.

Skills

There is a prediction that we will see in the future an increase in the demand of both high and low (especially in personal services) skilled workers creating a “polarization” of skill demands (WILSON, 2013) or an “hourglass model” (MORTENSEN; VILELLA-VILA, 2012).

Some efforts are being made to predict which skills will be most needed in the future (MOORE, 2016; SMITH, 2011). The 21st-century skills index created by Gallup, Microsoft, and the Pearson Foundation (MOORE, 2016) and The Partnership for 21st Century Skills organized by some states in the United States and global organizations have created lists of skills that they envision as crucial for the future (SMITH, 2011). These lists include critical thinking and problem solving, communication, knowledge construction, global awareness, self-regulation, real-world problem-solving, technology use in learning, collaboration, and creativity and innovation (MOORE, 2016; SMITH, 2011).

Given the new types of work contract discussed above and the weakening of the relationship between workers and companies that they entail, employers’ incentives to invest in the skills of their employees might be reduced in the future, and education will become an issue for workers and the government to solve (HODGSON, 2016). This issue is even more significant if the trend for continuous education throughout life (GRATTON, 2010; KUBIK, 2013; WILSON, 2013) becomes real in the future.

Work organization

In the future, how work is organized is going to change. As work gets more knowledge-intensive and workers to become more specialized, it gets harder to subject them to direct supervision (HODGSON, 2016). The geographical dispersion of workers will also make this type of supervision – traditional in the organizations of the Industrial Economy – more challenging.

Crowdsourcing is a relatively new type of work organization that is expected to have a surge in the future (HOBFELD; HIRTH; TRAN-GIA, 2011). A finer granularity of work characterizes it as the division of tasks goes up to the level of cheap micro-tasks that can be distributed among a big group of workers located anywhere in the world (HOBFELD; HIRTH; TRAN-GIA, 2011).

Another trend related to this topic is the capacity of decentralizing organizations, mainly due to the advances in technical capacity and cost (KHALLASH; KRUSE, 2012). In the future, more organizations that are self-organized, self-managed, peer-to-peer, participatory, and people-centered are expected to be created (KHALLASH; KRUSE, 2012).

3.3 Automation Impact on Work

From the challenges that the future of work presents, automation is undoubtedly one of the most discussed not only in this industrial revolution but throughout history. As such, this thesis focus on this specific aspect of the future of work that will be better explored in this Chapter.

By analyzing previous industrial revolutions and their impact, Acemoglu & Robinson (2013), and Schwab (2016) found out that the capacity of a nation to adapt to technological innovations is a determining factor of its progress. Autor (2015) shows that past waves of technological change caused job to be reduced in specific economic sectors while increasing in others, thus balancing the job market. So, in the long-run, technological change has been powering economic progress and increasing job quantity and quality.

The concern over the impact of technology on job quantity and quality is not new. Take, for instance, the story of the invention of the knitting machine. William Lee was an inventor that saw the high demand for knitted caps – a consequence of a law passed by Queen Elizabeth I – as an opportunity to invent the knitting machine to increase productivity. He went on to present his creation to the Queen, which refused to grant him a patent. He then built an improved version and saw his patent denied once again. The Queen said to Lee: "*Thou* aimest high, Master Lee. Consider *thou* what the invention could do to my poor subjects. It would assuredly bring to them ruin by depriving them of employment, thus making them beggars" (ACEMOGLU; ROBINSON, 2013).

Should the positive historical perspective of the interaction between work and technology reassure us about the future?

The past performance is not indicative of a positive, or at least neutral, relationship between work and technology because there are many other factors involved. It is not because things have worked out in the past that they will work in the future (ADAMSON, 2015). We cannot put aside the importance of worker's movements to defend their rights, public policies to help workers find new jobs, and employers' decision to slow down the application of technology on production so as not to destroy their consuming markets.

By looking only at the long-term impacts of technology, we risk ignoring the short-run impacts produced. As an example, Marx (1887) tells us about the invention, back in 1579, of the ribbon-loom, the machine used for weaving, whose inventor was murdered by the mayor of a town in Germany because he was apprehensive that the new technology might throw a large number of workers on the street. Marx (1887) also reports on the results of the gradual extinction of the English hand-loom weavers' jobs which took decades to took place and finished in 1838 causing many to die of starvation.

Throughout the history of technological change, stories like these abound. There are always dispute between technology and labor with different players on each side and various outcomes.

In general, technologies applied to production are designed to save human work (AUTOR, 2015; MARX, 1887). Be it tractors, production lines, or spreadsheets; the primary goal is to substitute human effort for the machine's effort (AUTOR, 2015). Nevertheless, automation not always results in workers being fired. Tasks that cannot be substituted are generally complemented by automation because most work processes depend on a multifaceted group of inputs such as rationality and physical effort or technical mastery and intuitive reasoning. Usually, each of these inputs plays an essential role and the improvement of productivity in a group of tasks almost necessarily increases the economic value of the remaining tasks (AUTOR, 2015).

The interplay between technology and employment has long been an important subject. The beginning of each new Industrial Revolution brings about new discussions on the topic, as the fear of technological unemployment reappears and the prospects of technological bonanza are revisited. We are now living one such moment, as increasing discussion about the 4th Industrial Revolution occurs.

Understanding the impact of new technologies applied to production in each industrial revolution might be one of the reasons why the impact of automation has been positive. In terms of job quality, the current wave of automation is expected to increase workers' precision in essential areas such as medicine, reduce repetitive tasks as data input, and augment workers' capacity to deal with large amounts of information

(ACTION AND RESEARCH CENTRE, 2019; CHARTERED INSTITUTE OF PERSONNEL AND DEVELOPMENT; PA CONSULTING, 2019). In terms of the impact of this new wave of technologies on job quantity, predictions tend to vary widely. However, the current industrial revolution provides opportunities to use automation in a broad range of occupations resurrecting the phantom of mass technological unemployment that has reappeared several times over the past two centuries (AUTOR, 2015).

One fact that is undisputed is that automation has impacted the world of work in the past, is doing it right now, and will do it in the future. The adoption of automation has been accelerated with the COVID-19 pandemic, as it happened with other trends that were expected to take years or decades to happen but are happening in a much shorter time (BLIT, 2020; CHERNOFF; WARMAN, 2020; DING; MOLINA, 2020; MCKINSEY GLOBAL INSTITUTE, 2020, p. 8; WORLD ECONOMIC FORUM, 2020).

In this scenario, companies, governments, and workers must prepare themselves faster than ever to deal with the increased pace of automation work if it is to bring about positive results once again as it did in the past. Sadly, it does not seem to be the case so far. When it comes to companies' preparedness, a recent survey with over two hundred Chief People Officers showed that only 36% consider themselves prepared to respond to the future complexity of business and technology to effectively support their business (SHRM EXECUTIVE NETWORK; WILLIS TOWER WATSON, 2020). In terms of nations' readiness for automation, as The Economist Intelligence Unit (2018) shows, even the more advanced economies, such as Germany and East Asian countries, are not prepared to deal with the current wave of automation.

In Brazil, this unpreparedness is even more prominent as no detailed analysis of the impact of automation on the country's diverse workforce has been done.

From the hope of shorter working weeks to the fear of mass unemployment, technology relationship with work has been an important topic for a long time now. In the past few years, with the advancement of AI, Robotics, and other technologies, society has been looking at the potential that technology represents for impacting work.

The current impact of technology on work can be seen as a myriad of phenomena that can be classified in four groups to facilitate our study of it (Figure 6): automation involves machines executing tasks that were previously done by humans or augmenting human work (e.g., self-checkout machines at grocery stores); brokerage is the mediation done by the technology of the relationship between buyers and sellers (e.g., Uber); management is when technology helps to recruit, monitor and organize workers (e.g., scheduling software used by retail); digitization is the use of technology to transform physical goods into digital assets that can be easily shared (e.g., Microsoft Office) (ACTION AND RESEARCH CENTRE, 2017).

Figure 6: Four ways in which technology and work interact. Based on Action And Research Centre (2017)

Automation itself happens in many forms. Usually, more than one of these forms occur at the same time when adopting a single technology. Automation can substitute expanding the former capacity of workers; generate new activities for humans to execute; and transfer activities from workers to customers (ACTION AND RESEARCH

CENTRE, 2017). The focus here is on the substitution capacity of automation technologies but it is essential to note the other possible facets of automation to recognize its impact as a whole.

When looking at the benefits of automation in the current 4th Industrial Revolution, we can highlight its potential for reducing errors, increase productivity, augment human capacity, overcome the challenge of the aging population, and improve speed and quality.

Unlike humans, machines do not get tired or have any feelings whatsoever; they can make decisions very fast, and based on troves of data. These characteristics give them an advantage over humans in certain activities where they can reduce errors and risks, such as driving cars and trucks or storing and dispensing medication in pharmacies (MCKINSEY GLOBAL INSTITUTE, 2017a).

Machines have great potential to augment human capacity in activities where they cannot replace us yet (AUTOR, 2015). One example is automated diagnostic advice that augments doctors' capacity to deal with a myriad of information from exams such as X-rays and Magnetic Resonance Imaging but does not replace the human capacity of adequately communicating with patients or interpreting their emotions. Another example is augmented human management as used by Uber to allow few human managers to organize thousands of drivers by using algorithms and data analysis (MCKINSEY GLOBAL INSTITUTE, 2017a). As these examples show, the capacity of the technologies in the 4th Industrial Revolution allows them to change not only "traditional" sectors such as agriculture and production, but also healthcare, and education (KRINGS; MONIZ; FREY, 2021; MONIZ; KRINGS, 2016).

The Mckinsey Global Institute (2017a) estimates that automation can raise productivity growth globally by 0.8 to 1.4% annually. This productivity injection brought by the adoption of automation also helps to mitigate the impact that aging populations will have in advanced and emerging economies (including Brazil) that have to deal with this challenge for the labor market (MCKINSEY GLOBAL INSTITUTE, 2017a). Furthermore, Steinmuller (2001) understands that ICTs – which are at the core of the current industrial revolution – are different from previous leading technologies, such as steel and chemicals, because of the conditions of entry and, sometimes, producing them do not require an expressive amount of investment. According to the author, this difference would allow developing countries to skip some of the accumulation of human resources and investments that advanced economies had to endure, thus “leapfrogging” in terms of economic advancement.

For all the optimistic predictions made about automation, the threat of technological unemployment threatened societies before and this time there is also no escape from this challenge. At least not from the debate about technological unemployment which abounds in the recent academic literature and popular discourse even though automation has not reduced employment levels in the past (ARNTZ; GREGORY; ZIERAHN, 2016; AUTOR, 2015; SPENCER, 2018). Still, this particular adverse effect of automation is back in the research agenda of academics (ARIZA; RAYMOND BARA, 2018; ARNTZ; GREGORY; ZIERAHN, 2016; FRANK et al., 2018; FREY; OSBORNE, 2017; KRINGS; MONIZ; FREY, 2021; MITCHELL; BRYNJOLFSSON, 2017; NEDELKOSKA; QUINTINI, 2018; SPENCER, 2018). Moreover, not only the academy is interested in better understanding the future of employment; international agencies, governments, and consulting groups are also exploring the theme. The International Labour Organization (ILO) put the future of work at the center of the activities that mark its 100th anniversary in 2019 (INTERNATIONAL LABOUR ORGANIZATION, 2015). The World Economic Forum has been publishing reports on the future of jobs and related themes since it started discussing the 4th Industrial Revolution (WORLD ECONOMIC FORUM, 2018a). Governments such as the United Kingdom and the United States have also been trying to understand the current wave of technology and its impact on employment (UK COMMISSION FOR JOBS AND SKILLS, 2014; US GOVERNMENT, 2016).

Some papers and reports about the impact of automation have been recently published. The methodologies of these studies can be different because they are concerned with different periods and countries.

With over five thousand citations, the paper written by Frey & Osborne (2017) is the most cited reference about the impact of automation. The authors focused on estimating the impact of what they call computerization (automation caused by computer-controlled equipment) on the occupations listed in the USA occupation classification. Their methodology involved relating the computerization bottlenecks they identified to work variables listed in the O*NET (an online service providing a detailed description of most USA occupations maintained by the USA Department of Labor). These bottlenecks were Social Intelligence, Creativity, and Perception and Manipulation. With the help of a group of machine learning researchers, they evaluated 70 of the 702 occupations in the O*NET in terms of each work variable. Using statistical methods, they were able to estimate the probability of automation of the full list of occupations. The results of their work showed that 47% of US occupations were at high risk (probability higher than 70%) of computerization in the coming decades.

Due to being such a relevant work, these results were applied to other countries. Deloitte (2015a) applied them to Switzerland and discovered that 48% of current jobs could be automated in the coming years or decades, and Deloitte (2014) applied them to the UK, where the results showed that 35% of jobs were at a high risk of automation. Brookfield Institute (2016) did a similar study for Canada and found out that 42% of the country's labor force is at high risk of automation. In Germany, the value is also of 42% of workers at a high risk of automation (BONIN; GREGORY; ZIERAHN, 2015; KRINGS; MONIZ; FREY, 2021). Other studies applied the same methodology to developing countries and the share of the workforce in jobs with a high risk of automation ranged from 55% (Uzbekistan) to 85% (Ethiopia) (SANTOS; MONROY; MORENO, 2015; WORLD BANK GROUP, 2016).

Different from Frey & Osborne (2017), other researchers focus on skill rather than tasks (ARNTZ; GREGORY; ZIERAHN, 2016; MCKINSEY GLOBAL INSTITUTE, 2017a; NEDELKOSKA; QUINTINI, 2018; PRICEWATERHOUSE COOPERS, 2018). Arntz, Gregory & Zierahn (2016) studied 21 OECD nations and found that, on average, 9% of jobs have a high risk of being automated. The level ranges from 12% in countries such as Germany and Spain to 6% in Korea and Estonia. Building on this work, Nedelkoska & Quintini (2018) broadened the study to 32 OECD countries. They estimated that 14% of jobs in these countries are highly automatable (probability of automation higher than 70%), ranging from 6% in Norway to 33% in Slovakia.

Pricewaterhouse Coopers (2018) also used the methodology of Arntz, Gregory & Zierahn (2016), calculating the potential job automation across industries, and found that Transportation and Storage, and Manufacturing are the ones with most workers at risk in the long run (up until 2030), with 51 and 45%, respectively. Still, in the short-run (early 2020), Pricewaterhouse Coopers (2018) believes that the areas at most risk (around 8% of the workforce) are Finance and Insurance, Service Professionals, Scientific and Technical, and Information and Communication.

The McKinsey Global Institute (2017a) estimated that less than 5% of occupations of the 46 countries studied are subject to full automation, considering the adaptation of currently available technology. They also estimated that about half of the activities that people are paid to execute could potentially be automated.

4. The Impact of Automation in Brazil

As can be seen from the previous Chapter, there is a growing body of research about automation, but a study focused on the impact of automation on Brazil's workforce was not done so far. The study presented on this Chapter is one of the first efforts of estimating the impact of automation on Brazil in the context of the 4th Industrial Revolution.

This effort becomes even more urgent as the current COVID-19 pandemic is set to accelerate automation worldwide (BLIT, 2020; CHERNOFF; WARMAN, 2020; DING; MOLINA, 2020; MCKINSEY GLOBAL INSTITUTE, 2020, p. 8; WORLD ECONOMIC FORUM, 2020). A recent global survey done by the World Economic Forum (2020) shows that 50% of employers are planning on accelerating the automation of tasks as a response to COVID-19 with the number reaching 68% in Brazil. Another survey, this one was done by the Mckinsey Global Institute (2020) with 800 executives, shows that 67% of companies have significantly (20%) or somewhat (47%) accelerated automation and artificial intelligence adoption since the start of the COVID-19 outbreak.

The effects are already being perceived, mainly by in-person service workers with a higher risk of viral transmission that are being replaced by machines so that companies do not stop providing their services (CHERNOFF; WARMAN, 2020). Regionally, the effect of automation during the pandemic is being felt as shown by a recent analysis done by the Federal Reserve Bank of Philadelphia (USA) where the workers in automatable occupations were more displaced during the pandemic than those that have a lower risk of automation (DING; MOLINA, 2020).

4.1 Data and Methods

In this study, the Brazilian Classification of Occupations (*Classificação Brasileira de Ocupações* — CBO) was used. The latest version of the CBO has 2,614 occupations, which are updated from time to time by selected institutions supervised by the Ministry of Labor (MINISTRY OF LABOR, 2018a). Another vital source of information was the Annual Report of Social Information (*Relação Anual de Informações Sociais* — RAIS) in its most recent release with data from December 2018. RAIS is a yearly data collection instrument of the Brazilian government through which companies with more than ten employees must inform about their employees themselves.

This study converts the computerization probability calculated by Frey & Osborne (2017) to the United States to the Brazilian occupations. To do so, we adapted the crosswalk between the CBO and the O*NET occupations created by Maciente (2014), a researcher from the Institute of Applied Economics (*Instituto de Economia Aplicada* – IPEA).

To explore the future impact of automation on employment in Brazil, the probability of automation of occupations was crossed with socioeconomic data, using the following formula that was created by Frank *et al.* (2018) to analyze the impact of automation on American cities.

$$I_a = \sum_{j \epsilon Jobs} p_{auto}(j) \cdot share_g(j),$$

In which:

$p_{auto}(j)$ denotes the automation probability of occupation j, and $share_m(j)$ is the number of people employed in occupation j in a given group g, divided by the total number of people employed in the same group.

The Automation Index (I_a) can be interpreted as the expected percentage of total employment in a given group subject to automation (FRANK *et al.*, 2018). The formula was used here to compare the impact of automation in different groups according to workers' education level, and age, and companies' economic sector, and size.

It is important to note the limitations of our methodology. The RAIS database used on this work covers 46 million workers, while, according to (IBGE, 2020), there are 91.2 million people in Brazil's workforce. The main reason for this gap is the number of self-employed people and those working off the books, which accounts for 34.1 million workers (37.4% of the total) (IBGE, 2020). Another group that is not reported in the RAIS is domestic workers, representing 6.2 million workers (6.8% of the total). Finally, filling in the RAIS form is only mandatory for companies with more than 10 employees which also accounts for part of the gap. Nevertheless, another limitation of the RAIS database is that 1,561,885 workers (3.4% of the total) were registered as non-classified and were left out of our study because we could not calculate the probability of automation for their occupations.

The methodology can be criticized for applying the automation probability calculated by Frey & Osborne (2017) to the Brazilian reality. Technology adoption occurs differently from country to country, and even more so from developed countries (e.g., USA) to developing nations as Brazil, as it usually takes more time for innovations to be adopted in the latter group. Comin & Hobijn (2010) analyzed the diffusion of 15 technologies in 166 countries over two centuries, and they found that, on average, it takes 45 years for countries to adopt a technology. However, this value varies significantly between technologies and from country to country. However, more recent technologies have been taking much less time to spread worldwide (COMIN; HOBIJN, 2010; STEINMUELLER, 2001). For example, the Internet took, on average, eight years to diffuse, while steam and motor ships took 123 years (COMIN; HOBIJN, 2010). Taking this into consideration, we believe that the gap of five years between the Oxford research — which was first published online in 2013 — and our own, and the fact that the predictions that resulted from it do not have a specific time frame for coming to fruition (the authors write of "some unspecified number of years, perhaps a decade or two") will help mitigate this limitation.

4.2 Results

4.2.1 Automation in Brazil

The impact of automation in Brazil is analyzed here in terms of the most impacted occupations, the impact of automation in the workforce as a whole, and the historical evolution of the workforce.

Table 2: List of the ten occupations with the most workers in Brazil

CBO Occupation Name	P(Auto)	Number of Workers	CBO Code	SOC Code
Administrative Assistant	96%	2,149,783	411010	439061
Office Clerk	96%	1,924,601	411005	439061
Retailer Salesclerk	92%	1,900,305	521110	412031
Janitor	66%	1,536,815	514320	372011
Production Line Feeder	93%	959,103	784205	537063
Cashier	97%	866,861	421125	412011
Truck Driver (Regional and International Routes)	79%	851,399	782510	533032
Middle-Level Teacher in Fundamental Teaching	56%	706,677	331205	259041
Nursing Technician	6%	625,372	322205	292061
Security Guard	84%	605,550	517330	339032
Total		12,126,466		
Total (Brazil)		46,631,115		

Table 2 shows the ten occupations with the highest number of workers in Brazil, representing over 26% of the total number of workers in the latest RAIS from 2016. As the table shows, seven of those occupations have a probability of automation higher than 70%, and in five of them, the probability is higher than 92%.

The distribution of the total Brazilian employment against the probability of automation is presented in Figure 7. In this graph, as well as in the next one, workers are grouped by the probability of automation in 5% increments, so the first group labeled "1" comprises the workers whose 0% ≤ P(Auto) ≤ 5% and so on. The probability of automation ranges from the occupation least susceptible to automation (Music Therapist — 0.0028) to the most susceptible (Telemarketing Operator — 0.99). The results show that 60% of Brazilian workers are at a high risk of automation (probability of automation equal to or higher than 70%), 18% are at medium risk (30% ≤ probability < 70%), and 22% are at low risk of automation (probability ≤ 30%).

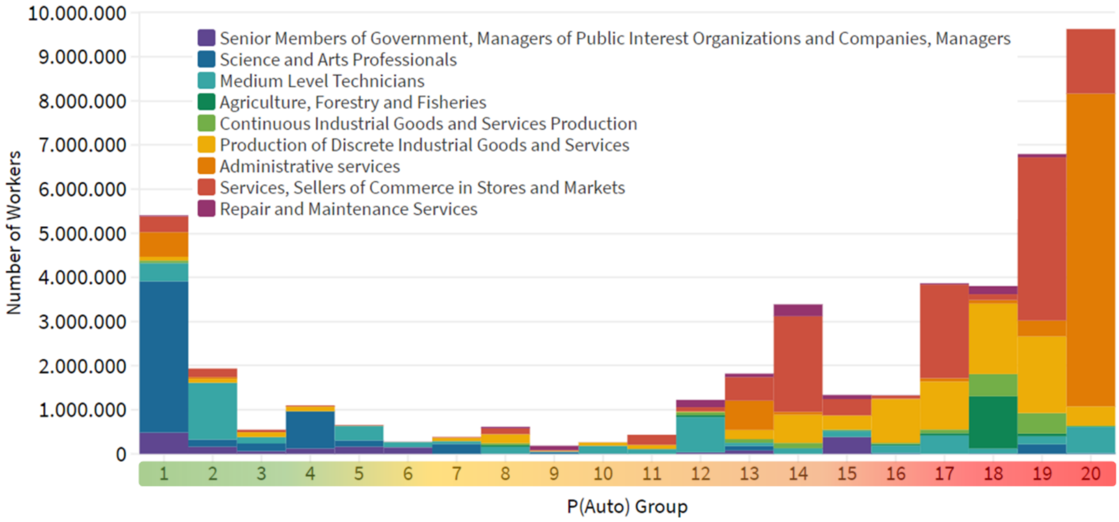

Figure 7: Brazilian workforce distributed by P(Auto)

As can be seen in Table 3, the occupational groups that contribute with the most workers in the high-risk level are Services, Sellers of Commerce in Stores and Markets with 7.8 million workers, Administrative Services with over 7.6 million workers at high risk of automation, and Production of Discrete Industrial Goods and Services with 6.1 million workers. On the low-risk side, the occupation group that contributes with the most workers is the Science and Art Professionals with 4.7 million workers, followed by the Medium Level Technicians with 2.2 million workers, and Senior Members of Government, Managers of Public Interest Organizations and Companies, and Managers with 1.13 million workers.

Table 3: Distrubution of workers by automation risk level

Occupational Group	Automation Risk Level						Total
	Low		Medium		High		
	Workforce	%	Workforce	%	Workforce	%	
Senior Members of Gov., Managers of Public Interest Org. and Companies, Managers	1,139,771	70%	108,600	7%	381,883	23%	**1,630,254**
Science and Arts Professionals	4,754,939	88%	389,637	7%	279,489	5%	**5,424,065**
Medium Level Technicians	2,278,404	42%	1,495,582	28%	1,588,154	30%	**5,362,140**
Agriculture, Forestry and Fisheries	13,941	1%	95,433	7%	1,350,213	93%	**1,459,587**
Continuous Industrial Goods and Services Production	51,970	3%	321,683	21%	1,123,801	75%	**1,497,454**
Production of Discrete Industrial Goods and Services	409,557	5%	1,314,442	17%	6,161,892	78%	**7,885,891**
Administrative services	596,647	7%	753,417	8%	7,621,615	85%	**8,971,679**
Services, Sellers of Commerce in Stores and Markets	651,942	6%	3,179,887	27%	7,861,828	67%	**11,693,657**
Repair and Maintenance Services	29,448	3%	652,044	61%	388,505	36%	**1,069,997**
Total	**9,926,619**	22%	**8,310,725**	18%	**26,757,380**	60%	**44,994,724**

The analysis of the change in occupations in the past in terms of their probability of automation shows that, in every automation group, the change in employment from 2003 to 2018 was positive, which means that the workforce rose in all groups (Figure 8). The workforce at high risk of automation was increased by over 9 million workers while the low-risk group was raised by 4.4 million workers. The group with the most significant increase in employment was the twentieth, assisted mainly by the 2.5 million workers from the Administrative Services and the 759 thousand workers from the Services, Sellers of Commerce in Stores and Markets groups.

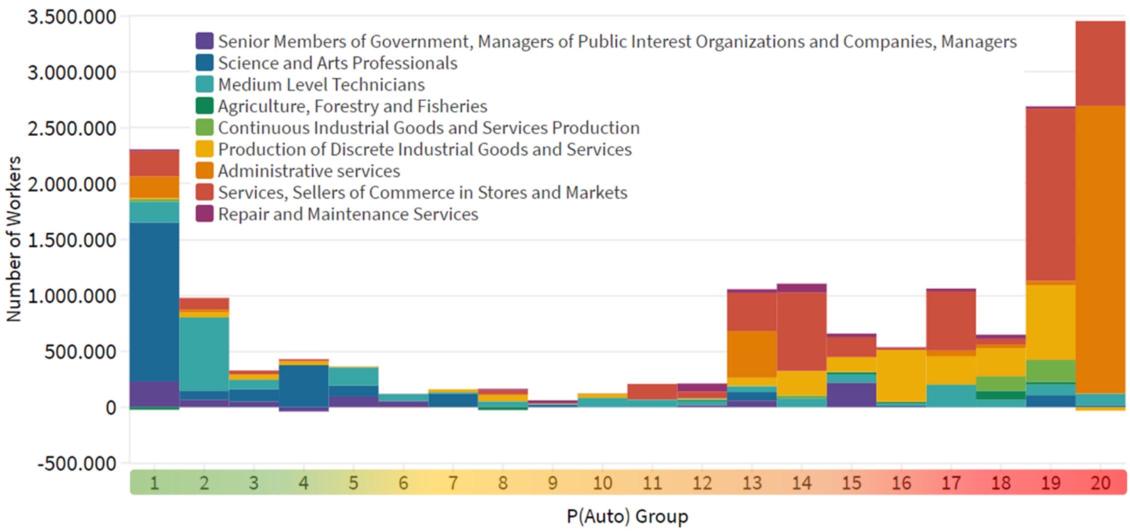

Figure 8: Change in the number of workers, from 2003 to 2016, for each automation group

4.2.2 Automation and workers' characteristics

The impact of automation was analyzed according to three workers' characteristics: education level, age, and wage. The impact of automation on the different education levels in Brazil is shown in the graph in Figure 9. The value of the index is higher when the education level is lower, and there is a considerable drop in the index between the Incomplete Higher Education and Complete Higher Education levels from 0.69 to 0.37 and then another drop to the Master's Degree level to 0.2.

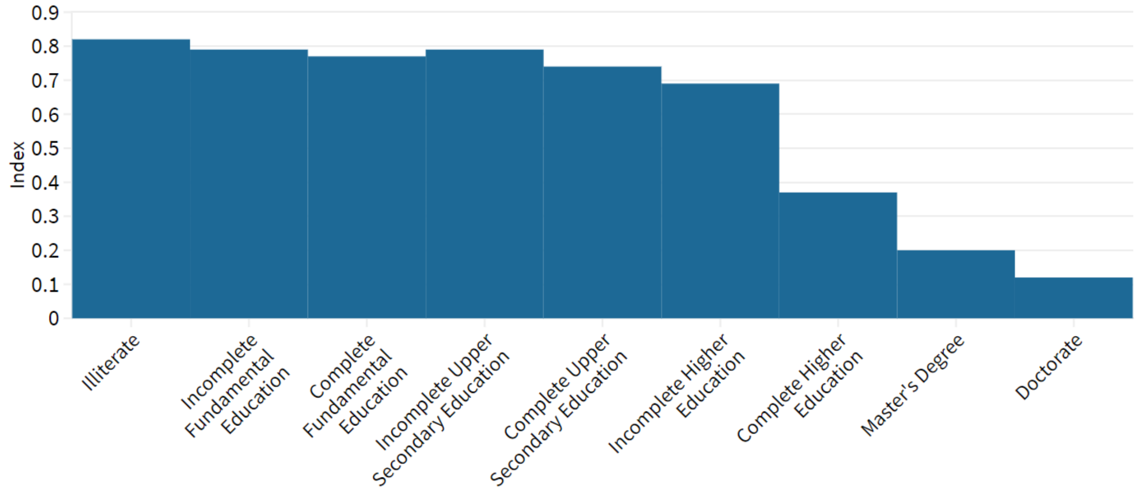

Figure 9: Automation index for each education level

Another workers' characteristic that we analyzed was age. The results show that for workers in the 18-24 years old age group, the index is 79%, and for those in the 25-29 years old group, the index drops to 70%. After that, the index stabilizes at around 61-63% for the other age groups.

The scatter plot in Figure 10 shows the automation probability and the mean monthly wage of each occupation. The model is significant (p-value < 0.0001) and shows a decrease in the automation probability as the medium wage rises but the relationship between the two variables is not as strong as the value of the determination coefficient was low (0.16).

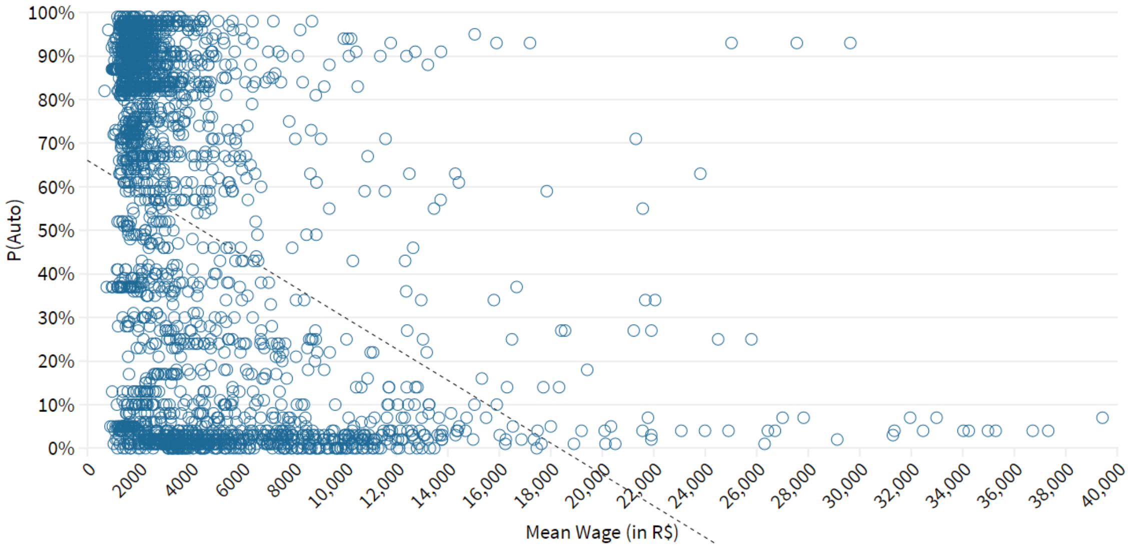

Figure 10: Scatter graph of occupations distributed according to the P(Auto) and the mean monthly wage

4.2.3 Automation and company sector and size

The analysis of the index of automation for the companies sector shows that the three most affected sectors and their automation indexes are as follows: Agriculture, Forestry, Fishing, and Hunting (79%), Commerce (76%), and Manufacturing Industry (75%). The three least affected sectors are Public Administration (49%), Services (65%), and Public Utility Services (67%).

Company size is another characteristic that can be analyzed. Here, the companies are classified according to the number of employees: micro (1–19), small (20–99), medium (100–499), and large (>500). The results show that, as company size increases, automation impact decreases as the automation index of micro-companies is 75%, small companies is 69%, medium companies is 65%, and large companies is 57%.

4.3 Discussion

Automation in Brazil is set to have a considerable impact, as 60% of the workforce or 26.9 million workers are expected to experience a high impact (automation probability higher than 70%), as Figure 7 shows. Also, among the ten occupations with the most workers, seven are in this high-risk group comprising nearly 9.2 million people, as the results presented in Table 2 show. As such, even considering the size of the informal workforce in Brazil that was not part of the analysis, the impact of automation is expected to be high in the coming decades for at least 30% of the whole Brazilian workforce.

These numbers alone would be enough to create a worrisome scenario, but when we consider how poorly the country is prepared for automation, the problem seems even worse. The Automation Readiness Index — calculated by The Economist Intelligence Unit (2018) — considers the innovation environment, education policies, and labor market policies of 25 countries and gives Brazil a score of 46.4 (the average score is 62.1), puts the country in the 19th position. Brazil is in last place for the category of innovation environment, 17th on education policies, and 13th regarding labor market policies.

When we look at the past, over 9 million jobs were created in Brazil between 2003 and 2018, in occupations that are highly susceptible to automation, as Figure 8 shows. Deloitte (2015a, 2015b) made the same analysis for Switzerland and the UK showing that both countries — differently from Brazil — are shifting toward a less automatable workforce, by reducing the number of people occupied in highly automatable occupations and increasing the number of workers in occupations less likely to be automated. This transition depends partly on the education of those workers entering the workforce, if this is not changed, companies will not be able to invest in adopting new technologies as the country lacks the workforce to deal with them. As shown by the Automation Readiness Index discussed above, education policies are a deficit component of the Brazilian preparation to deal with the current wave of automation.

Even if the scenario is complicated for Brazil, when compared with other developing countries, the country fares relatively well. In comparison with the other 42 nations, Brazil occupies the eighth position as the least impacted country. Considering that the workforce at risk for the OECD nations is 57%, only three points lower than the one for Brazil, we can see that Brazil is closer to the average of the more advanced economies than to the average of the developing countries (67%). When looking at other Latin American countries such as Ecuador (69%), Argentina (65%), and Uruguay (63%), Brazil has a lower share of its workforce at risk of automation (WORLD BANK GROUP, 2016).

Still, when compared with the impact of automation in one of the most advanced economies of the world, the result of 60% for Brazil is distant from the 47% value estimated by Frey & Osborne (2017) for the USA. One factor that can explain this difference is the occupation structures of both countries, as presented in Figure 11. The Brazilian structure, in 2011, had a larger share of workers in highly automatable activities than the USA; for example, Farming (10.6% vs. 1.3%), Private Household (7.5% vs. 0.5%), and Blue Collar (29.5% vs. 19.7%) (MAIA; SAKAMOTO, 2015). These differences can be partially explained by the opportunities of using automation still untapped by the sectors that have some of the highest automation indexes according to our results: Agriculture with 79%, and Manufacturing with 75%. In the future, we can expect that these sectors, along with Commerce, which has an automation index of 76%, increase their usage of automation, consequently reducing the workforce employed that could migrate to less affected sectors such as Public Administration, and Services.

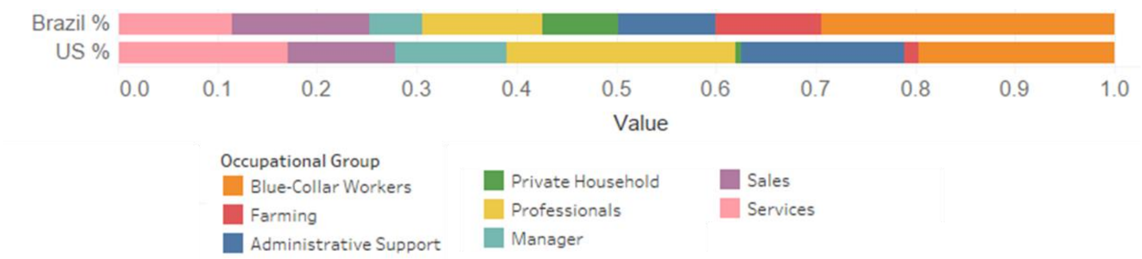

Figure 11: Brazil and US Occupational Structures (2011). Source: MAIA; SAKAMOTO, 2015

Besides the different occupational structures, developing countries are also more susceptible to automation because cheap labor is abundant (OXFORD MARTIN SCHOOL; CITI GPS, 2016). Despite a recent reduction in real wage growth in Brazil (INTERNATIONAL LABOUR ORGANIZATION, 2016), the cost of labor is relatively high when compared to other developing countries due to taxes — the total cost of an employee is around 2.5 times their gross wage (SOUZA *et al.*, 2012). This high cost of paying an employee in Brazil might be greater than the capital investment required to make automation happen (PIKETTY, 2015) thus accelerating automation impact.

The Mckinsey Global Institute (2017a) sees automation as an opportunity for Brazil. According to the institute, if used with other productivity-enhancing strategies such as process transformations, automation could help countries such as Brazil, Russia, China, and Argentina increase current GDP, given that there is an expected decline in the growth of the working population of these countries. Steinmuller (2001) supports this view by defending that ICTs could help developing countries in “leapfrogging,” which involves reducing the productivity gap between advanced economies and developing ones by bypassing some of the steps to accumulate human capabilities and fixed investment. To do so, the countries must satisfy three prerequisites: have absorptive capacities to produce or use ICTs; have access to equipment and know-how necessary to make productive use of later stages in technological development, without developing technological precursors; and have access to technological capabilities that are complementary to the use of ICTs (STEINMUELLER, 2001).

Even though the adoption of automation can be used to increase productivity and GDP, the distribution of these positive results must also be a matter of concern. In the last decades, developed economies have been facing this distributive issue as they increased their GDP, but workers did not experience an expected increase in their wages as well (BRYNJOLFSSON; MCAFEE, 2011; LEWIS; BELL, 2019).

In this sense, one of the most pressing issues that Brazil will have to tackle in the future of employment is the increasing impact that automation will have on the social groups that have the most trouble in transitioning to new jobs. This problem has been highlighted by previous studies on the subject (ARNTZ; GREGORY; ZIERAHN, 2016; FREY; OSBORNE, 2017; NEDELKOSKA; QUINTINI, 2018; PRICEWATERHOUSE COOPERS, 2018) and confirmed by our results to the Brazilian scenario. Less-educated workers, most prominently those without complete higher education, have an automation index of 68% while the value for those that completed their higher education is only 37%. Young workers tend to be more impacted than their older counterparts as the automation index goes from 79% for workers in the 18-24 years old group to 61-63% for those over 30 years old. Our results also show a tendency for workers with lower wages to be more impacted than those with higher wages. A different type of inequality in the impact of automation that was not shown by previous studies but is demonstrated by our results is that micro-companies, with an automation index of 75%, tend to be more affected than large companies with an index of 57%.

Aggravating this situation is the COVID-19 pandemic that, coupled with the accelerated pace of automation, have been causing a dual impact on jobs that disproportionately affects more vulnerable groups such as women, less-educated and younger workers with the risk of increasing inequality (CHERNOFF; WARMAN, 2020; DING; MOLINA, 2020; MCKINSEY GLOBAL INSTITUTE, 2020; WORLD ECONOMIC FORUM, 2020).

Given this scenario, companies and the government will have to find ways to deal with a possible increase in unemployment and the need to retrain these vulnerable workers with the aggravating that a significant portion of them will be working at micro-companies that have fewer resources to retrain workers. As such, education should be a priority issue in the 4th Industrial Revolution since it influences not only the retraining of displaced workers but also the new jobs that are going to be created. Initiatives such as those in the studies of Nesta, Oxford Martin School & Pearson (2018), Partnership For and 21st Century Learning (2018) aimed at understanding the future demand for skills are a good indication for helping the Brazilian companies to prepare its employees for a more automated work and also for the government to update its educational system. In general, the skills that will be demanded from the workers of the future are those that are recognized as bottlenecks for present computing technology; namely, creativity, social intelligence, and fine motor skills (AUTOR, 2015; FREY; OSBORNE, 2017). As automation will not only replace jobs but in many cases, augment them, digital literacy will become an even more important determinant of employability than it already is (BEJAKOVIĆ; MRNJAVAC, 2020). In a country such as Brazil, where 11.3 million people still are illiterate, let alone digitally illiterate, the danger of excluding part of the workforce from jobs that require digital skills or slowing down the adoption of new technologies is considerable.

Another issue that can be aggravated by the impact of automation is that Brazil has a social protection system based on traditional employment relationships, which is already a problem as a large portion of the country's workforce consists of informal workers (WILLIAMS; HORODNIC, 2019). Solutions such as Universal Basic Income and Universal Basic Assets could be analyzed by the government as ways of providing workers, both formal and informal, with a safety net that enables their transition to new jobs (LABORATÓRIO DO FUTURO, 2017; SPENCER, 2018).

4.4 Conclusions

The study presented in this Chapter is an important step in understanding and estimating the impact of automation in Brazil. As such, the information presented can be used by companies, government, and individual in their decision-making. Our results show a preoccupying scenario for the future of employment in Brazil because of the high impact that automation is expected to have in the following decades. Making this situation even worse, those in the most vulnerable social groups — low income, lower education level, and young workers — are the ones who are expected to suffer the most from automation in the coming decades.

The present labor situation in Brazil is already poor, as the unemployment rate in the trimester ended in July 2020 was 13.8% (IBGE, 2020). Thus, the country is left not only with the challenge of creating new jobs that are not going to be automated in the coming decades but also of providing more job opportunities for its population in the short term. The COVID-19 pandemic is a new factor that is expected to accelerate automation and will demand an even faster and incisive response from those involved. Tackling these challenges will require a combined effort of several social actors such as government, companies, and unions that might allow the country to tap into the benefits that automation presents to the economic advancement as a possible driver of productivity and GDP increase.

In order to take the necessary measures to adopt automation in the most favorable way for society, decision-makers themselves need to learn about digital transformation and to keep themselves updated with the latest information about the technological possibilities available. As a recent survey with over five hundred executive shows, only 35% of them believe that future Chief People Officers (CPOs) are getting the development they need (SHRM EXECUTIVE NETWORK; WILLIS TOWER WATSON, 2020). This is a critical issue that has to be addressed if employers are to take their role as drivers of this technological revolution and to be capable of making decisions that steer technology adoption towards positive outcomes while avoiding the many challenges ahead (CHARTERED INSTITUTE OF PERSONNEL AND DEVELOPMENT; PA CONSULTING, 2019).

Society's failure in preparing itself for automation is likely to cause problems such as the concentration of the benefits of automation in the hands of a few, high unemployment rates, and reduced GDP growth. On the other hand, being prepared for the automation wave that is set to last some decades means that companies can increase their output, jobs can become more meaningful and less dangerous, and society can reap the benefits of automation. In the end, it is a matter of understanding technology as a tool that can be used for better or worse.

5. Towards a Model for the Collaborative Assessment of Automation Technologies

As the study presented in the previous Chapter shows, automation is expected to have a considerable impact on 60% of the Brazilian workforce. This high impact is not something necessarily negative. As the literature review about automation in Chapter 3.3 demonstrates, automation has several benefits such as reducing the need for humans to work on dangerous or undesirable jobs, increase precision and effectiveness in important areas such as Health and Transportation, and allow for an increase in productivity.

The challenge that automation presents to society is how to enjoy these benefits while avoiding its perils such as an increase in unemployment and inequality. The first step here is to create knowledge about automation that goes from the broader understanding of the phenomenon to a more specific perception of its impact. This knowledge would enable decision-makers to effectively drive automation to bring about its most positive impact.

The following two chapters present two models that seek to do just that. The first one, whose design process is presented in Chapter 6, involves the application of Crowdsourcing to support the implementation of the methodology created by Frey and Osborne (2017). Differently from the original proposal of the authors which involves asking experts in Computer Science if the state of the art of Artificial Intelligence and Robotics can do a given activity, the proposed model involves the participation of laypeople, mainly workers, in the process of estimating the impact of automation on occupations. This is done by allowing the crowd to register automation technologies on a system where it is then possible to assess these technologies in terms of their readiness and expected impact on specific activities or occupations.

The collective knowledge produced by the crowd in this first model is consolidated in a dashboard that shows which technologies are expected to impact a given occupation and to what extent this is expected to happen.

Even though this model provides an interesting alternative to the expert-centered approach of estimating the impact of automation that dominates the literature about the subject, it does little more than that.

The second model, presented in Chapter 7, goes further in terms of understanding the more specific impact of automation on a given occupation. This model is based on another theory from the economy, this one from David Autor (2015), that considers that a worker will be substituted by a machine if the three main activities of his job can be done by the machine. The model involves using FTA methodologies to discover which automation technologies are relevant for a specific economic sector and then assessing one of these technologies to understand its impact on work.

The technology assessment is done collaboratively with the support of groupware that allows for the registration of technologies, similar to the first model, and their evaluation. The evaluation is first done by an expert that tries to understand which activities the selected technology can do. Then, in a focus group with workers from a given company, the work organization is understood by analyzing the activities that the impacted occupation does in the company. The focus group also discuss the evaluation done by the expert about the possible impact of the technology.

The model also supports the suggestion of job transition pathways for the most impacted workers that are going to be displaced to other occupations if the technology being evaluated is adopted by the company. The model proposes to do this by analyzing information about the worker and the labor market. This is implemented in an algorithm in the system.

This second model is tested in a company to assess the impact of the adoption of the self-checkout technology in a chain of convenience stores. The test showed that the model can help companies understanding the real impact of automation on work by allowing the analysis of its work organization.

As such, the second model contributes to a specific and relevant part of the automation challenge. The model could also be tested in different environments such as government institutions or unions. Still, companies are the *loci* where the adoption of automation technologies into production happens and by acting in these spaces to make clearer the consequences of this process, we can expect a better planned and less damaging automation technology adoption.

6. LABOR*e*: 1st Design Cycle

This Chapter, as well as the next one, are focused on presenting the models that were developed to allow the collaborative assessment of the impact of automation technologies on work. The present Chapter will follow all the steps of the Soft Design Science Research, as shown in Figure 12.

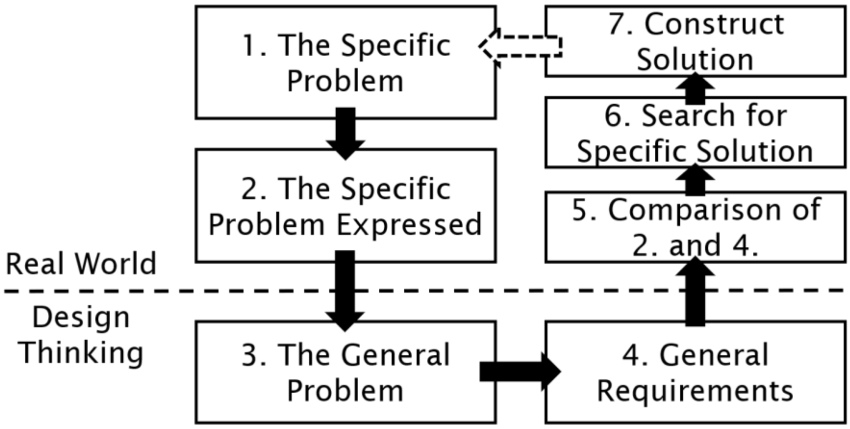

Figure 12: SDSR steps

6.1 Specific Problem

As advocated by Design Science Research, every cycle of design should encompass a simplification of the research question, which will be improved as the work progresses.

Thus, the specific problem that this first design cycle is concerned with can be formulated as to how can a crowd estimate the impact that a set of emerging automation technologies will cause on occupations?

6.2 Specific Requirements

This second step of the SDSR involves expressing the specific problem as a set of requirements, which are presented below. It is important to note that these specific requirements are not to the functional requirements that are used for the development of a computer system. Instead, these specific requirements are a step of the SDSR approach in which the specific problem is broken down into smaller ones and stated as requirements that the model must fulfill to reach its intended goal.

- Requirement 1: the model should allow the classification of the emerging technologies that are going to be assessed;

- Requirement 2: the model should allow individuals to estimate the impact of a given technology;
- Requirement 3: the model should allow the consultation of the impact of a group of technologies on each occupation.

6.3 General Problem

Despite the name, this step of the SDSR is not concerned with generalizing the problem created in step one, but to use design thinking to make the specific requirements more general. Thus, the general problems of this cycle can be stated as follows.

- General Problem 1: how can technologies be classified?
- General Problem 2.1: what Technology Assessment techniques can be used to allow a group of people to give their opinion?
- General Problem 2.2: how to estimate the impact that a group of technologies will have on an occupation?
- General Problem 3: how to combine individual opinion to compose a common collective knowledge?

6.4 General Requirements

This step involved the search for components of the general solution. It is divided into two parts. In the first one, a search for general components is made; in the second, the components of the solution are expressed in imperative terms.

Listed below are the searches that were done to answer each of the general requirements and the imperative terms that express the solution components.

- General Requirement 1:
    a. Investigate technology classification methodologies. In this search, two types of classifications were found, one for differentiating types of technologies and the other to define technology maturity;
    b. The model should incorporate at least one methodology to classify the type of technology to be assessed and its maturity.
- General Requirement 2.1:
    a. Explore Technology Assessment methods. This exploration resulted in the discovery of a wide range of methods used for Technology Assessment (GRUNWALD, 2009; TRAN; DAIM, 2008);

    b. The model should use one or more TA methodologies to allow the involvement of a broad group of people.
- General Requirement 2.2:
    a. Search for technology impact estimation techniques. The result of this search was the widely cited work done by Frey & Osborne (2017). Despite the critics received for considering the activities that compose an occupation and not the skills involved (ARNTZ; GREGORY; ZIERAHN, 2016; MCKINSEY GLOBAL INSTITUTE, 2017a), this paper presented a compelling strategy for estimating automation impact in the future;
    b. The model should incorporate Frey & Osborne's methodology to allow for the estimation of automation probability.
- General Requirement 3:
    a. Search for techniques to quantitatively summarize the opinion of individuals. Several techniques could be used to do this. The search focused on building an index based on different variables by using multi-criteria analysis;
    b. The model should integrate the opinion of individuals by using an index building technique.

6.5 Comparison Between General Requirements and Specific Problem

This step involves comparing the general requirements found through design thinking in the previous step with the specific requirements described in step 2. Table 4 presents the specific requirements on the left column and the imperative terms that resulted from the search for general components of the general problem on the right column.

To meet the specific requirement 1, the classification methodologies proposed could provide relevant information about the technology in terms of its type and maturity that can help the assessment of the technology and the search for technologies in the system.

The specific requirement 2 states that a group of people should be able to give their opinion about the impact of a technology on an occupation. This could be achieved by combining TA techniques with the methodology to estimate automation probability developed by Frey & Osborne (2017).

The imperative statement presented by the general requirement 3 delineates a solution to deal with the need to combine various individual estimates about the impact of different technologies on a given occupation by aggregating these values in a quantitative measure such as an index provided by multi-criteria analysis.

Table 4: Comparison of the specific and general requirements of the first design cycle

Specific Requirements from Step 2	**General Requirements from Step 4**
1. The model should allow the classification of the emerging technologies that are going to be assessed	1. The model should incorporate at least one methodology to classify the type of technology to be assessed and its maturity
2. The model should allow individuals to estimate the impact of a given technology	2.1 The model should use TA methodologies to allow the involvement of a broad group of people
	2.2 The model should incorporate Frey & Osborne methodology to allow for the estimation of automation probability
3. The model should allow the consultation of the impact of a group of technologies on each occupation	3. The model should integrate the opinion of individuals by using an index building technique

6.6 Search for Specific Solution

The search for the specific solution involves looking for different components that could be part of the model to solve the specific problem. Here, the work is divided by general requirement, and, as Table 5 shows, each one may require one or more searches that are presented next.

Table 5: Search for a specific solution to fulfill each general requirement of the first design cycle

General Requirements from Step 4	**Search for Specific Solution**
1. The model should incorporate at least one methodology to classify the type of technology to be assessed and its maturity	1.1 A search has to be made to find the options of technology typology that are available
	1.2 Another search has to be made to find technology maturity classifications
2.1 The model should use TA methodologies to allow the involvement of a broad group of people	2.1 A search has to be made to find TA methodologies that apply to the problem at hand

2.2 The model should incorporate Frey & Osborne methodology to allow for the estimation of automation probability	2.2 A search has to be made to find how the methodology can be done by a group of people
3. The model should integrate the opinion of individuals by using an index building technique	3. A search has to be made to find an adequate method to build an index that shows the impact of technologies on occupations

6.6.1 Search for Specific Solutions 1.1 and 1.2

For the specific solution 1.1, there are several different taxonomies to classify technologies such as the International Patent Classification (WORLD INTELLECTUAL PROPERTY ORGANIZATION, 2018), the NASA Small Business Innovation Research / Small Business Technology Transfer (SBIR/STTR) (NASA, 2014), and the IEEE Taxonomy (IEEE, 2018). In the first analysis, the three taxonomies are broad enough to register the most diverse types of technologies. Still, considering that the goal of the model is to support the assessment of emerging technologies, the chosen taxonomy has to be continuously updated. Among the taxonomies found, only the IEEE Taxonomy is updated yearly and should be used in the model.

The specific solution 1.2 concerns the technology maturity; the most popular classification available is NASA's Technology Readiness Level (TRL) used by research institutions such as the Brazilian Agricultural Research Corporation (*Empresa Brasileira de Pesquisa Agropecuária*, EMBRAPA) (EMBRAPA, 2018) and standardized in the Brazilian Norm ABNT NBR 16290 (ABNT, 2015). Developed in 1989, the TRL is also used by international organizations such as the US Department of Defense and the European Union. The TRL is composed of the nine levels listed below that go from 1 (least mature) to 9 (NASA, 2012):

- TRL 1 – Basic principles observed;
- TRL 2 – Technology concept formulated;
- TRL 3 – Experimental proof of concept;
- TRL 4 – Technology validated in the lab;
- TRL 5 – Technology validated in a relevant environment;
- TRL 6 – Technology demonstrated in a relevant environment;
- TRL 7 – System prototype demonstration in an operational environment;
- TRL 8 – System complete and qualified;

- TRL 9 – Actual system “flight-proven” through successful mission operations.

6.6.2 Search for Specific Solutions 2.1 and 2.2

The search for specific solution 2.1 involved a literature review of the Technology Assessment methodology. The papers reviewed presented several different classifications for TA methods (DECKER *et al.*, 2004; GRUNWALD, 2009; TRAN; DAIM, 2008; VAN DEN ENDE *et al.*, 1998).

Van Den Ende *et al.* (1998) propose a classification of TA methods that is particularly interesting. The authors separate methods by their scope (project layout or tools) and their type (tools for analysis or intervention tools). As we are looking for tools for analysis, it is necessary to understand the types of methods from this group which are the following:

- *Trend Extrapolation*: involves using methods such as the product life cycle to forecast the diffusion of technologies;
- *Structured Interaction*: used to gather the opinion of experts or relevant actors in a structured manner;
- *Checklists*: practical tools for ensuring that no aspect of a TA study is disregarded.

Analyzing these three types of tools for analysis, the Structured Interaction tools is the group that seems to be most aligned with the goal of this first cycle of design because of its capacity to gather the opinion of individuals. Van Den Ende *et al.* (1998) give three examples of this type of tool:

- *Delphi*: a consensus-seeking method that includes interviewing experts about future developments and exchanging answers between them;
- *Cross-impact analysis*: similar to Delphi, is applied when it is necessary to understand the chance of an event happening given that another event will happen;
- *Social simulations*: involves a real-world situation simulation by a group of people.

Concerning the specific solution 2.2, Frey & Osborne (2017) used as methodology the division of a group of occupations into activities and asked computer science researchers to estimate the probability of these activities of being automated in the coming decades. The next step of their methodology involved statistically replicating this effort to the full list of US occupations.

In this first cycle of the design, the model should combine the Delphi technique with crowd computing to allow the crowd to evaluate the occupations' activities as it was done by the researchers in the methodology proposed by Frey & Osborne (2017).

6.6.3 Search for Specific Solution 3

The search for specific solution 3 was made easier because the author was working on a research that used the Analytical Hierarchy Process (AHP, a multi-criteria analysis method) to create an index combining several different variables for the identification of Aedes Aegypti mosquito breeding places (LIMA *et al.*, 2018). AHP is one of the most popular methods of Multi-Criteria Decision Making (MCDM) (ODU, 2019).

AHP is an index building methodology that could also be used in the proposed model to combine the view of the users and provide a single quantitative measure for the impact of each technology on occupations.

In order to use the AHP, a list of variables is compared in a pairwise manner with regard to the criterion preceding them in the hierarchy. If two variables are of equal importance, a value of 1 is given in the comparison; if one variable has moderate importance over the other, a value of 3 is given in the comparison; if the importance is strong, a value of 5 is given; if the importance is very strong, a value of 7; a value of 9 is the highest one and indicates the extreme importance of one variable over the other (ROSZKOWSKA, 2013).

The index that shows the impact of technologies on occupations will be composed of two subindexes. The first one will be the user reputation and the second one the technology relevance. The user reputation is composed of four variables: expertise, a binary that indicates whether the user works in the occupation that he is evaluating or not; time using system, measured in minutes to indicate how much time the user has spent in the system; nº of contributions that shows how many times the user evaluated a technology; and net like/dislike, the difference between likes and dislikes received by the users in the posts that he made in the discussion part of the systems.

By applying the AHP method to the first subindex, we obtain the weights presented in Table 6.

Table 6: Variables and weights for the user reputation

Variable	Weight
Expertise	52,3%
Time using system	9,9%
nº of contributions	26,3%
Net like/dislike	11,6%

The second subindex, technology relevance, uses three variables: occupations impacted, which is the number of occupations that the technology is going to impact according to the information registered in the system; sample size, the number of people that registered any impact of the technology; and sample reputation which is the reputation, as calculated above, of the sample.

Table 7: Variables and weights for the technology relevance

Variable	Weight
occupations impacted	10,5%
sample size	25,8%
sample reputation	63,7%

6.7 Construct Solution

The model built will be presented here by its BPMN activity diagrams and its mock-up prototype of the mobile system, called LABOR*e*. The activity diagrams (Appendix A) show the standard flow of the system and will be presented with the related screen mock-up. The prototype with the transitions between the screens can be seen online[1]. The use case diagram in Figure 13 shows that the use cases of the system involve registering and viewing technologies, assessing the technology and its impact on occupations, and commenting on the Debate section.

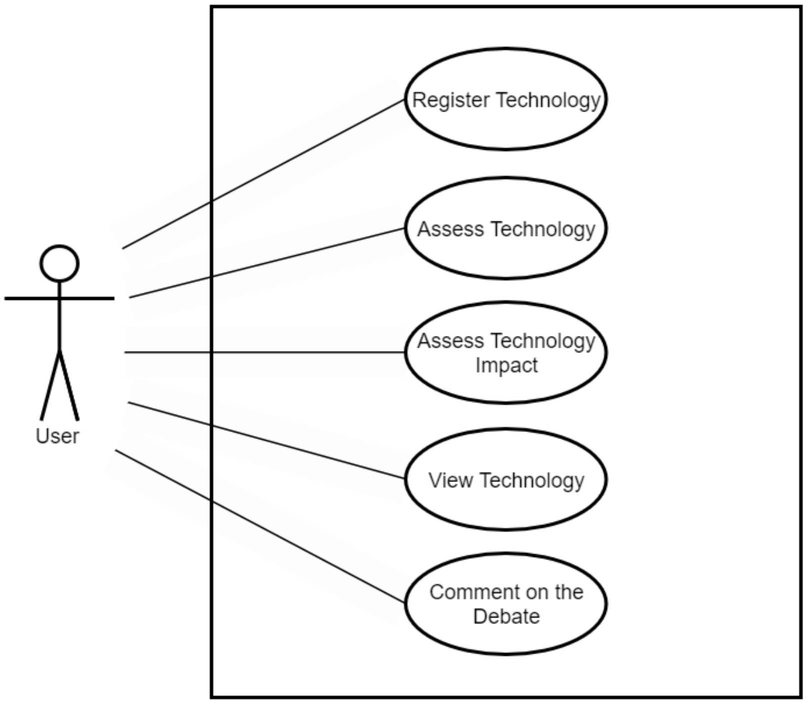

Figure 13: Use Case Diagram for LABORe

In order to use the system to assess a technology, it first has to be registered in the system. The first workflow in Appendix A shows this process which will be described here in detail.

[1] https://marvelapp.com/8h47717

As it can be seen in Figure 14, LABORe provides its users with some information about the technologies to be assessed. For a technology to be created, a user has to provide its name, main and secondary category (according to the IEEE classification), and its description.

Figure 14: An example of a technology registered in the system

Besides providing basic information about the technology, the user can also upload several different knowledge resources such as images, videos, documents (e.g., news, white papers), and links to other resources on the internet (e.g., official website).

Figure 15 shows three images of the system that exemplifies the capacity of the system to serve as a knowledge repository about automation technologies to be assessed. From left to right, the screens show resources such as a picture of the technology, a white paper published by the company developing the technology, and a video of a news outlet discussing the technology.

After filling this information in the system, the user will save the technology which will be made available to any other user that accesses the system.

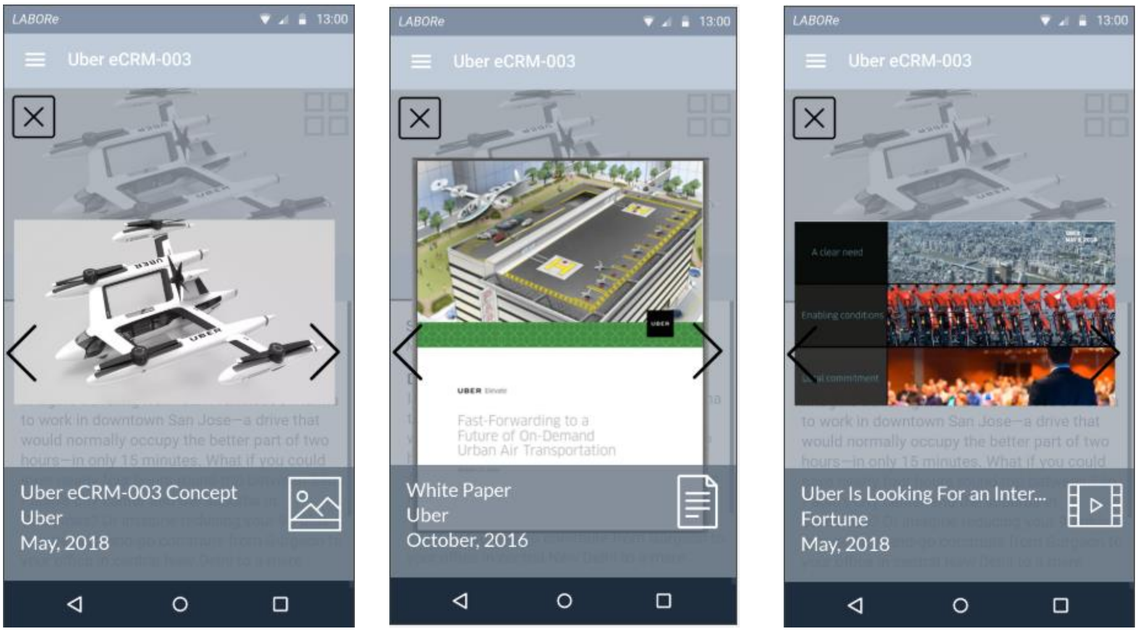

Figure 15: Three screens showing examples of knowledge resource about the same technology

Following the registration of technology, any user can assess it by using the system. The second activity diagram in Appendix A shows the activity flow for this part of the system.

Having accessed the screen, which leads to the technology assessment, the user has access to two tabs. In the first one, titled "Technology", the user is asked to give his opinion about the readiness level of the technology and its availability year. The user can select one of the readiness levels (based on the 10-level scale used by the European Commission, NASA, and Embrapa) and use the question-mark button beside each level to find more information about it. It is also possible to opine on the year in which the selected technology will be available in the market.

Figure 16: "Technology" tab of the Technology Assessment

It is important to remark that if a given user's opinion is too different from those who assessed the technology before him, he will be asked to justify his opinion as it is reccomended by the Delphi methodology. Leaving a comment is also available for users who do not go out of the expected margin, but it is optional in this case. In the "Technology Readiness Level" field, the expected margin is of +/- 2 levels from the crowd mean. Meanwhile, in the "Technology Availability" field, the user is required to justify his opinion if it is +/- 5 years away from the crowd mean value.

The second tab of the technology assessment screen serves to collect the user's opinion about the impact that the technology will cause on a given occupation or a specific activity. Here, as Figure 17 exemplifies, the user can search for the occupation(s) or activity/activities that he believes will be impacted by the technology that is being assessed. Then, he is able to tell how much it will be impacted by selecting a value in a 5-point Likert scale in which "0%" means that the user understands that the technology will have no impact and "100%" means that he believes that the technology will make the selected occupation/activity entirely obsolete.

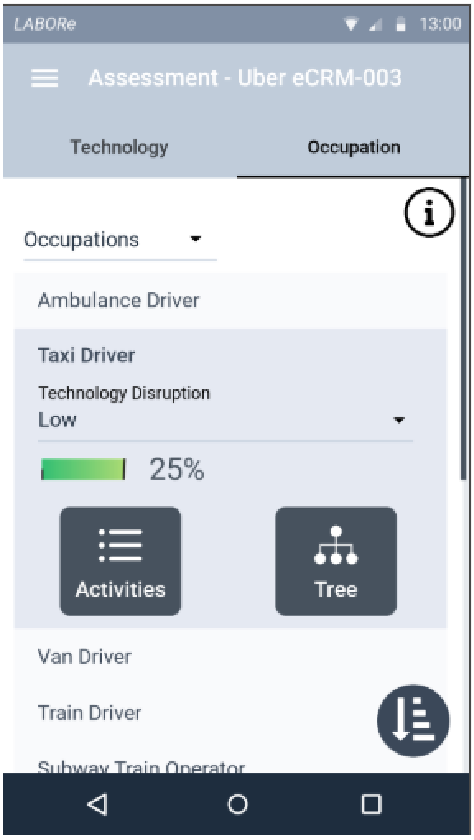

Figure 17: "Occupation" tab of the Technology Assessment

In this tab, as in the other one, the user is also required to justify his opinion. In this case, the comment is necessary is if the user's selected value is +/- 2 points away from the crowd mean value.

The information filled in the Technology Assessment is made available in other parts of the system. Each technology has its own "Assessment" screen in which the knowledge of the crowd is summarized. As the screen on the left of Figure 18 shows, the users can see the assessment results of both the technology characteristics and of the impact caused by the technology. The switch button on the top right-hand side allows the user to switch between the crowd assessment and his own. Another piece of information that can be accessed from this screen by pressing the information button ("i") is the profile of the crowd that assessed the technology, as the screen on the right of Figure 18 demonstrates. This feature shows the user the number of people that contributed with their opinion to each part of the assessment. Besides, it tells the user the proportion of experts in that group. Here, "experts" are the users whose job is either the occupation being impacted or involves executing one or more of the activities being automated.

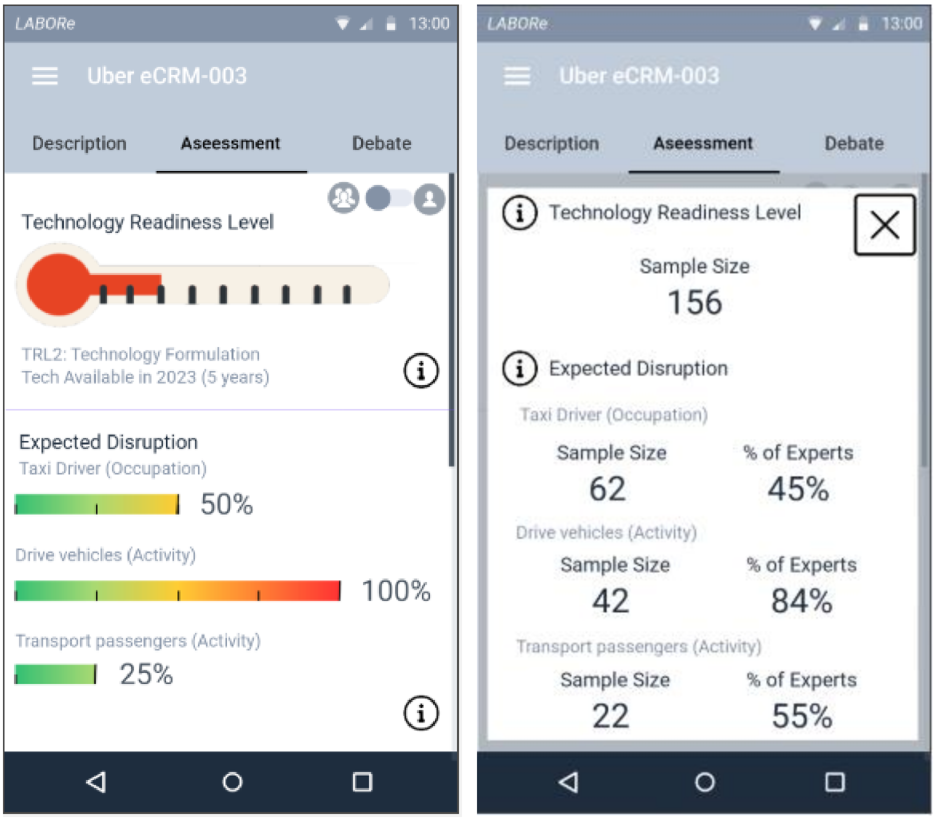

Figure 18: Technology Assessment results screens

Another functionality that is partially fed with the results of the assessments is the “debate” tab available both for each technology and for each occupation. Every comment made during the assessment of any aspect of a technology – be it a justification for a divergent opinion or not – is automatically posted in this debate space. Furthermore, by selecting a comment, several buttons are made available to the user, allowing anyone to participate in the debate by posting messages, replying to previous ones, up or downvoting commentaries, and reporting harmful behavior (Figure 19). This space provides a more qualitative and subjective alternative to the Delphi technique applied in the other part of the assessment in the system.

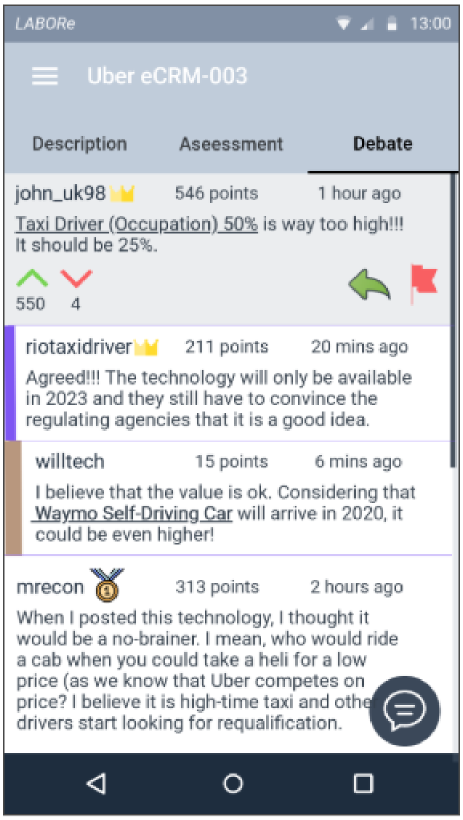

Figure 19: Debate screen

Finally, information gathered by the system can also be viewed in the occupation dashboard presented in Figure 20. In this screen, the Disruption Index is presented which is calculated based on the number of activities of the occupation being disrupted and the level of impact of each technology on it, and the number of technologies disrupting the occupation. In this dashboard, the user can also see the position of the selected occupation in the ranking of occupations from the least to the most automatable as well as how many positions the occupation went up or down in this ranking in the last month.

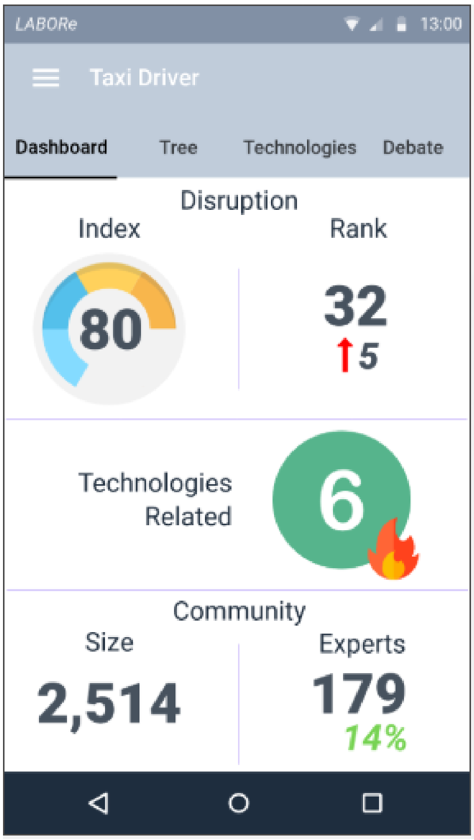

Figure 20: Occupation Dashboard

Other piece of information shown on this screen is the number of technologies related to that occupation in the system, meaning how many technologies are expected to impact the occupation. The dashboard also presents the community size of that occupation which is the number of people who, in the last month, cited the occupation in the debate forums or associated the occupation with a technology. The number of experts in the community is also shown here.

6.8 Evaluate Solution

There are several types of methods for evaluating designs, from observational (e.g., case study) to testing methods (e.g., functional testing) (DRESCH; LACERDA; JÚNIOR, 2015; HEVNER et al., 2004). In general, evaluation in DSR can be divided into two types: artificial, which, as the name tells, involves evaluating the model in artificial environments such as laboratory experiments and using theoretical arguments, and; naturalistic, which entails exploring the performance of a model in its real environment (OSTROWSKI; HELFERT, 2012).

In this first cycle of design, an artificial type of evaluation was done. It involved the construction of a scenario that was presented in the mock-up prototype screens of the previous chapter that was meant to show the model utility. The other method used was a static analysis, initially planned to be a structured evaluation of the model usability, functionality, and completeness using well-established metrics and a questionnaire to be applied in the European Computer-Supported Cooperative Work Conference (ECSCW) where this first design cycle was presented (LIMA; DE SOUZA, 2018). Despite not using the structured questionnaire, the poster was presented to the conference attendees, and the model was evaluated in a more unstructured fashion. Besides this presentation at the conference, this first model was also presented to the Research Director of the International Labour Organization (ILO), to the working group on "Robotics Technology Assessment" of the Institute for Technology Assessment and System Analysis (ITAS) of the Karlsruhe Institute of Technology (KIT), and researchers of the Brazilian Interunion Department of Statistics and Socioeconomic Studies (DIEESE). All these opportunities served as an important evaluation of this first design cycle and, more broadly, of the thesis by experienced researchers from different backgrounds and research fields such as Computer Science, Management, Economy, and Sociology.

The feedback received during the evaluation of this first cycle is listed below.

- Who is the final user of the model? Defining it should help the research progress as considering different users will result in different models;
- Sharing the result of the Technology Assessment with the creators of the evaluated technologies could help them understand the impact that their work is expected to cause;
- It is essential to consider more variables in the model to calculate the reputation of the user besides the fact that the user is a worker of the discussed occupation or not;
- Creating a technology tree, similar to the occupation tree already designed for the model, could help users categorizing and searching technologies;
- Could specific instantiations of the model be developed for specific companies or unions, allowing them to assess only the technologies that interest their industries?
- Should users' companies or unions be identified in the model?
- How can the model consider the positive impact of economic factors such as reshoring caused by new technologies such as 3D printing in raising demand for specific activities or occupations that were previously done offshore?
- Could the impact be estimated in terms of economic sectors?
- How can the model be used to help to reduce occupational segregation?

- Could the model be used to predict new occupations that will be created by emerging technologies?
- Technology cannot be the only factor being considered. Work organization should be considered when evaluating the impact of a new technology being applied to production. The same technology being applied to organizations with different work organizations will result in different outcomes;
- Not only quantitative variables should be used to assess technologies;
- Delphi method involves experts and is established in cycles where participants receive the feedback from a first-round and give their opinions again based on this feedback. Meanwhile, the developed model is dynamic as the results of the evaluation are continually changing;
- How to keep the users engaged with the model, continually coming back to use the system and participating in the assessment of new technologies?
- The registration of new technologies in the model needs to be simplified as the users are not experts in innovation.

7. LABOR*e*: 2nd Design Cycle

This second design cycle starts by recalling the goal of this thesis, which is to develop a model that allows the collaborative assessment of the impact of automation technologies on work. This goal guided the first design cycle and will also guide this second cycle.

As it will be seen in this Chapter, the second model is focused on understanding the impact of a given technology on a specific occupation in a company while the first one was broader and tried to estimate the impact of technologies on any occupation that exists in Brazil. This difference results in two main differences between the first model and the second one.

The first difference is the economic theory behind the models. The first one was based on Frey & Osborne (2017) theory that it is possible to estimate the impact of automation on occupations by analyzing its activities in light of the state of the art technology. This second model is based on Autor (2015) view that if a technology automates the three main activities of a job, then the worker will be displaced to another occupation.

The second difference is the CSCW theory supporting the implementation of the model in the supporting system. The first model is supported by a system that is based on crowdsourcing while the second one is supported by groupware.

The present Chapter will follow all the steps of the Soft Design Science Research, as shown in Figure 12 as the previous Chapter did.

7.1 Specific Problem

The first design cycle started with the following simplification of the goal of the thesis: how can a crowd estimate the impact that a set of emerging automation technologies will cause on occupations?

The specific problem of this second cycle is how can a group estimate the impact that an automation technology will have on a specific occupation of company?

It is essential to highlight the differences between the specific problem posed in the first and second cycles of design. In the second cycle, “crowd” is substituted by “group”. The focus on the organizational environment shows that the second cycle will focus on more specific situations where a selected automation technology impacts a certain occupation within a given company.

7.2 Specific Requirements

The requirements from the first cycle are still relevant, with a change in the second and third ones following the modification of the specific problem.

- Requirement 1: the model should allow the classification of the emerging technologies that are going to be assessed;
- Requirement 2: the model should allow a group of workers, guided by experts to estimate the impact of an automation technology on an occupation of a specific organization;
- Requirement 3: the model should allow for the consultation of the impact of an automation technology on an occupation of a specific organization.

Added to these three requirements is the next one.

- Requirement 4: the model should provide options for career pathways for the most impacted workers.

7.3 General Problem

As the specific requirements of the first cycle are relevant for the second cycle, the general problem 1 and 3 are the same as the first cycle. As the second specific requirement was changed, the general problem associated with it was also reviewed.

- General Problem 1: how can technologies be classified?
- General Problem 2.1: what Technology Assessment techniques can be used to allow a group of laypeople to assess technologies?
- General Problem 2.2: how to estimate the impact that a technology will have on an occupation?
- General Problem 2.3: what job characteristics that are both specific enough to an organization and relevant to estimate the impact of automation on occupations should be considered by the model?
- General Problem 3: how to combine individual opinion to compose a common collective knowledge?
- General Problem 4: how to calculate job transition pathways?

7.4 General Requirements

General Problems 1, 2.2, and 3 are the same from the first cycle; thus, the respective General Requirements are also the same and are repeated below together with the new requirements.

- General Requirement 1:
  a. Investigate technology classification methodologies. In this search, two types of classifications were found, one for differentiating types of technologies and the other to define technology maturity;
  b. The model should incorporate at least one methodology to classify the type of technology to be assessed and its maturity.
- General Requirement 2.1:
  a. Explore Technology Assessment methods that include the laypeople in the assessment process. This exploration resulted in the discovery of some methods used for participatory Technology Assessment (pTA);
  b. The model should use one or more pTA methodologies in order to allow the involvement of a group of workers.
- General Requirement 2.2:
  a. Search for technology impact estimation techniques. The result of this search was the widely cited work done by Frey & Osborne (2017). Despite the critics received for considering the activities that compose an occupation and not the skills involved (ARNTZ; GREGORY; ZIERAHN, 2016; MCKINSEY GLOBAL INSTITUTE, 2017a), this paper presented a compelling strategy for estimating automation impact in the future;
  b. The model should incorporate Frey & Osborne's methodology to allow for the estimation of automation probability.
- General Requirement 2.3:
  a. Search the literature about automation to understand which job details are used to estimate the impact of automation on occupations. This search revealed two schools of thought: one defending that the tasks that compose an occupation should be analyzed to understand how an automation technology would impact it (ACEMOGLU; AUTOR, 2011; AUTOR, 2015; FREY; OSBORNE, 2017); the other one defends that the skills should be analyzed (ARNTZ; GREGORY; ZIERAHN, 2016;

MCKINSEY GLOBAL INSTITUTE, 2017a). As the Brazilian Classification of Occupations does not provide the skills associated with each occupation, the available data constrains the choice of job details to the tasks;

b. The model should consider the tasks of each occupation as the job detail information to estimate the impact of automation.

- General Requirement 3:
  a. Search for techniques to quantitatively summarize the opinion of individuals. Several techniques could be used to do this. The search focused on building an index based on different variables by using multi-criteria analysis;
  b. The model should integrate the opinion of individuals by using an index building technique.
- General Requirement 4:
  a. Search for methodologies to calculate job transition pathways. The search resulted in two different methodologies to calculate job transition pathways (CARROLL; STURMAN, 2009; WORLD ECONOMIC FORUM, 2018b). As both of these methodologies are concerned with the case of the USA and this thesis is focused on the Brazilian situation, the methodologies found cannot be directly applied to this thesis as the available information is different.
  b. The model should use its own methodology to calculate job transition pathways that can be inspired by the methodologies found.

7.5 Comparison Between General Requirements and Specific Problem

The specific requirements from step 2 and the general requirements from step 4 are summarized in Table 8. Given that the specific problem 1 is the same as the first design cycle, the general requirement associated with it is still relevant. As such, the model should still incorporate at least one methodology to classify the type and the maturity of the technology to be assessed.

The specific requirement 2 was changed from the first cycle, and the general requirements are considerably different. The general requirement 2.1 seeks to answer the need for the participation of workers (generally considered as laypeople when it comes to automation technologies discussions) in the process assisted by the experts which is the proposal of the Participative Technology Assessment methodologies. The general requirement 2.2 has been adapted from the first cycle because Frey & Osborne's methodology does not consider workers' opinions, only experts', and should thus be adapted for the specific problem posed. The general requirement 2.3 is concerned with the capacity of the model to consider the work organization of each company. The general requirement associated with it seeks to answer this challenge by proposing the use of the tasks of each job as the most important characteristic of the work organization considering that we are interested in evaluating the impact of automation technologies on jobs.

The specific requirement 3 is also the same as the first cycle. However, the change in the specific requirement 2 that differentiates workers and experts in this second cycle will impact how this general requirement is fulfilled.

The specific requirement 4 is concerned with giving the model the capacity to support decision-making besides the diagnosing capacity that it already had in the first cycle. The general requirement associated with it proposes that a methodology for the recommendation of job transition pathways for impacted workers should be developed for the model.

Table 8: Comparison of the specific and the general requirements of the second design cycle

Specific Requirement from Step 2	**General Requirements from Step 4**
1. The model should allow the classification of the emerging technologies that are going to be assessed	1. The model should incorporate at least one methodology to classify the type of technology to be assessed and its maturity
2. The model should allow a group of workers, guided by experts to estimate the impact of an automation technology on an occupation of a specific organization	2.1 The model should use one or more pTA methodologies in order to allow the involvement of a group of laypeople
	2.2 The model should incorporate Frey & Osborne methodology to allow for the estimation of automation probability
	2.3 The model should consider the tasks of each occupation as the job detail information to estimate the impact of automation

3. The model should allow for the consultation of the impact of an automation technology on an occupation of a specific organization	3. The model should integrate the opinion of individuals by using an index building technique
4. The model should provide options for career pathways for the most impacted workers.	4. The model should use its own methodology to calculate job transition pathways that can be inspired by the methodologies found

7.6 Search for Specific Solution

The searches for specific solutions related to each general requirement are listed in Table 9.

Table 9: Search for specific solutions to fulfill each general requirement of the second design cycle

General Requirements from Step 4	**Search for Specific Solution**
1. The model should incorporate at least one methodology to classify the type of technology to be assessed and its maturity	1.1 A search has to be made to find technology typologies
	1.2 A search has to be made to find technology maturity classifications
2.1 The model should use one or more pTA methodologies in order to allow the involvement of a group of laypeople	2.1 A search has to be made to find pTA methodologies that apply to the problem at hand.
2.2 The model should incorporate Frey & Osborne methodology to allow for the estimation of automation probability	2.2 A search has to be made to adapt the Frey and Osborne methodology to consider the workers' knowledge.
2.3 The model should consider the tasks of each occupation as the job detail information to estimate the impact of automation	2.3 A search has to be made to find a method to survey the workers' tasks.
3. The model should integrate the opinion of individuals by using an index building technique	3. A search has to be made to find an adequate method to build an index that shows the impact of a technology on an occupation.
4. The model should use its own methodology to calculate job transition pathways that can be inspired by the methodologies found	4. A search has to be made to find a method to calculate job transition pathways.

7.6.1 Seach for Specific Solutions 1.1 and 1.2

As the result of the search for taxonomies to classify technologies was not a problem raised in the evaluation of the model, the use of the IEEE Taxonomy should be maintained.

The classification of technology readiness was considered too complex to be undertaken by workers as they can be considered laypeople regarding technology assessment. Thus, the classification of technologies is one of the activities that will be done by technology experts. The use of NASA's Technology Readiness Level will be kept in this second cycle's model.

7.6.2 Search for Specific Solutions 2.1, 2.2 and 2.3

The search for pTA methods has resulted in several options to be used in the model. Table 10 presents the methods classified according to the size of the group.

Table 10: Classification system for participatory methods (THE MILLENNIUM PROJECT, 2009)

	Small group (1-100)	**Large group (100+)**
Meeting in person	Focus Groups, Future Search Conferences, Consensor, TeamFocus, VisionQuest, Simulation-Gaming	Charrette, Syncon, Simulation-Gaming, Voting
Meeting remotely	Computer Groupware, Collaboratories, Integrated, Multi-Media, Simulation-Gaming	Option Polling, Syncon, Public Delphi, Simulation-Gaming, Voting

In this second design cycle, the model is being designed to be used by a small group of less than ten people meeting in person. Thus, the pTA method to be chosen should be in the upper-left quadrant of Table 10. Also, to allow for remote meetings, among other benefits, the model should be developed as a groupware, as seen in the lower-left quadrant of Table 10. How these methods will be used depends on the specific solution 2.2 discussed next.

The work of Frey & Osborne (2017) builds on the literature of labor economics that considers the task content of jobs to estimate the impact of automation on work. In their seminal paper, they use two approaches. First, they asked researchers to hand label 70 occupations with 1 if automatable and 0 if not by answering the question "Can the tasks of this job be sufficiently specified, conditional on the availability of big data, to be performed by state of the art computer-controlled equipment?". Secondly, they looked at the present capacity of computing technologies (particularly Artificial Intelligence and Robotics) to understand the limits of these technologies in terms of their capacity to substitute human labor. The three bottlenecks that they found that these technologies still have in terms of automation are Social Intelligence, Creativity, and Advanced Perception and Manipulation. The authors then found O*NET variables corresponding to these bottlenecks. Considering both approaches, Frey & Osborne develop an algorithm to calculate the automation probability of 702 occupations (FREY; OSBORNE, 2017).

As can be seen by this summary of Frey & Osborne's work, they estimated the probability of a list with hundreds of occupations, relying on experts and on statistics to achieve their goal. This result was adapted for Brazil in the research presented in Chapter 4.

Different from estimating the probability of automation of hundreds of occupations, the model designed in this thesis, especially in this second cycle, is concerned with more specific cases of automation adoption. Thus, the methodology developed by Frey & Osborne cannot be adopted, as is, to solve the challenge at hand.

By looking at Frey & Osborne's main references in terms of methodology, Ingram and Neumann use skills present in the US Dictionary of Occupational Titles (DOT), and Acemoglu and Autor use a task model where the tasks are divided between routine/nonroutine and manual/analytic tasks (ACEMOGLU; AUTOR, 2011; FREY; OSBORNE, 2017; INGRAM; NEUMANN, 2006).

Ingram methodology cannot be adopted because the Brazilian Classification of Occupations (CBO) does not have the skills of each occupation as only the activities of each occupation are listed in the CBO, as exemplified by the first two activity groups of the occupation "Retail Salesperson" on Table 11.

Table 11: Example of activities for occupation "Retail salesperson". Source: (MINISTRY OF LABOR, 2018a)

Activity Group	**Activity**
Control Incoming and Outgoing Products	List products to be replaced
Control Incoming and Outgoing Products	Order products
Control Incoming and Outgoing Products	Receive products
Control Incoming and Outgoing Products	Post products receipt and products issue
Exhibiting Products at Points of Sale	Ensure cleanliness of the exposure point
Exhibiting Products at Points of Sale	Examine products condition (validity and physical condition)
Exhibiting Products at Points of Sale	Define location to display the products
Exhibiting Products at Points of Sale	Organize products according to store layout
Exhibiting Products at Points of Sale	Replace products at points of sale

The skills are only listed in the CBO for each occupation family, not for every occupation. Also, they are personal skills (such as “dealing with diversity”, “demonstrate dynamism”, and “teamwork”) instead of skills in general, as shown by the list below of skills of the occupation family “Operators of commerce in stores and markets” of which the occupation “Retail Salesperson” is part of:

- Demonstrate sensory ability (smell, taste);
- Dealing with diversity;
- Apply nursing basics;
- Establish customer relationships;
- Transmitting confidence;
- Teamwork;
- Demonstrate objectivity;
- Dealing with the public;
- Demonstrate credibility;
- Demonstrate verbal communication skills;
- Demonstrate dynamism;

- Demonstrate rhetorical ability;
- Demonstrate flexibility;
- Work around adverse situations.

Thus, the model has to use the occupation's tasks as the job design element to be analyzed.

Besides looking at the characteristics of occupations, Frey & Osborne also analyzed the capacity of the state of the art technologies to perform tasks currently performed by humans. As they were interested in analyzing the US labor market as a whole, their work does not explain how a specific technology (i.e., self-checkout) would impact a specific occupation (i.e., cashier). Instead, their methodology considers robotics and AI in general.

As the model developed in this second design cycle is not concerned with the labor force of a whole country – this was the goal of the first design cycle model – there has to be a consideration of specific technology capabilities instead of an analysis of the state of the art of robotics and AI in general.

A proposal to do this is to look at an automation technology as if it were a worker in terms of what it can do. Thus, the experts can analyze a given technology and list the tasks that it can perform. To make a comparison between the workers' tasks and the machines' ones, the tasks that the machine can perform will be taken from the CBO table of activities.

After the experts evaluate the capabilities of a technology, a focus group will be arranged with the workers that are set to be affected by the adoption of the technology. The goal in this focus group is to understand their job specificities to increase the accuracy of the experts' diagnosis. To determine which activities from the CBO the workers actually perform, a public poll mediated by groupware should be undertaken. It should also be made clear in the focus group which challenges and opportunities the workers perceive for adopting the technologies being assessed.

7.6.3 Search for Specific Solution 3

David Autor, one of the primary references in Frey & Osborne's research about automation, defends that if the three main activities of a job are automated, then the worker will be substituted by the machine and will need to be allocated in another job

(AUTOR, 2015). Adopting this theory to the model, it is possible to quantitatively estimate a probability of automation by using the analysis described above where the activities of the workers are compared with the capabilities of the technology being assessed if the information about the three main activities of the job is also collected.

Besides calculating an automation probability, the focus group allows for a qualitative view of the adoption of technology by exploring the challenges that arise from the discussion and cannot be summarized in an index but can be part of the final result of the model.

7.6.4 Search for Specific Solution 4

As commented in Chapter 7.4, there are two methodologies for calculating job transition pathways in the literature, one from the School of Hotel Administration of the Cornell University (CARROLL; STURMAN, 2009) and the other one from the World Economic Forum (WORLD ECONOMIC FORUM, 2018b).

The first methodology, from Cornell University, uses the O*NET, an occupation database maintained by the United States Labor Bureau which covers 812 occupations and has 277 descriptors for each occupation. The descriptors are very thorough and describe, for each occupation, worker characteristics (e.g., abilities, work styles, and values), experience requirements (e.g., training), workforce characteristics (e.g., labor market information and occupational outlook), and occupation-specific information (e.g., tasks, tools, and technology) (CARROLL; STURMAN, 2009).

By using this database, the methodology focuses on the skills needed for an occupation. In the O*NET, there is a list of 35 skills and for any occupation, the skills are rated on a 7-point scale according to their importance for a given occupation. The methodology then compares the current occupation with the target occupation in terms of the similarity of the skills required to perform the occupations. Using this methodology, the authors calculate the Job Compatibility Index and present a table with the index and the Mean Hourly Pay for the current occupation and the target occupations. The idea is that possible career paths have a good Job Compatibility Index and offer an equal or higher Mean Hourly Pay (CARROLL; STURMAN, 2009).

The second methodology found in the literature is from the World Economic Forum and was elaborated in collaboration with the Boston Consulting Group and

Burning Glass Technologies. Their methodology uses the O*NET and the United States Bureau of Labor Statistics databases as well as the Burning Glass Technologies database which aggregates over 50 million online job postings in the United States over two years. Differently from the first methodology, which uses just one of the available descriptors of an occupation, this second methodology involves nine different variables: work activities, knowledge, skills, abilities, years of education, years of work experience, years of job family experience, wage, and job numbers (WORLD ECONOMIC FORUM, 2018b).

By aggregating the data about the six first variables listed above of a given current occupation and the other occupations available in the O*NET, each pair of occupations is given a similarity score between 0 and 1. In this methodology, scores with high similarity are of at least 0.9, medium similarity are between 0.9 and 0.85, and low similarity are the scores below 0.85. A second factor in determining viable job transition options is the years of job family experience which is measured by the so-called “job zones” of the O*NET. These “job zones” range from 1 to 5, where an occupation in zone 1 requires little or no preparation and an occupation in zone 5 requires extensive preparation. The methodology only considers an occupation a viable job transition option if its similarity score is medium or high and if the job zone change ranges from -1 to +1 (WORLD ECONOMIC FORUM, 2018b).

The methodology goes one step further as an occupation might be a viable transition option without being desirable. The authors define a desirable job transition option as having two characteristics: stable long-term prospects, the target occupation must have job numbers forecasted not to decline, and wage continuity or increase between the current and target occupation (WORLD ECONOMIC FORUM, 2018b).

As noted in Chapter 7.4, the two methodologies explained above are concerned with the reality of the United States, but analyzing them should help in the proposal of a methodology for Brazil. The first methodology shows the importance of skills when suggesting transition pathways, but it only focuses on two variables, skills and mean hourly wages. The second methodology is considerably more thorough as it uses nine variables in three different steps and relies on three different databases. Still, it has one limitation which is the fact that it does not consider the characteristics of an individual worker while suggesting a transition. For instance, some occupations might be available in a given city that is different from the city that the worker is located.

To create a method to calculate job transition pathways for the model, five different methods from three different subjective approaches for Multi-Criteria Decision Making MCDM were applied: Ranking (rank sum, exponent weight, and reciprocal weights), Pairwise Comparisons (Analytical Hierarchy Process – AHP), and Point Allocation (ODU, 2019; ROSZKOWSKA, 2013).

The first step in any of these methods is the same and involves listing the criteria for decision-making. Here, the variables available in the RAIS database and the resulting automation probability from Chapter 4 will be used. As such, the variables to be considered in the decision-making are listed in Table 12 and a further description of the variables as well the methodology for their quantification is presented in Appendix B.

Table 12: Variables to be considered in the construction of the job transition pathways method

Variable	**Source**	**Description**
Automation Probability	Chapter 3	The probability of automation of the occupation in the next decades
Occupation Activities	CBO	The list of activities that the worker in the occupation could do
Occupation Family Skills	CBO	The list of skills that a worker in the occupation family is expected to have
Economic Activity	RAIS	The economic activity of the employing company as given by the CNAE
Wage	RAIS	The monthly wage of the worker
Education Level	RAIS	The education level of the worker
Municipality	RAIS	The municipality in which the worker is working
Variation (last five years)	RAIS	The relation between the variation in the last five years of the number of people employed in the origin occupation and the destination occupation
Variation (last year)	RAIS	The relation between the variation in the last year of the number of people employed in the origin occupation and the destination occupation

After listing the variables, it is necessary to give them a weight to determine the importance of each one by using the methods advocated by each one of the three approaches. In the Ranking method, the variables must be ordered in a ranking from the most relevant to the least relevant; in the pairwise comparison method, each variable is compared individually with another one in pairs until comparisons between all the variables are done; and in the Point Allocation method, a certain number of points is distributed among the variables with those that receive the most points considered the most important for the defined goal (ODU, 2019; ROSZKOWSKA, 2013). This task was done through an online form that was filled by three researchers with a background related to the subject of the research.

Knowing the importance of each variable, the weight of the variables is calculated using the formula of each one of the five methods. The table with the results of this process is presented in Table 13 and should be implemented in the model.

Table 13: Weight of the variables used in the job transition pathways method

	MCDM Method				
Variable	**Rank Sum**	**Rank Exponent Weight**	**Rank Reciprocal Weights**	**Point Allocation**	**AHP**
Automation Probability	0.081481	0.050312	0.066365	0.066667	0.066597
Occupation Activities	0.185185	0.259875	0.252186	0.15	0.248172
Occupation Family Skills	0.177778	0.239501	0.210155	0.133333	0.276719
Economic Activity	0.051852	0.020374	0.054823	0.113333	0.038237
Wage	0.096296	0.07027	0.074172	0.143333	0.081195
Education Level	0.140741	0.150104	0.11463	0.183333	0.080331
Municipality	0.044444	0.014969	0.052539	0.066667	0.02524
Variation (last 5 years)	0.133333	0.134719	0.105078	0.083333	0.114367
Variation (last year)	0.088889	0.059875	0.070052	0.06	0.069142

7.7 Construct Solution

The model built in this design cycle will be presented here by its BPMN activity diagrams and print screens from the system[2], called LABOR*e* v2. Different from the first design cycle, this time the system was developed in its entirety based on the prototype that was created. The activity diagrams (Appendix C) show the standard flow of the system and each of its steps will be presented with the related screen. The prototype with the transitions between the screens can be seen online[3]. The use case diagram in Figure 21 shows that the use cases of the system are for the expert to register technologies, analyze the technology capabilities, and conduct the focus group; for the worker, the uses are to select job activities, evaluate the technology capabilities analysis; and for the manager, the uses are to select the technology to be assessed and to view the assessment results.

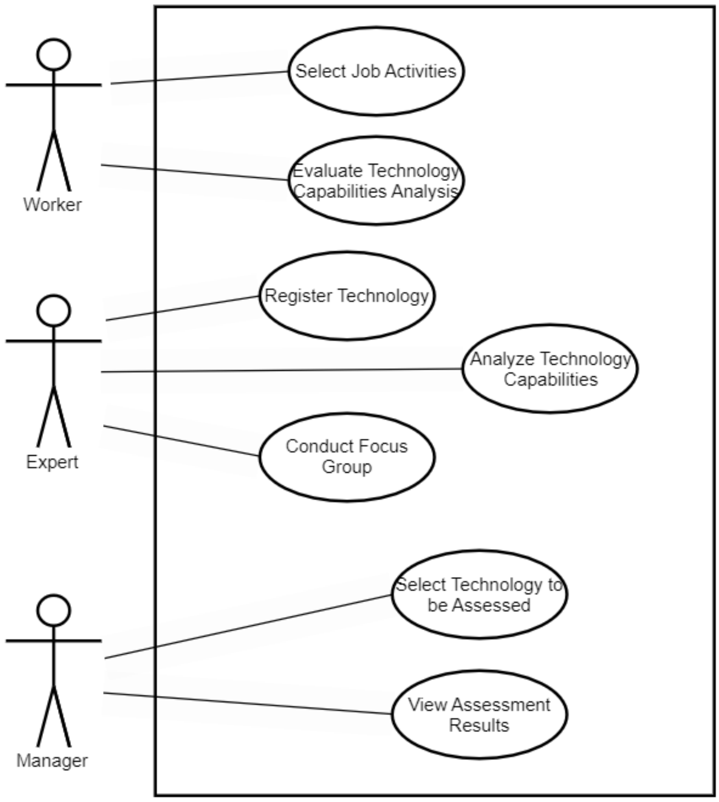

Figure 21: Use Case Diagram for LABORe v2

[2] The system can be accessed via the link: https://prod.laboregov.com/ with the credentials user (yurilima) and password (123456)

[3] The prototype can be accessed via the link: https://marvelapp.com/prototype/57e3516/

As shown by the first activity diagram in Appendix C, the methodology starts by choosing a company and defining a specific sector to be the focus of the Technology Assessment. Next, a technology forecast about the sector is done using FTA methodologies whose choice depends on the situation and may involve Brainstorming, Futures Wheel, Scenarios, and others (BARBOSA, 2018; THE MILLENNIUM PROJECT, 2009).

The next step is similar to the previous framework and involves registering the technologies presented by the second activity diagram in Appendix C. The registration of the technology includes the same information as the first version of the system but, this time, the technology readiness level is selected during the registration. In the first model, this activity was done in the technology assessment phase. Another significant difference here is that the technology registration is done by an expert that understands the emerging technologies relevant to the economic sector of the organization. The registered technology is visualized in the system as exemplified by Figure 22.

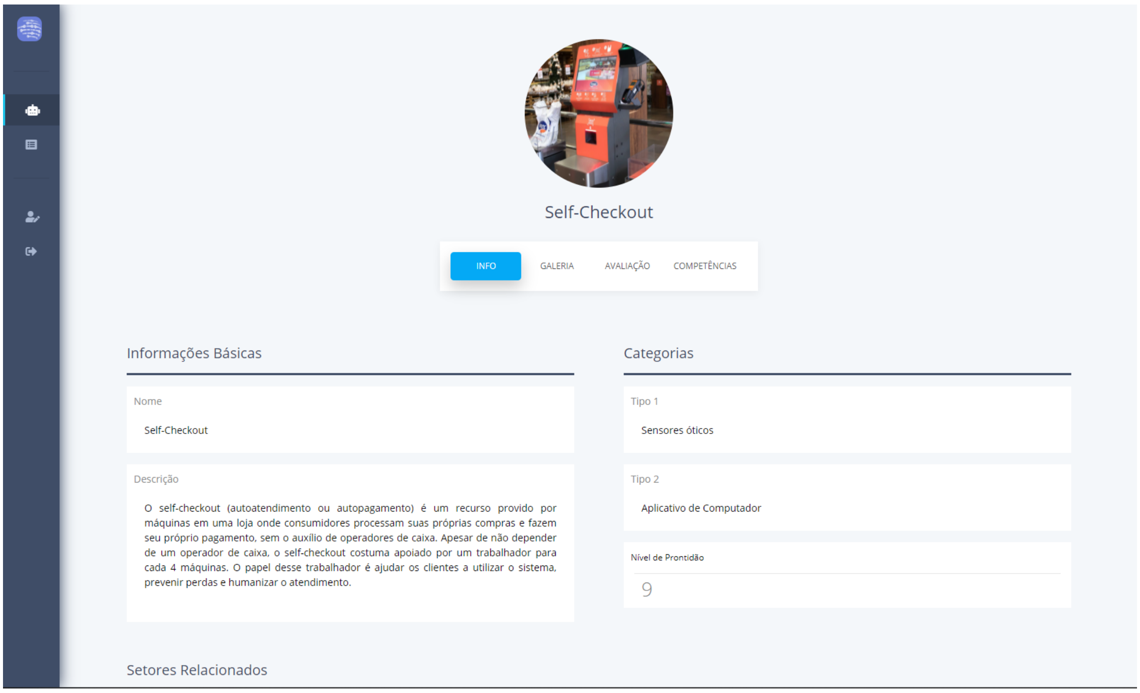

Figure 22: Example of technology registered in the system

After registering the technologies, the expert has to register the assessment in the system. The first step in creating the assessment is giving it a name, description and selecting the economic sector related to it (Figure 23).

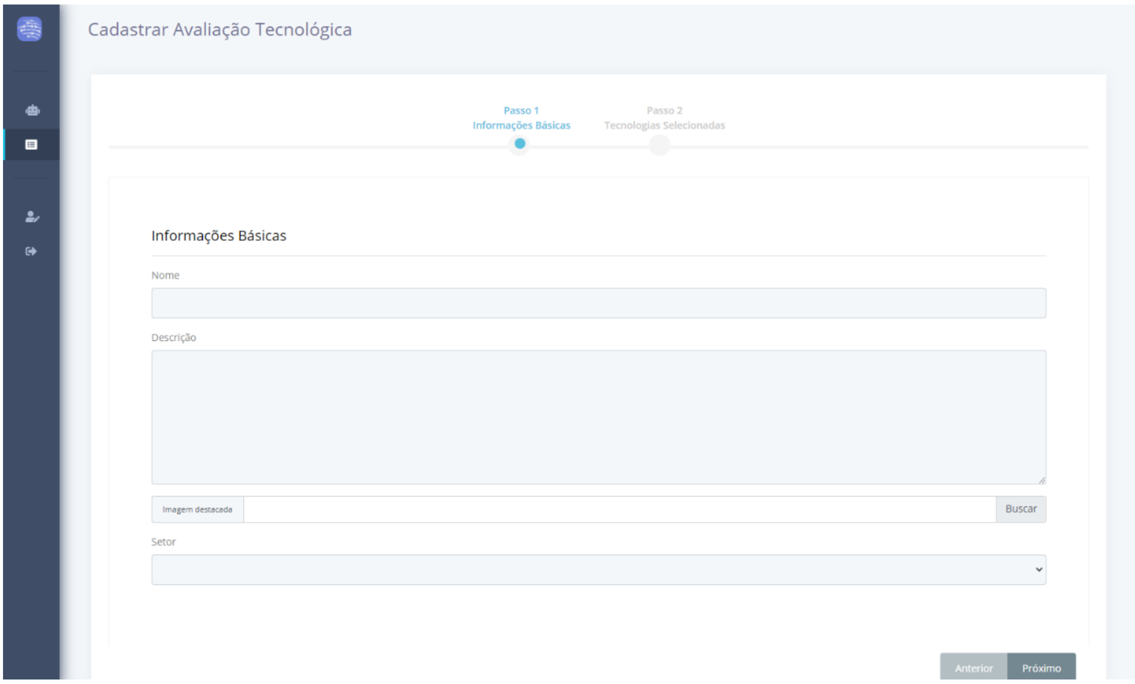

Figure 23: Assessment Registration

In the second step, the expert, with the help of a manager of the organization, has to select the technology that will be assessed (Figure 24). Depending on the case, the manager can make this selection after the registration of the technology assessment by the expert as the system also supports this option.

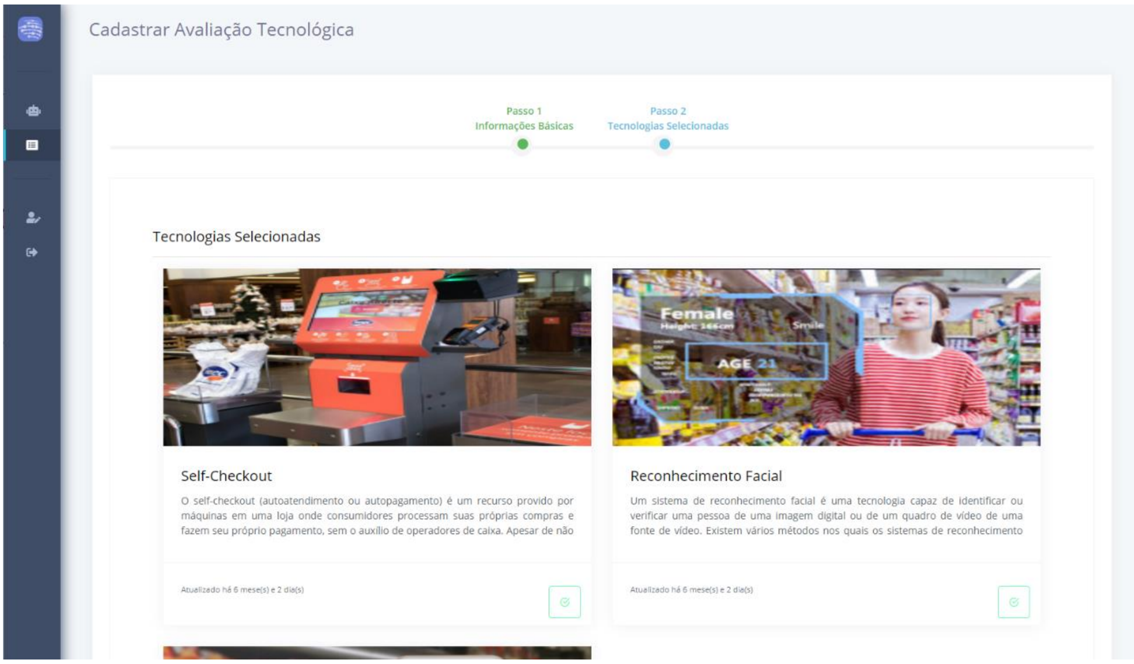

Figure 24: Technology selection during the Assessment registration

After registering the assessment, the expert evaluates the capabilities of the technology that the manager has selected to be assessed. This step is similar to the technology assessment done in the first design cycle. The difference in this second framework is that the expert is not saying what occupations or activities the technology is going to impact but what activities the technology can perform (Figure 25). Also, this analysis done by the expert will be later evaluated by the workers of the company according to their reality and opinion.

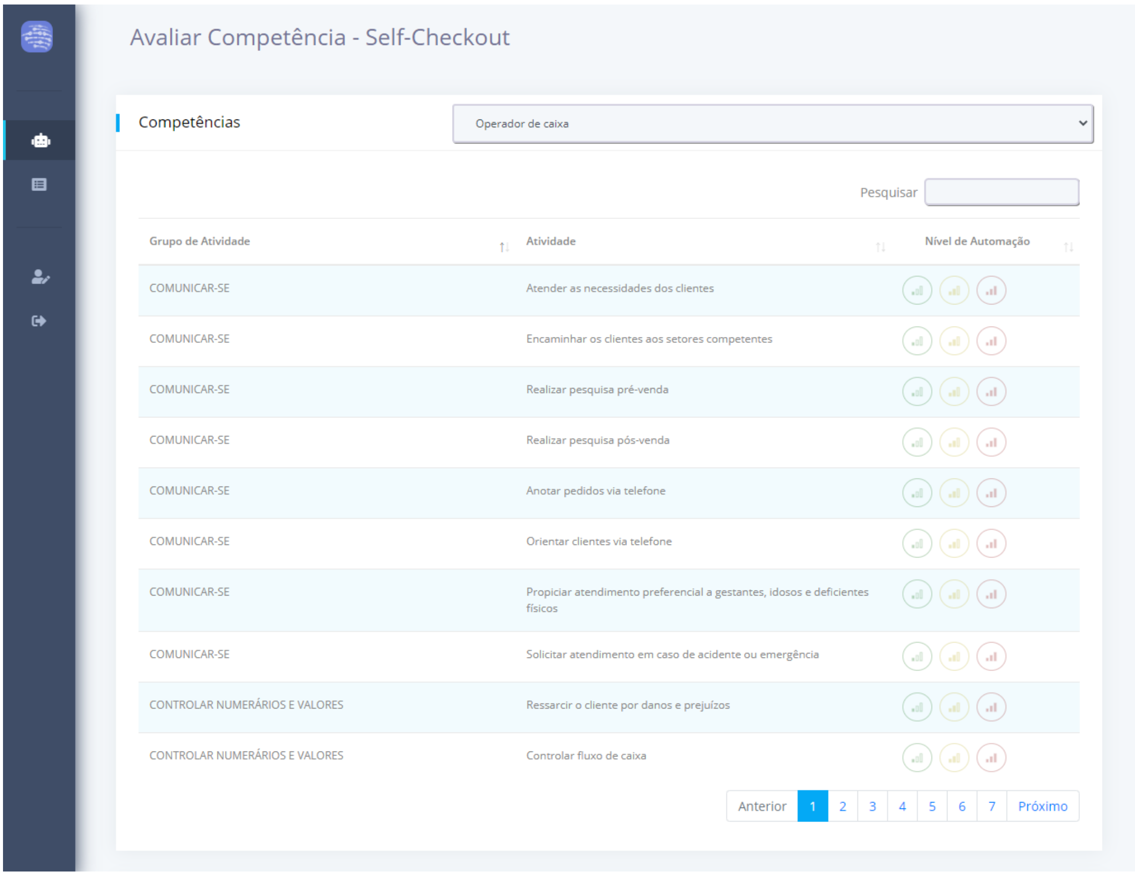

Figure 25: Evaluation of the capabilities of the technology

As shown by Figure 26, in addition to a list of activities that the technology can perform, this step also results in a list of occupations that tend to be more impacted by the technology. This list of occupations will define which employees of the organization should participate in the Technology Assessment process.

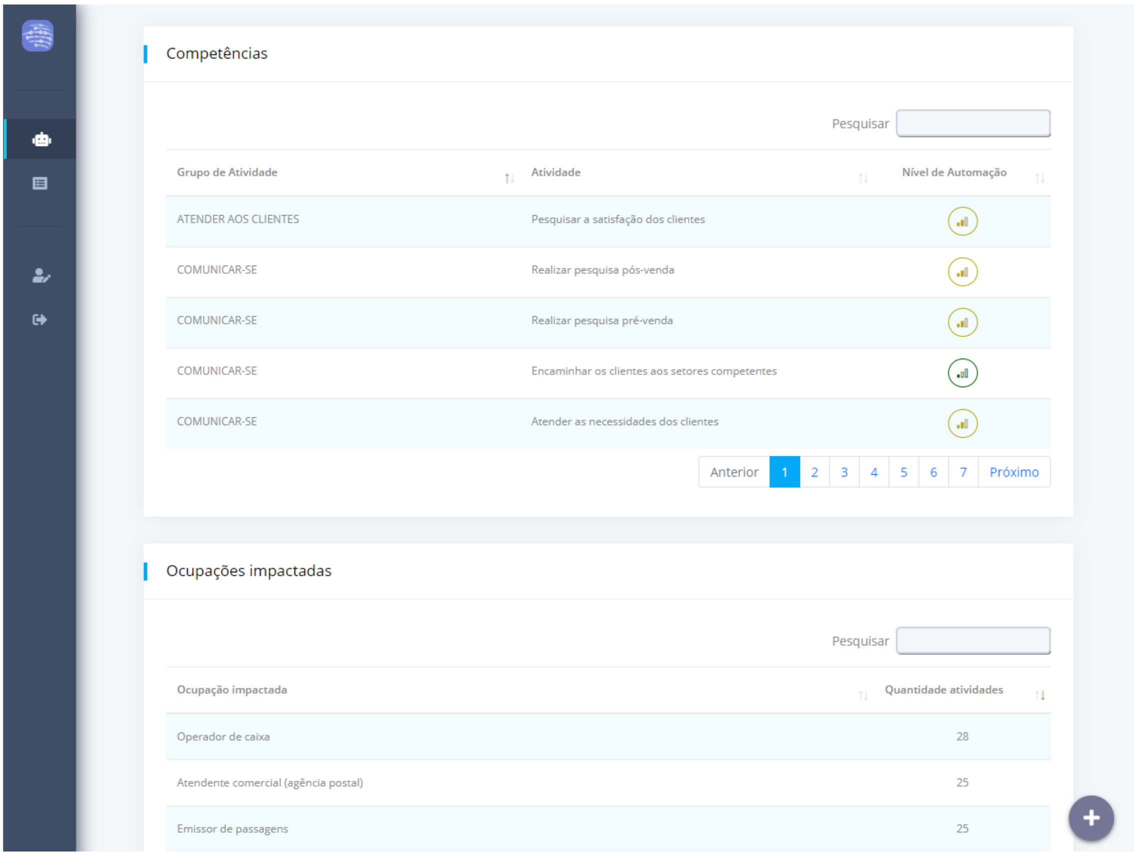

Figure 26: Results of the evaluation of the technology capabilities

Having evaluated the competencies of the technology, the expert will register the workers of the organization that will participate in the focus group. The list of workers and their information (name, age, educational level, current and previous occupation) is provided by the manager of the organization to the expert.

The expert, then, needs to schedule with the manager of the organization a focus group session with around five employees that will participate in the assessment. Preferably, this group should be of workers of the same occupation to facilitate the discussion.

The focus group session will involve five steps summarized by the third activity diagram in Appendix C. In the first one, the expert will present the technologies that are going to be assessed. The workers must have a relatively good understanding of the technologies to discuss them later.

The workers do the second, third, and fourth steps on their smartphones by accessing a link provided by the expert. These three steps are done as silently as possible by the workers as the discussion will be done in the fifth step.

The second step involves the selection by the workers of the activities that they execute in their jobs. To do so, the workers are presented with the list of activities in the CBO that their occupation is expected to do and inform whether they execute or not each activity on their jobs. The third step is where the worker chooses, from the activities that he said are part of his job, the three main activities of his job (those on which he spends the most time. Figure 27 shows the screens that represent these activities in the system, the left image being from the second step and the right one from the third step of the focus group.

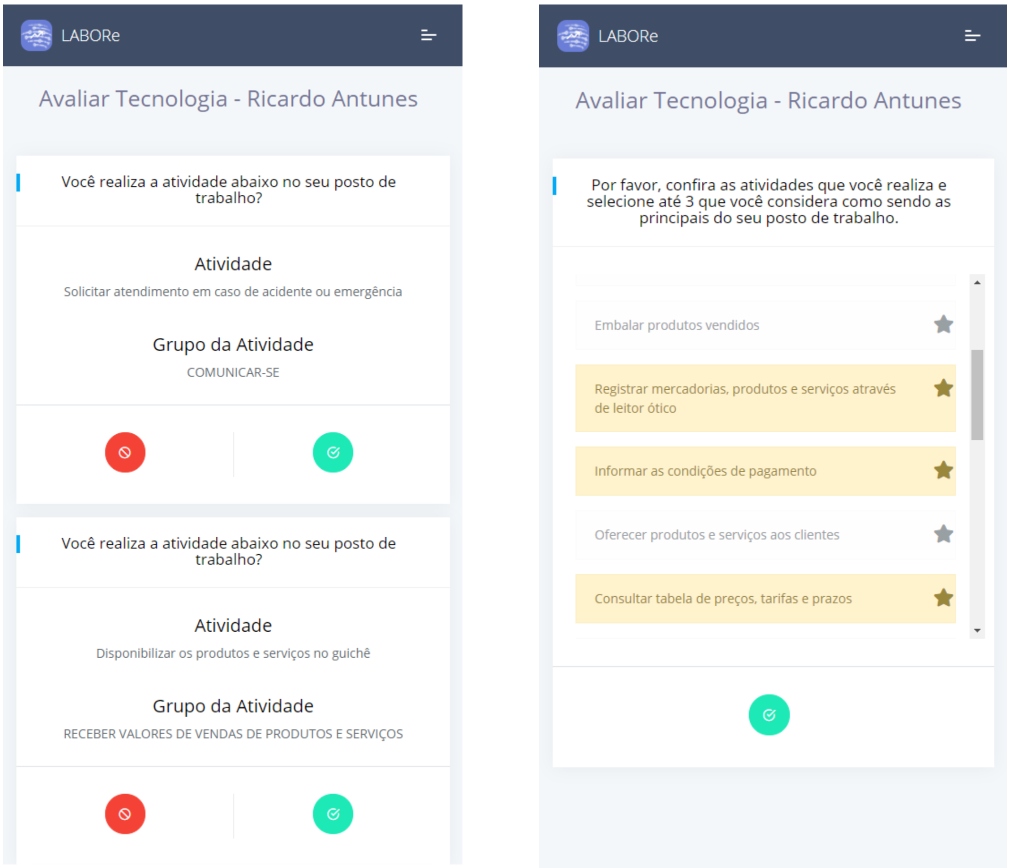

Figure 27: Selection of the activities that compose a job (left) and the main activities of a job

In the fourth step, the system presents the capabilities of each technology to the workers. For each activity, the workers, individually, evaluate if they agree or not with the presented technology capability and the automation level of the activities that they perform on their jobs (Figure 28, left). If any worker disagrees with the automation level, the system allows him to leave a comment to justify his disagreement (Figure 28, right).

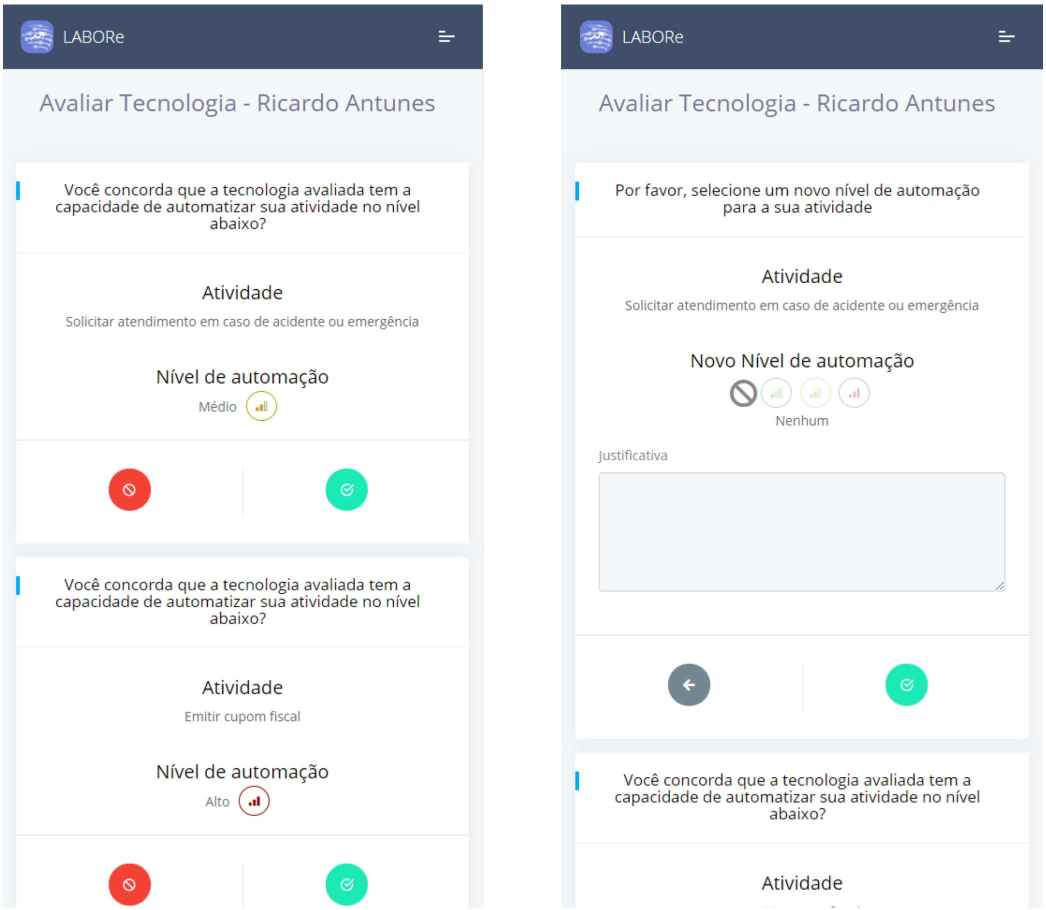

Figure 28: Evaluation of the technology capability (left) and choice of a new automation level

The fifth and last step of the focus group session is the discussion of the results of the assessment done by the employees. During this step, the expert can see in the system how many and which people in the group disagreed with his evaluation of the technology capability and the comment that each one left, as shown in Figure 29. With this information, the expert stimulates a discussion between the group and can register his own comments in the system. As a result of this process, the expert can change the technology competencies to fit the specific context of the organization.

After the focus group session, the expert presents to the manager of the organization a final report with the description of the whole process, the resulting assessment of each technology, and job transition pathways to the most impacted workers.

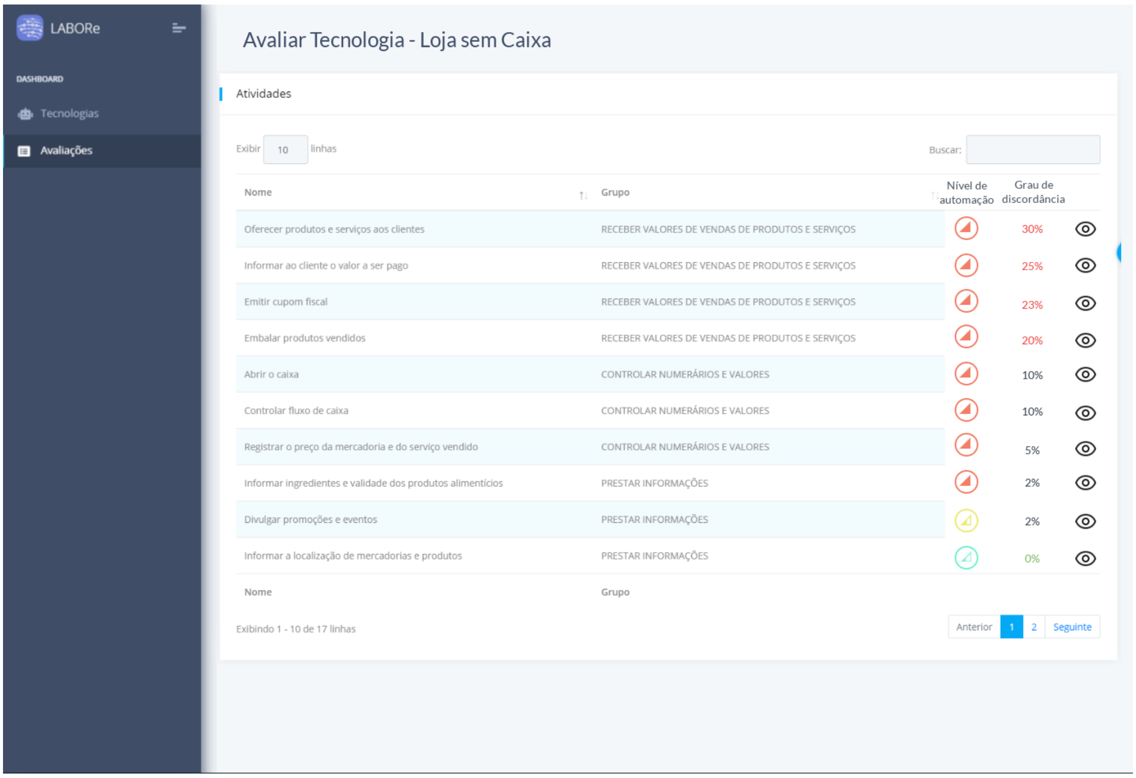

Figure 29: Support for the discussion during the focus group

7.8 Evaluate Solution

In this first cycle of design, an artificial type of evaluation was done. In this second cycle of design, a naturalistic evaluation was undertaken, which involved exploring the performance of the model in its real environment

The model was tested in Company X, a large Brazilian company from the fuel distribution sector, for five months from February 27th to September 24th, 2020. All the steps described in the previous Chapter were followed and will be presented in the following order:

1. Define the company area to be analyzed;
2. Perform the technology forecast;
3. Select the technology to be evaluated;
4. Analyze Technology Capabilities;
5. Select the employees to participate in the focus group;
6. Perform the focus group;
7. Present the results of the evaluation.

7.8.1 Define the company area to be analyzed

This step represents the first meeting with the company to present the project methodology and define a specific area to be chosen by the company as the project focus.

On February 27th, 2020, in a meeting with the Innovation Management sector of the company, the project was presented, and it was asked that Company X choose one of its functional areas to be analyzed. The company should choose an area where there were more possibilities for automation technology adoption.

During the meeting, it was suggested that the area to be analyzed could be the one responsible by the Convenience Stores (c-stores) of the Fuel Stations. This choice was justified by three reasons: the thousands of people employed in these stores would make the test quantitatively relevant, the possibilities of technological innovation in the Retail sector that abound, and because technological innovations that impacted the work of the Fuel Station Attendants (another possible option in the Fuel Stations) would conflict with regulations that would make the test of the methodology harder while weakening its relevance.

After the meeting, the areas of Innovation Management and the one responsible for the Convenience Stores discussed the study, and, on March 3rd, it was confirmed that the focus of the study would be the Convenience Store area.

The Convenience Store Management area of the company is responsible for over two thousand stores all over Brazil. It has an incentive program for employees of the fuel stations, with over eight thousand employees registered. Among these employees, the following roles exist:

- Cashier;
- Support;
- Stock/Display Disposing Clerk;
- Baker (for c-stores with bakery);
- Bakery Attendant (for c-stores with bakery);
- Beer Expert (for c-stores with beer-dedicated space);
- Store Manager.

7.8.2 Perform the technology forecast

In this step, between March 4th and 30th, 2020, research exploring the Future of the Convenience Stores through Futures Research methodologies was undertaken. The goal was to discover which automation technologies would be more relevant for the future of this sector in the following 3-5 years.

To explore the future of the c-stores, two methodologies were used: Bibliometric Analysis and Scenario Building. The bibliometric analysis was based on academic papers, news, and reports about the subject. The goals of the analysis were the exploration of the sector and its future and the discovery of technologies that are being developed for the sector.

The goal of the scenario building was to provide some models or archetypes of c-stores of the future that would represent possibilities for the development of the sector and showcase the combined use of the forecasted technologies.

Bibliometric Analysis

The search for reports about the theme returned a good number of reports published in the previous three years that were focused on understanding specifically the future of the c-stores. As such, it was not necessary to broaden the search to the future of fuel stations or the future of retail as a whole.

Convenience stores are seen as one of the paths for the future of physical retail as a whole since the brick and mortar stores are being strongly impacted by the growth of e-commerce. Among the competitive advantages of the c-stores that allow growth when compared with other types of physical retail, it is possible to highlight the business model based on speed and efficiency, the location close to working or residential areas, and the offer of products that meets the most personal and immediate needs (CCRC; NACS, 2018).

The competitive advantages of the c-stores become even more critical as customers' profile changes to a more convenience-based consumption. This change happens because, among others, the following reasons (NIELSEN, 2018):

- The rapid advance of urbanization, given that 58% of the world population will live in cities until 2025 with this number reaching 83% in North America, 82% in

Latin America, and 75% in Europe. The faster rhythm of living in cities makes customers seek faster and more convenient consumption options;

- Reduction of the physical space of the houses as well as of the size of families that tend to reduce from 3.1 to 2.7 people, on average, by 2025. Having less space for preparation, consumption, and disposal of food, people will seek more adequate and instantaneous consumption options to cut costs and avoid waste, something that is currently offered by c-stores and will be reinforced in the future;
- Higher female participation in the labor market coupled with families where both partners work allows for a more equal division among the family of the role of going shopping, cooking and taking care of the house. This causes an increase in the demand for products that supports this lifestyle.

Besides its relevance for retail as a whole, c-stores are seen as being of great importance for the future of fuel stations. In a survey done in 2019 about the behavior of fuel consumers, the National Association of Convenience Stores (NACS) showed that 44% of fuel station customers enter the attached c-stores, a number that increased from 35% in 2015 (L.E.K., 2019).

An analysis by the consulting firm L.E.K. using data from the NACS shows that the financial result of the c-stores in the USA in 2018 was US$82 billion of profit with a gross profit margin of 34%, while the fuel sales had a profit of US$37 billion with a gross profit margin of 9% (L.E.K., 2019). Thus, there is even the perspective that the c-stores could exist separately from the fuel stations, something that already happens more frequently in European countries.

Despite the importance of c-stores in the present and near-future (next 5 years or so), in the long-run (20 years from now) as the fuel industry itself is modified to be less dependent on fossil fuels, some c-stores will become financially unsustainable and the whole business model will have to be rethought (AECOM, 2017; BOSTON CONSULTING GROUP, 2019; L.E.K., 2019).

Figure 30 shows the vision of Squire and Partners, an English architecture office, of how a fuel station would be in 2050, where its goal is not only to attract vehicle drivers but pedestrians and bikers. In terms of function, the proposed fuel station has recharging stations for electric vehicles partly fed by waste, a workshop for the reuse of nonrecyclable waste, and spaces dedicated to shopping, entertainment, and education (DESIGNCLASS, 2019).

Figure 30: Gas Station of the Future by (DESIGNCLASS, 2019)

On March 22nd, for the bibliometric analysis of academic papers, a search was done for the terms “convenience store” and “convenience retailing” on the title of papers from the Scopus database, and 280 results were found. Figure 31 shows that the academic production about the subject was very low in the period from 1976 to 2008 when the number of papers varied from 1 to 5. In 2008, the number of papers reached 11 and it remained at a level of 9 to 20 papers each year since then. In 2019, the number of papers published reached the record number of 38 and, in 2020, until the search was done, there were already 8 papers which is an indication that, if the rhythm remains the same, the number can reach over 30 papers until the end of the year.

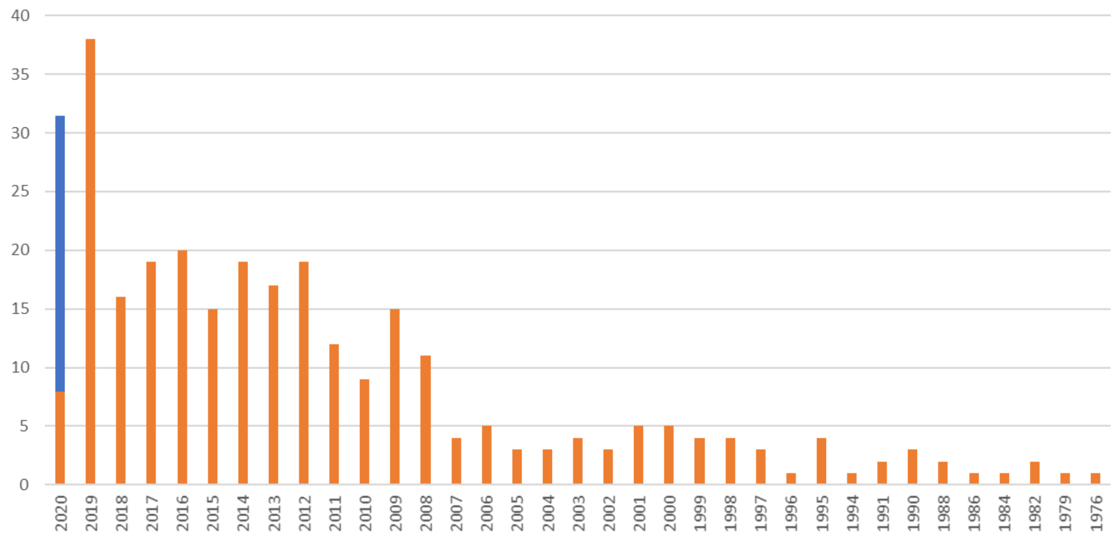

Figure 31: Distribution of papers about the future of convenience stores by publication year

Since the interest in this bibliometric analysis is with the future, the focus was on more recent papers published since 2017, resulting in 81 papers. Of these 81 papers, eleven had some relation with the research, but just five presented or discussed any kind of relevant technology for the goals of the analysis. These five papers were from Asian researchers with three being from Japanese authors and two from Chinese authors.

Among the selected papers, two were about robots for the disposal of items on c-stores' shelves. They presented research that participated in the Future Convenience Store Contest, a challenge created for the development of technologies for the future of c-stores that takes place annually, since 2017, in the World Robot Summit (SAKAI *et al.*, 2020; TSUJI et al., 2020; WADA, 2017). The challenge is divided into three categories of tasks: shelves disposal and stocking, customer interaction, and bathroom cleaning. One of the reasons for Japan's interest in the development of automation technologies is the aging of the population which will result in the reduction of the labor force of the country by 9 million people in the period between 2013 and 2025 (WADA, 2017). Besides, the labor force is well-educated in Japan, making it harder to find people interested in working in more simple activities with the relation between job postings to candidates being of 1.5 in general and 3 in the Services sector (WADA, 2017).

The robots presented in these papers can move around the c-store identifying, grabbing, and holding items; and putting them on the shelves. They can also be eventually used for interacting with customers. The main challenges for this technology are the speed and the capability of manipulating items of different formats and dimensions (SAKAI *et al.*, 2020; TSUJI *et al.*, 2020).

The two Chinese papers in the search are concerned with analyzing a specific type of self-service c-store, the unattended store. The first paper focuses on the perception of the consumers (LYU; LIM; CHOI, 2019) while the second one focuses on the operational performance of this type of store (XU et al., 2020).

The authors of the first paper believe in an increase in self-service in Chinese c-stores but throw light on some challenges that can reduce the acceptance of this type of store by consumers. Among the problems that are still being faced by self-service c-stores are the limited diversity of the items that can be sold at these stores, the longer time for the restocking of the items when they go out of stock, a greater difficulty for consumers to find items in stores due to lack of employees, and the dependency that self-service technologies have on a sound network infrastructure which can cause a delay or fault in the service (LYU; LIM; CHOI, 2019).

In the second paper, the authors analyzed 32 self-service c-stores and observed that, in general, 31 of them had a performance relatively lower than their regular counterparts. The performance from the economic perspective of the profitability of the stores pulled the global performance down, but the social perspective that included variables such as customer satisfaction and government support had a better performance (XU *et al.*, 2020).

Scenario Building

The scenario building seeks to describe different perspectives of the future in different models of c-store of the future that can be considered as possible in the next 3-5 years. Based on what was found in the literature in terms of social and technological trends, the following three c-store models were created:

1. Store without employees;
2. Self-service store supported by employee;
3. Offline e-commerce.

These stores represent a possible reunion of available technologies or technologies in advanced development stages and represent the limit of a given idea being possible to adopt their ideas more mildly.

1. Store without employees

The first model represents an improvement of the unattended c-stores by offering a broader range of products in bigger stores and by operating without employees since unattended c-stores need employees for the restocking of products.

The main technologies used in the store without employees are the payment by apps for mobile devices supported by Internet of Things technologies deployed throughout the store such as cameras and sensors in the products and shelves.

For the identification of products that need restocking, robots can be used. There are already robots available in the market for the identification of items (Figure 32, left) (SIMBE ROBOTICS, 2020), and new robots for items disposal on shelves are already being developed (Figure 32, right) (SAKAI *et al.*, 2020).

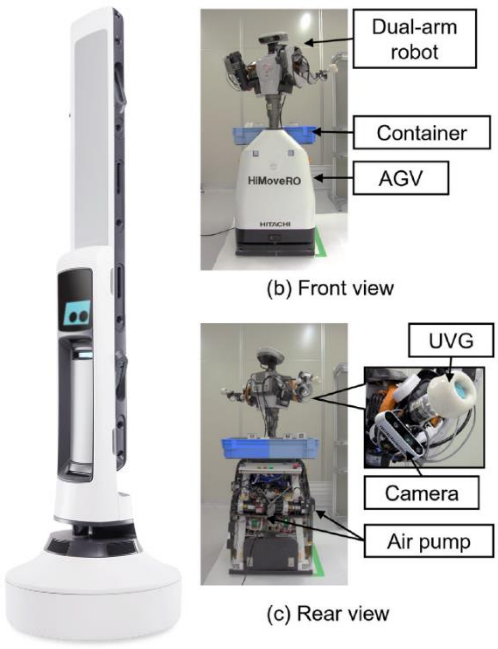

Figure 32: Shelve scanning robot (SIMBE ROBOTICS, 2020) (left) and prototype of a robot for item disposal (SAKAI et al., 2020)

Figure 33: Marty, a cleaning robot (STOP & SHOP, 2020)

Store cleaning would be done by autonomous robots currently available (such as the robot in Figure 33) capable of doing a more thorough and more massive cleaning of stores and more specific activities such as the detection and cleaning of small spillages (STOP & SHOP, 2020).

Finally, the customers would be attended by robots such as the one in Figure 34 that is capable of monitoring and mapping the stock of the store and interacting with customers by taking them to the products they want to find (MOBILE ROBOT GUIDE, 2020).

Figure 34: Navii, a robotic attendant (MOBILE ROBOT GUIDE, 2020)

This model of c-store without employees has the pros and cons listed below.

- Pros:
  - Modern shopping experience;
  - No cost with employees;
  - High capacity for collecting and processing data about clients and their consumption.
- Cons:
  - Extremely high technology cost. Robotics cost will still be high in the 3-5 year horizon, even more for c-stores that have a smaller scale gain when compared with supermarkets when adopting these technologies;
  - Lack of human touch might alienate part of the clients;
  - Considerable security challenges considering that there are no employees in the store to take care of accidents and loss prevention.

2. Self-service store supported by employees

In this second scenario, the proposed model is the self-service store where the client has more protagonism than currently, but the store employees also gain a more important role. Both client and employee use technology for a more customized and autonomous consuming experience.

The activities of product registration, payment, and packaging are made by clients in self-checkout machines, giving customers a more active role in the purchase process. By transferring these activities to the client, the employees can have the role of sales consultant also supported by technology. Upon entering the store, the client is identified by facial recognition allowing the employees to attend to their needs in a more customized manner by the automatic analysis of their purchase history data.

Figure 35: iBeacon (ESTIMOTE, 2020)

To attract clients that are passing by the store, devices such as the iBeacon from Estimote (Figure 35) would be used to send notifications of customized promotions to clients (ESTIMOTE, 2020). This would incentivize clients to return to the store more frequently and reinforce the client's perception that the c-store is a space where their most immediate needs can be fulfilled in a fast and efficient way.

Finally, a chatbot would be responsible for understanding the behavior of the customers in terms of their evaluation of the store, purchasing process, and the fulfillment of their needs by the store.

The self-service store supported by employees presents the following pros and cons.

- Pros:
  - Serves an audience that wants a more modern shopping experience by adopting new technologies, but without alienating more traditional consumers by maintaining a service that involves employees;
  - Smaller team, but more specialized and focused on adding value to the customer's shopping experience;
  - Medium capacity for collecting and processing data about clients and their consumption.
- Cons:
  - Preoccupation with security and loss prevention needs to be higher than the normal;
  - Considerable investment in technology and employee training since they need to learn how to work with new technologies.

3. Offline e-commerce

The third and last scenario proposed involves the store model that differs the most from the traditional one. This model is less dependent on more advanced technologies and involves a change in the customer experience. The function of the fuel station and the c-store is rethought in this model where the clients do not need to enter the store to choose the products, the payment of the products is done digitally, and space previously used by the store has new functions.

In the case of vehicle drivers, the order can be done in advance by an app for mobile devices that shows the store products and allows the client to inform when he plans to grab his order, facilitating the stock management and order fulfillment process. The client can also make a last-minute purchase at the fuel pump by choosing from a range of products when paying for the fuel via the app. A store employee is responsible for delivering the product to the client at the fuel pump, allowing the client to remain in his vehicle.

For the clients that are not driving a vehicle, it is possible to order via the app and collect the order in a window at the store where the attendant delivers the items of the order.

The space that was previously used to showcase the items in the store is no longer necessary because the purchase is done online, allowing the store to use less space and to become more of a stocking room. This change allows the fuel station to become a living space with coworking structures, sales of local products, and food trucks, thus becoming more integrated with the community where it is located.

Like the previous models, the offline e-commerce store also brings some pros and cons.

- Pros:
    - Serves an audience that wants a more modern shopping experience;
    - The team needed to operate the store is significantly reduced when compared to the traditional model;
    - Great capacity of collecting and processing data about clients and their consumption because the transactions are all made digitally;

  - Security and loss prevention are no longer a preoccupation as the customers do not need to enter the store;
- Cons:
  - Smaller investment in technology when compared with the previous models;
  - Need to invest in remodeling the store's physical space;
  - Risk of queues at fuel pumps at peak times;
  - Possible loss of more traditional customers who would not accept the differentiated model of the store operation.

7.8.3 Select the technology to be evaluated

This step entailed the presentation to the Company X of the report of technological forecasting so that the company could decide among all the found technologies which one should be the object of the Technology Assessment.

On April 2nd, 2020, the presentation was done to one of the analysts of the Innovation Management area and the analyst of the Convenience Stores Management area. The second one said that the "self-service store supported by employees" was the most interesting for Company X among the three scenarios for the Future of the Convenience Stores that were presented.

After the presentation, the information about Self-Checkout, Facial Recognition, and Chatbot that were part of the "Store with Self-Service" scenario were registered on LABORe v2. The credentials to access the system were then sent to the analysts that participated in the presentation. On April 13th, one of the analysts selected in the system that the technology to be assessed would be the Self-Checkout.

7.8.4. Analyze Technology Capabilities

In this step, the technology of Self-Checkout was analyzed considering the capabilities of the technology to execute a set of tasks. This analysis was done using LABORe v2.

Before presenting the analysis of the technology itself, it is crucial to understand the relevance of its possible impact on employment in Brazil. Commerce is the second economic sector that employs more people in Brazil (20.82%, over 9 million workers) only behind the Services sector (37.45% or more than 16.6 million workers) as can be seen in Table 14 (MINISTRY OF LABOR, 2018b). Besides, it has the second-highest Automation Index in the country with 75%. The economic sector with the highest Automation Index is Agriculture, Forestry, Fishing and Hunting with 79% but it is an economic sector with little representativity as it comprises only 3.32% of the Brazilian workforce (LIMA *et al.*, 2019). These numbers show the relevance of this economic sector in terms of workforce size and the risk of automation of its workers.

Table 14: Workforce of each economic sector (LIMA et al., 2019; MINISTRY OF LABOR, 2018b)

Economic sector	Workforce 2016	Workforce (%)	Automation Index
Agriculture, Forestry, Fishing and Hunting	1,475,201	3.32%	79%
Commerce	9,263,499	20.82%	75%
Manufacturing Industry	7,146,747	16.06%	75%
Construction	1,984,347	4.46%	70%
Extractive Industry	221,231	0.50%	68%
Public Utility Services	424,921	0.95%	67%
Services	16,666,150	37.45%	64%
Public Administration	7,316,217	16.44%	49%
Brazil (Total)	44,498,313	100%	67%

Further exploring the data about the Commerce sector, the ten occupations with more workers (summarized in Table 15) represent 50% of the sector and over 10% of the Brazilian workforce. The Retail Salesperson and the Cashier can be highlighted as the third and seventh occupations with more workers in Brazil, with over two million and over 800 thousand workers, respectively (MINISTRY OF LABOR, 2018b). Another important fact about these occupations is that for seven of them, the risk of automation is high (above 70%) with five of them having an Automation Probability of over 90%, including Retail Salesperson and Cashier (LIMA *et al.*, 2019).

Table 15: Top ten occupations with more workers in Brazil (LIMA et al., 2019; MINISTRY OF LABOR, 2018b)

#	CBO Ocupação 2002	Workforce 2016	Automation Probability
1	Retail Salesman	1,760,514	92%
2	Cashier	683,525	97%
3	Office Assistant	459,194	96%
4	Restocker	430,098	64%
5	Admimistrative Assistant	275,803	96%
6	Fuel Station Attendant	247,066	83%
7	Stock Assistant	204,872	64%
8	Truck Driver	204,825	79%
9	Janitor	171,317	66%
10	Butcher	154,940	93%

Self-checkout, the technology that was selected to be assessed in the evaluation of the model, seeks to automate the Cashier job, the second occupation with more workers employed in the Commerce sector, and the seventh occupation with more workers in Brazil. As such, the adoption of this technology can cause a considerable impact not only on the workers in Company X but also on the Brazilian workforce in general, even more, if its integration into production is not well-planned.

Some numbers help to understand the appeal for the adoption of the Self-Checkout:

- The estimated reduction in waiting time in the line of up to 30% (CISS, 2017);
- Four Self-Checkout machines can attend to 120 to 140 clients each hour (CISS, 2017);
- Store space optimized by 50% as four Self-Checkout machines use the space of two traditional cashiers (CISS, 2017);
- Until the end of 2019, the estimate was that over 325 thousand Self-Checkout machines would be adopted worldwide (BZTECH, 2019);
- In a survey, 22% of people globally said that they had already used a Self-Checkout machine, and 65% said that they would be willing to use one in the future. In Latin America, these numbers are 17% and 71%, respectively (NIELSEN, 2015).

To do the technology assessment properly, it was necessary to define a standard of the technology among those participating in the assessment, especially those involved in the focus group. For this purpose, the NCR FastLane SelfServ Checkout R6C (Figure 36) was selected as the standard Self-Checkout machine[4] (NCR, 2019).

Figure 36: NCR FastLane SelfServ Checkout R6C (NCR, 2019)

The NCR machine features the registration of products through the barcode scanner or the display, the weighing of products, the payment with cards or cash with the possibility of change, the space to pack the products with a scale to verify if the packed products have been registered, and the indication of intervention by an attendant done by a lamp above the machine (NCR, 2019).

After the definition of the standard self-checkout machines, an analysis of the capabilities of the machine (as exemplified in Figure 37) was done with the support of the LABORe v2 by using the activities in the database of the CBO organized according to the occupations that do each one of them.

[4] A presentation video of this machine can be found on https://www.youtube.com/watch?v=1VHYlMLpp8c.

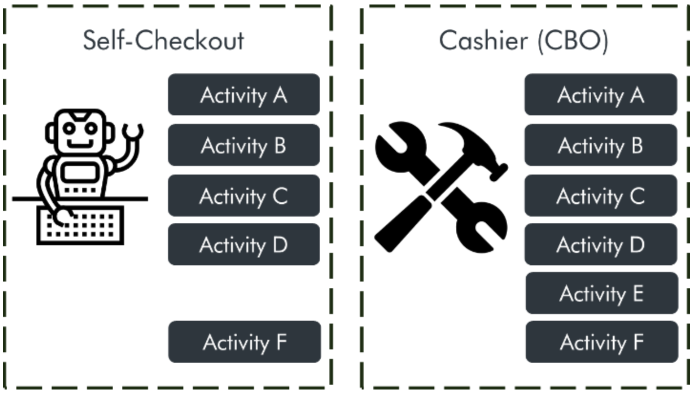

Figure 37: Comparison between the capabilities of the Self-Checkout and the activities of the Cashier occupation

For each activity considered as doable by the machine, one of the following three levels of automation was assigned:

- Low: the machine supports the worker who is responsible for most of the execution of the activity.
- Medium: the worker supports the machine that is responsible for most of the execution of the activity.
- High: the machine is responsible for carrying out the activity independently.

Appendix D presents the result of the analysis of the Self-Checkout capabilities[5].

7.8.5 Select the employees to participate in the focus group

The analysis of the technology capabilities in the previous step revealed which occupations would be most affected by the occasional adoption of the Self-Checkout. On April 15th, 2020, the results of the analysis were presented to Company X where it was revealed that, among the occupations that exist in the c-stores of the company, the occupation that would be most impacted by the Self-Checkout would be the Cashier.

Company X was then asked to select a group of around five Cashiers to participate in the focus group. During the meeting, the analyst of the Convenience Store Management area said that, under the social distancing measures imposed by the COVID-19 pandemic, it would not be possible to execute remotely the focus group with the Cashiers, mostly because it would be hard to explain them the circumstances of the study.

[5]This result can also be visualized in the system by accessing https://prod.laboregov.com/ with the credentials user (yurilima) and password (123456) then going to Tecnologias > Self-Checkout > Competências.

It was decided that the methodology would be adapted to this new and insurmountable obstacle and, instead of having the participation of the Cashiers, the focus group would be done with the participation of employees of Company X that had a good understanding of the operation of the c-stores of the company, including some supervisors of these stores.

7.8.6. Perform the focus group

This step involved the execution of the Focus Group with four employees that had substantial knowledge of the operations of the Company X c-stores. During the Focus Group, the following steps were followed:

1. Presentation of the methodology.
2. Presentation of the Self-Checkout.
3. Analysis of the Cashier activities.
4. Evaluation of the capabilities of the Self-Checkout.
5. Discussion about the evaluation of the capabilities of the Self-Checkout.

The Focus Group was done in two meetings. In the first one, on July 15th, 2020, the first four steps above were done, and the second meeting was done on July 29th, where the last step was done. Two analysts of the Innovation Management area and two analysts of the Convenience Store Management of the Company X area on both meetings.

The first meeting started with the presentation of the methodology and the Self-Checkout to the participants. Next, the analysis of the activities of the Cashier was done with the support of the system. The analysis consisted of the selection by each of the participants of the activities that they considered that the Cashiers of Company X carry out. This analysis was made with the support of the CBO, as exemplified by Figure 38.

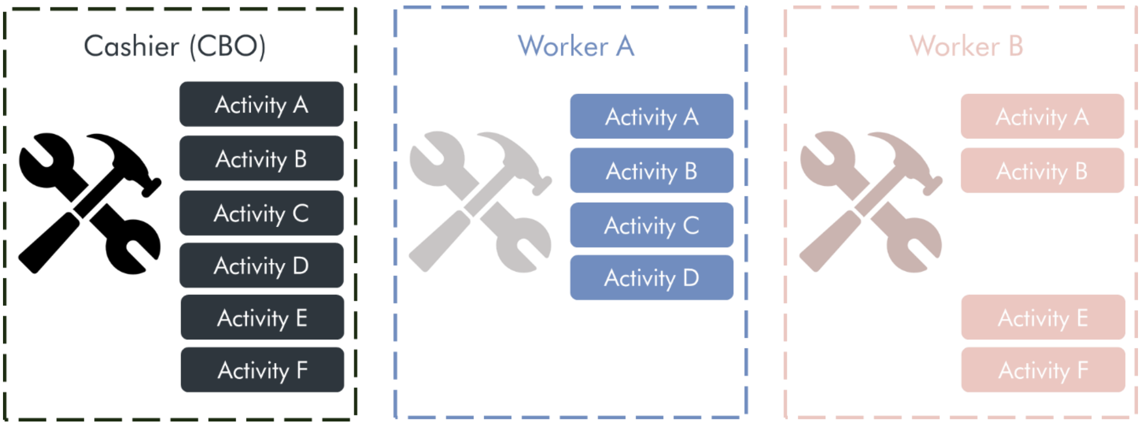

Figure 38: Analysis of the activities of the Cashier based on the CBO

The system showed to each participant the complete list of activities that, according to the CBO, a Cashier tends to perform, and the participant was asked to inform if he considers that the Cashier of the Company X executes.

Appendix E shows the result of the analysis of the activities of the Cashier. Among the 46 activities listed on the CBO for the Cashier, 14 were considered by 100% of the participants as being executed by the Cashiers from Company X and 11 of them were said to be executed by these employees by 75% of the participants. Only five activities from the CBO list were not considered part of the Cashiers job by any of the participants.

After selecting the activities that the cashier executes, each one of the participants of the focus group chose, among these activities, the three activities that they considered as being the main activities of the cashier job, those that they spend more time doing. The results are presented in Table 16.

Table 16: Main activities of Cashiers in Company X

Activity Group	Activity	% of Participants
Receive Sales Values for Products and Services	Register Goods, Products and Services Using an Optical Reader	75%
Receive Sales Values for Products and Services	Pack Products Sold	50%
Receive Sales Values for Products and Services	Inform the Client the Amount to be Paid	50%
Receive Sales Values for Products and Services	Issue the Invoice	25%
Receive Sales Values for Products and Services	Inform Payment Options	25%
Receive Sales Values for Products and Services	Offer Products and Services to Customers	25%
Control Cash and Values	Cash up according to limit values	25%
Communication	Meet Customers' Demands	25%

The fourth step of the focus group was evaluating the capabilities of the self-checkout. The participants evaluated the automation degree of the activities that they considered that the Cashiers execute (Appendix E) and that were also defined previously as being executable by the Self-Checkout (Appendix D). Figure 39 presents a scheme that exemplifies this step.

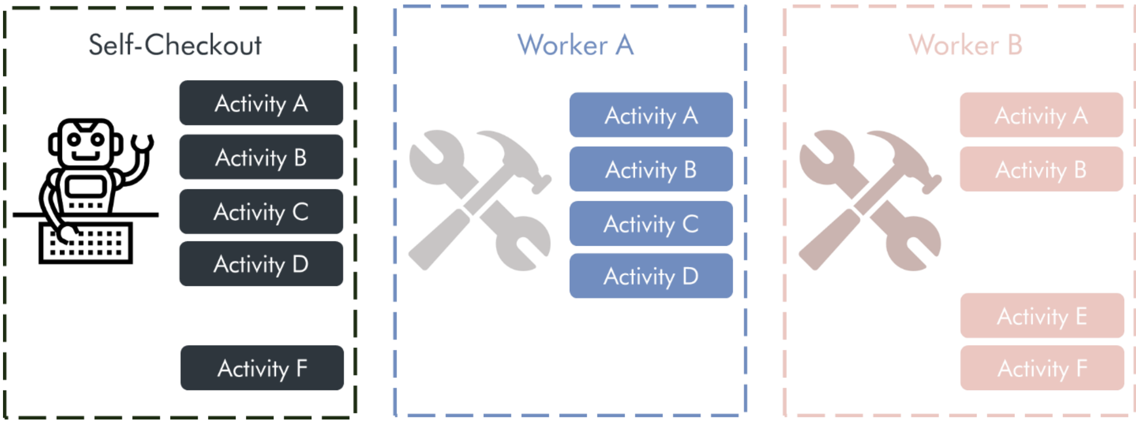

Figure 39: Evaluation of the Self-Checkout capabilities based on the activities of the Cashiers

In the system, the users could inform if they agreed or not with the automation level presented. If a user disagreed with the automation level, he could choose a new automation level that he considered adequate and leave a comment to justify his opinion if he wanted to.

The fifth and last step of the focus group was the discussion of the evaluation of the Self-Checkout capabilities. This step was more interactive than the previous ones because it involved a discussion among the participants mediated by the coordinator of the focus group. The list of activities evaluated and the degree of disagreement was shared during the meeting with the participants. In the system, it was also possible to see the automation level that each participant selected and his comment that justified that choice while being possible for the coordinator to register new comments.

During the discussion, the visualization of the results of the evaluation in the system was shared with the participants by the coordinator that went through each one of the activities where there was divergence and incentivized the participants to comment their views, both those that agreed and those that disagreed with the initial evaluation.

Among the 31 activities that were previously considered as automatable by the Self-Checkout at some level (Appendix D), in eight of them, there was some level of divergence between the opinion of the researcher and the participants. Appendix F presents the list of activities where there were some divergence and the commentary of the participants that justifies this divergence.

After discussing each specific activity, the participants had the opportunity to make general comments about the self-checkout and the focus group as a whole. The general perception of the group was of confidence in the capacity of the self-checkout to execute the activities to which it was designed and that were discussed during the focus group. There was a discussion on loss and theft control and on the need for cultural change to assist in the adoption of the technology. Regarding the focus group, the group assessed that the dynamics were interesting, causing reflections and discussions and that the system that supported the focus group helped a lot in the process.

7.8.7 Present the results of the evaluation

The last step of the methodology was the compilation of the whole process of Technology Assessment and its results in a report to be presented to Company X. The final presentation of the methodology was done on September 18th, 2020 and the final version of the report was sent to the company on September 24th. The model of collaborative assessment of technologies tested with Company X had as its primary goal to understand how the adoption of a new technology by the company would affect the work done by the impacted workers.

Table 17 summarizes one of the main conclusions that the model allows. Analyzing the main activities selected by each participant during the focus group and the automation level of each one, we can see that the adoption of the Self-Checkout would result in a high automation probability for one of the participants and medium for the other three. This result shows that the evaluated technology has considerable potential for substituting the work of the Cashiers of Company X's convenience stores.

Table 17: Result of the evaluation of the self-checkout technology

Participant 1 - Automation Probability: 66%		
Main Activities		**Automation Level**
Activity Group	**Activity**	
Receive Sales Values for Products and Services	Pack Products Sold	Zero-Low
Receive Sales Values for Products and Services	Inform the Client the Amount to be Paid	High
Receive Sales Values for Products and Services	Register Goods, Products and Services Using an Optical Reader	Medium

Participant 2 - Automation Probability: 66%		
Main Activities		**Automation Level**
Activity Group	**Activity**	
Communication	Meet Customers' Demands	Medium
Receive Sales Values for Products and Services	Pack Products Sold	Zero-Low
Receive Sales Values for Products and Services	Inform the Client the Amount to be Paid	High

Participant 3 - Automation Probability: 88%		
Main Activities		**Automation Level**
Activity Group	**Activity**	
Receive Sales Values for Products and Services	Issue the Invoice	High
Receive Sales Values for Products and Services	Inform Payment Options	High
Receive Sales Values for Products and Services	Register Goods, Products and Services Using an Optical Reader	Medium

Participant 4 - Automation Probability: 44%		
Main Activities		**Automation Level**
Activity Group	**Activity**	
Control Cash and Values	Cash up according to limit values	Zero
Receive Sales Values for Products and Services	Offer Products and Services to Customers	Medium-High
Receive Sales Values for Products and Services	Register Goods, Products and Services Using an Optical Reader	Medium

Nevertheless, that probability of automation does not mean that the Cashiers will become irrelevant and can be replaced. What it shows is that the company, in the case of adoption of the Self-Checkout, will have to rethink the activities that the Cashiers must execute by giving them new responsibilities that were not viable previously due to time constraints. As such, the work of the Cashiers could be reviewed to deliver more value to the clients of the stores as the automatable activities would be transferred to the Self-Checkout.

If it is not interesting for Company X to reassign the Cashiers to similar functions in their stores, there are professional pathways that can be stimulated by Company X both inside and outside of the company. As part of the methodology and the system that supports it, some professional pathways are indicated for the workers[6]. Figure 40 shows the result of the calculation (using Point Allocation) of professional pathways for participant 3 who is the only one at high risk of automation.

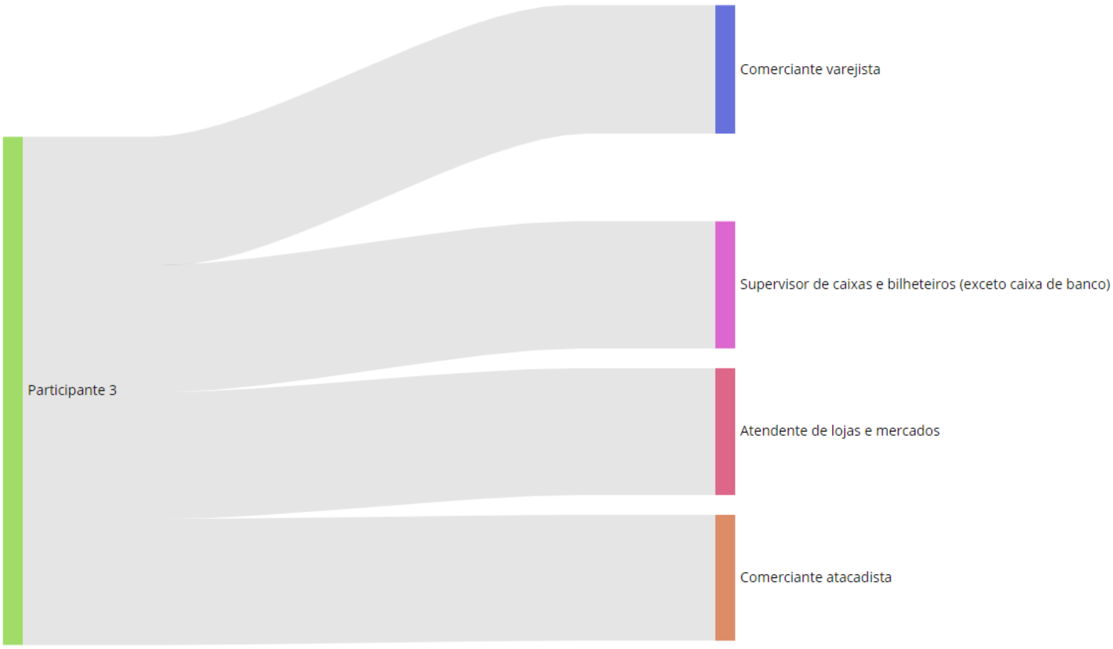

Figure 40: Result of the calculation of professional pathways for the participant 3

7.8.8. Feedback on the 2nd Design Cycle

To understand how the model of the 2nd Design Cycle performed, a questionnaire with eight questions (Appendix G) was answered by the analyst from the Innovation Management area of Company X that was the only participant that accompanied the whole process of the test of the model. The results are summarized below:

1. Capacity of the tested methodology to help those involved in discovering new technologies that are relevant for their sector: Very High (5/5)
2. Capacity of the tested methodology to help those involved in better understanding the challenges of integrating emerging technologies: Very High (5/5)

[6]The professional pathways can be seen in the system by accessing https://prod.laboregov.com/ with the credentials user (yurilima) and password (123456) then going to Avaliações > Company X > Trajetórias.

3. Capacity of the tested methodology to help those involved in knowing more about the Self-Checkout technology: Very High (5/5)
4. Capacity of the tested methodology to help the participants to explore the impact of the Self-Checkout technology on the work of the Cashiers of the Company X's Convenience Stores: Very High (5/5)
5. Capacity of the system that supports the methodology to help the assessment of the impact of the Self-Checkout technology on the work of the Cashiers of the Company X's Convenience Stores: Very High (5/5)
6. In your opinion, what are the positive aspects of the model for the collaborative assessment of technologies that was tested in Company X? Knowledge democratization, realist view of the work, and intuitive system.
7. And the negative aspects? None were observed.
8. What suggestions for the improvement of the model would you give? I believe that it would be interesting to have a signaling and deepening, in the final report, when there is a disruption of behavior/model based on technology, aiming to materialize the opportunities.

During the test of the model on Company X, the author of this thesis and his co-advisors have perceived a couple of possible improvements for the model that are listed below.

- During the technology forecasting, it would be interesting to include methodologies that involve the workers from the company that has considerable knowledge about the chosen sector as well as those workers whose work involves the monitoring of new technologies. The knowledge of these workers could provide new insights into the process and improve the quality of the findings;
- When registering the workers from the company in the system, it could be useful to have the full list of workers registered instead of just those participating in the focus group. One way of doing it is by having access to the RAIS database from the company that is automatically generated by the RAIS system when the company submits the information about its employees to the Ministry of Economy. The full list of workers would help identify those workers that are more affected by the technologies being evaluated in cases where this identification is not as straightforward as the one in the test. Also, it would improve the capacity

of the professional pathways algorithm to indicate which transitions exist inside the company;

- In the registration of the technology, it would be better to use a simpler list of technology classification than the one provided by the IEEE. As the platform is used and more technology is registered on its database, a simpler classification could be used to present the technology options for the users. Some options are given by (MELLUSO *et al.*, 2020) where only nine categories are used to classify Industry 4.0 technologies;
- During the Focus Group, some activities from the CBO were confusing for the participants. Even though the researcher was moderating the focus group and was able to explain the activities better, it would be an improvement for the system if it could provide the input of alternative titles for the activities as well as more detailed descriptions when necessary;
- Also, during the Focus Group, right after finishing one activity, such as indicating what the main activities of the Cashiers job are, the participants could see in the system the screen for the next activity. Here, the researcher also helped organize the group by asking them to wait for all of the participants to finish the current step before initiating the next one whose instructions were going to be explained by the researcher. Still, the system could be improved to show a waiting screen that asks the participants to wait until all the participants finished the current activity. Also, the system could have the functionality of allowing the moderator to know when all the participants have finished the current activity and to initiate the next one after he finishes explaining it;
- During the discussion phase of the focus group, the system could allow the moderator to go from the details of one activity to the other one without having to close the details pop-up in order to facilitate the discussion;
- Also in this phase of the focus group, the participants noted that some activities are not automated by the Self-Checkout but instead are transferred to the customers (such as packing the products). The methodology is focused on the automation of the activities of the workers and it could be improved to consider situations where there is an externalization of activities to external actors, such as customers;

- The results of the methodology were built with the help of the database from the system but the system itself could have the functionality to present the results since the needed information is on its database. One of the possible results that the system could present is how much of each worker's job would be automated by the technology that was assessed and what would be left for the worker to perform.

8. Conclusion

This last Chapter of the thesis brings some final remarks and reflections about the research as a whole and is organized as follows: first, the contributions of the research are discussed; then, the limitations of the research are presented; and, finally, future work possibilities are presented.

8.1 Contributions

We are going through another period in history where rapid changes are happening to work. In the future, the results of this 4th Industrial Revolution might be more and better work opportunities. Nevertheless, this better future will only be possible by the combined efforts of different social actors to lead us to this future. These efforts include but are not limited to: rethinking workers' collective movements, developing new technologies, regulating new technologies, updating education according to the demands of the new professions, and responsibly adopting new technologies.

The goal of this thesis is to contribute to the responsible adoption of new technologies by developing a model that allows the collaborative assessment of the impact of automation technologies on work.

The trajectory of the research for the thesis started with a comprehensive exploration of the future of work that considered not only academic papers but also reports from consulting companies and international organizations (DELOITTE, 2014, 2015a, 2015b; INTERNATIONAL LABOUR ORGANIZATION, 2015; MCKINSEY GLOBAL INSTITUTE, 2017a, 2017b; WORLD ECONOMIC FORUM, 2018b, 2018a).

In fact, my interest in the future of work started back in my Undergraduate thesis about the organization of cognitive work in the Post-Industrial society (LIMA; SPIEGEL, 2014). This exploration of the future of work and my background in Engineering made me decide that the best contribution that I could give in this thesis would be to design a model that could somehow help society coping with the impact of new technologies on work.

The research field of Technology Assessment gave the background that the thesis needed to build on top of theory and tried a practice that had been solidified by decades of existence with applications that range from government to local communities passing by universities and companies.

With the knowledge from Computer and Systems Engineering, mainly Data Engineering, Knowledge Management, and CSCW, the possibilities for the design of the model were at hand.

The first cycle of design represented a first approach to the goal of creating a model that could help in assessing the impact of technologies on work. The result was the prototype of a system for mobile devices that involved the recruiting of the crowd to evaluate automation technologies. This first model was highly influenced by the work of Frey & Osborne (2017) and had a too broad and quantitative approach to the challenge of evaluating technologies.

Parallel to this first cycle, I worked with fellow researchers from the Future LAB to estimate the impact of automation in Brazil. That effort allowed me to see that quantifying the impact of technologies on work was an essential contribution to the discussion on the future of work. Still, even if this quantification has helped to raise awareness about the challenges of automation, it did not help in mitigating the problems caused by it.

For this reason, the second design cycle was focused on developing a model that could assist in evaluating the impact of one technology on one occupation in one company. The company is the *locus* where automation happens, and the design of the second model is dedicated to helping in the responsible adoption of technologies. The idea was that if companies responsibly adopt automation, its negative impact on society as a whole would be better controlled.

In summary, the contributions of this thesis are the following.

- A review of the academic literature about the future of work;
- An estimation of the impact of automation in Brazil;
- A proposal of a model supported by a crowdsourcing system to survey the impact of automation technologies on occupations;
- A proposal of a model supported by groupware to collaboratively assess the impact of automation technologies on companies;
- A proposal of an algorithm that calculates professional career pathways for workers considering the data available in Brazil;
- An evaluation of the Self-Checkout technology impact on the Cashier’s work;

- A technology forecasting about the future of convenience stores;
- Two examples of the application of the Soft Design Science Research approach.

Even though the thesis focused on the collaborative assessment of automation technologies, my efforts in the past four years contributed to the discussion about the future of work as a whole. As such, the work goes beyond the thesis and will be briefly presented.

In 2016, in the first year of the doctorate, I was one of the founders of the Laboratório do Futuro, directed by professor Jano Moreira de Souza, where I coordinate the “Future of Work” research line. The Laboratório do Futuro is an interdisciplinary research group with nearly 20 participants interested in prospecting scenarios and developing solutions for governments, companies, and societies that help move towards a more egalitarian, participatory, and sustainable society for future generations[7]. The Laboratório do Futuro allowed me to publish articles and technical reports, organize events, and give lectures and interviews on the topic of the future of work.

In 2019, I founded a startup called LABORe that is dedicated to developing systems and doing research about the labor market[8]. The first product we developed was LABORe Gov, a software that presents a series of dashboards with information about local employment for public managers[9]. Our second project is LABORe Carreira which seeks to help students to choose a career based on their aspirations and data about the labor market[10]. We are also working on another system, called LABORe IES, which is going to be a competitive intelligence platform for Higher Education Institutions. Finally, the second model of this thesis is inspiring the development of two methodologies for the company: LABORe Tech Discovery consists in the use of Futures Research methodologies to provide a forecast of a given economic sector, and LABORe Tech Integration seeks to help companies in the responsible adoption of automation technologies.

Another effort worth mentioning is the research about the impact of the COVID-19 pandemic on work in Brazil, to which I have dedicated myself since March 2020. From

[7] More information on https://labfuturo.cos.ufrj.br/
[8] More information on https://labore.tech
[9] Demo available on https://laboregov.com/
[10] A beta version is available on https://dev.laboregov.com/carreira

this research, the main result was the creation, with the help of a fellow researcher from the UFRJ, of a platform called "*Impacto COVID*". In this platform, we present the estimated risk of COVID-19 contagion of each of the more than two thousand Brazilian occupations with the estimated risk for economic activity and municipality[11]. This research helped public managers understand the risks of COVID-19 for workers and develop plans for the safe reopening of businesses, researchers in exploring the impact of the virus, and informed the general public through the media.

My most recent research project is about gender equality in STEM education and work[12]. This project includes researchers from UFRJ and Técnico Lisboa. It has two goals: calculating the size of the gender inequality in STEM education and work, and catalog initiatives dedicated to the promotion of gender equality in STEM. Both of these goals are guided by Unesco's STEM and Gender Advancement (SAGA) project.

The democratization of the knowledge produced in these studies was intensive during the doctorate with several interactions with the general public including interviews in the major television channels, radio stations, and newspapers. In terms of academic contributions, the table in Appendix H summarizes the 25 publications that were published during the period of the doctorate or are going to be published soon.

8.2 Limitations

As a whole, the work presented in this thesis is limited because of the interdisciplinarity demanded by the subject compared to the limited scope of knowledge of its author. This limitation was mitigated by the effort of the author to go beyond his research field to find references that belong to other areas and by the critical contributions that experienced researchers from other fields have given to the thesis.

In terms of the limitations of the models presented, the feedback provided during the evaluations was thorough, but the most relevant limitations can be summarized here. The first version of the model was a proposal too broad in terms of the types of users and technologies that could be evaluated in it. It also represents a first approach to the problem and, as such, a crystalization of the knowledge of the researcher at the time which changed significantly afterward. Finally, the model was tested in an artificial method that involved

[11] The platform is available on https://impactocovid.com.br/
[12] More information on https://www.igualdadestem.com/

its presentation to peers, but the best scenario would have been to test in its real intended application.

Regarding the second model, it can be considered a limitation of the fact that some of the work in the methodology, such as the calculation of the probability of automation, had to be done “manually” by the researcher while it could have been implemented in the system. Another limitation was that the test of the model was done with workers that were not from the occupations that would be directly impacted by the technology being assessed, as the methodology advocates. This limitation was minimized by the participation of workers with experience and knowledge about the c-stores operation.

8.3 Future Work

The research presented in this thesis allows for several future works. The first design cycle resulted in a system that allows the crowd to collectively estimate the impact of automation on work. Previous work about the estimation of the impact of automation involves only researchers and does not consider the opinion of workers. Thus, there is potential in further exploring this approach that uses crowd computing.

Regarding the second design cycle, there are possibilities to improve further the methodology and the system as discussed before. Other future work involves the test of the model in different environments such as unions and governments. It would be interesting to know how the challenge of the collaborative assessment of automation technologies differs in places other than companies.

Looking more broadly at the challenges that automation imposes on society, the research could also contribute by looking at the professions of the future and their demands for new skills and new education.

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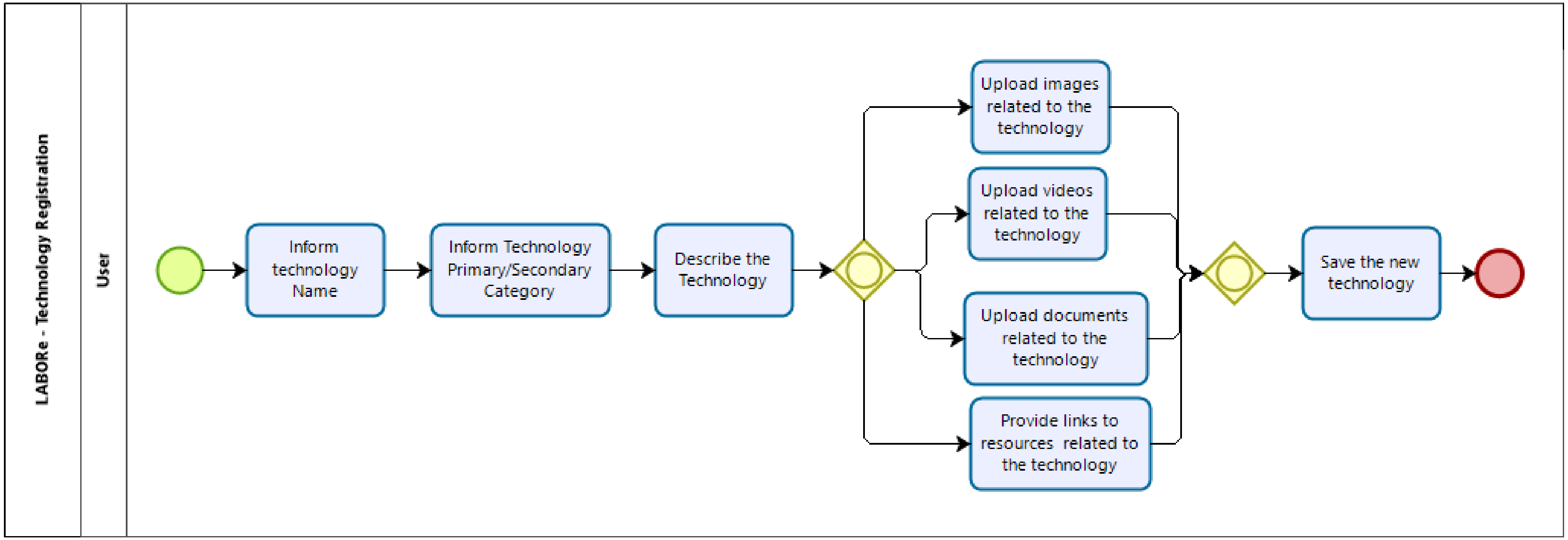
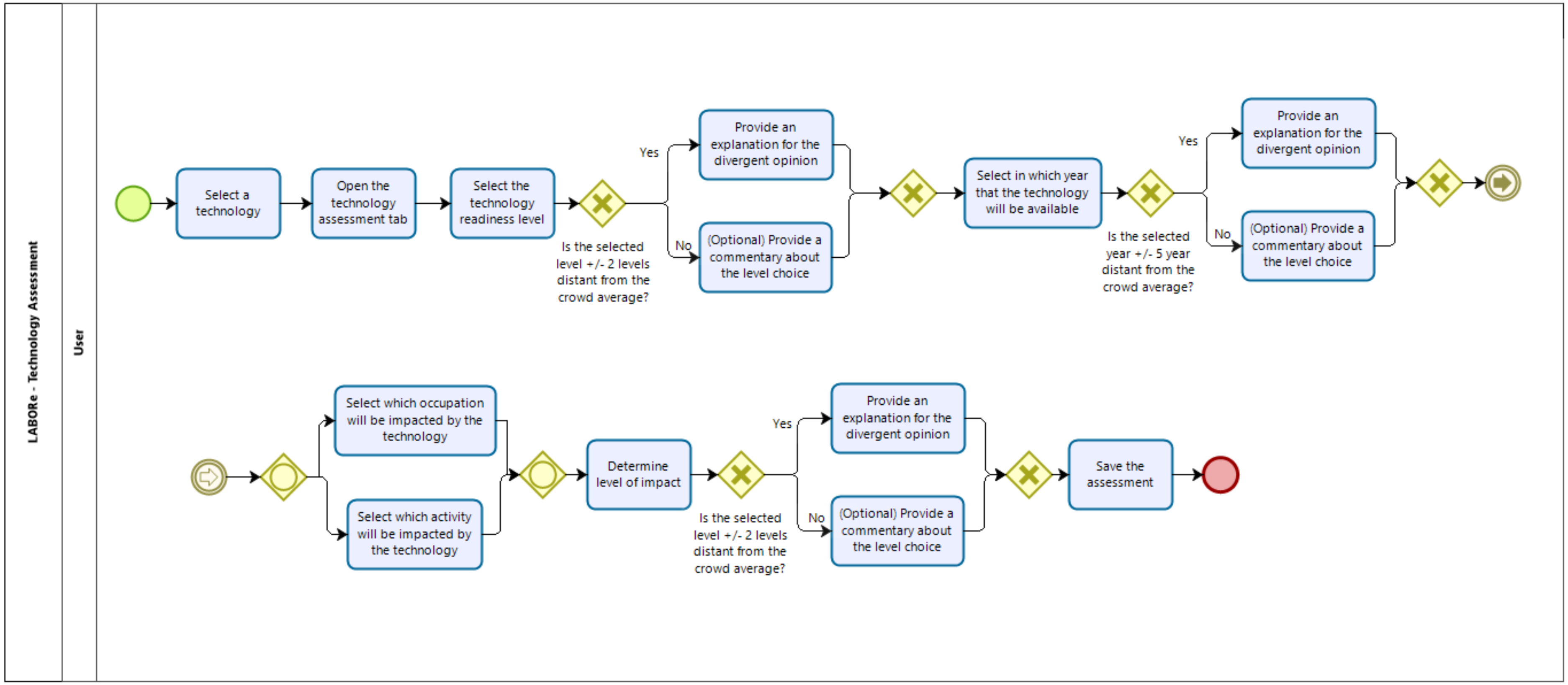
Appendix A: BPMN Activity Diagrams for LABORe





LABORe - Technology Assessment
User
Select a technology
Open the technology assessment tab
Select the technology readiness level
Is the selected level +/- 2 levels distant from the crowd average?
Yes
No
Provide an explanation for the divergent opinion
(Optional) Provide a commentary about the level choice
Select in which year that the technology will be available
Is the selected year +/- 5 year distant from the crowd average?
Yes
No
Provide an explanation for the divergent opinion
(Optional) Provide a commentary about the level choice
Select which occupation will be impacted by the technology
Select which activity will be impacted by the technology
Determine level of impact
Is the selected level +/- 2 levels distant from the crowd average?
Yes
No
Provide an explanation for the divergent opinion
(Optional) Provide a commentary about the level choice
Save the assessment

Appendix B: Description of the variables used in the job transition method

Difference between the automation probability of the origin and destination occupations

Source: Report "The Future of Employment in Brazil: Estimating the Impact of Automation" - Laboratory of the Future, 2019

Example: Industrial Cook, probability of automation = 61%

Difference Calculation:

• P (A) of origin occupation - P (A) of destination occupation = [-1.1]

Similarity between the activities of the destination and origin occupations

Source: Brazilian Classification of Occupations

Example: Industrial Cook, activities: defrost food, sanitize food, heat pre-prepared food, etc.

Calculation by Similarity Index:

• Total activities of the origin occupation that the destination occupation also encompasses / total activities of the destination occupation = [0.1]

Similarity between the personal skills of the occupational family of the destination and origin occupations

Source: Brazilian Classification of Occupations

Example: Chefs, personal skills: working as a team, demonstrating professional honesty in food preparation, demonstrating the ability to be flexible, developing taste and smell, etc.

Calculation by Similarity Index:

• Total personal skills of the occupational family of the origin occupation that the occupational family of the destination occupation also encompasses / total personal skills of the occupational family of the destination occupation = [0.1]

Similarity between the economic activity of the current employer and that of most workers in the destination occupation

Source: National Economic Activity Code / Annual Social Information Report

Example: Subclass 56.11-2 Restaurants and other food and beverage service establishments, Subclass 56.20-1 Catering, buffet and other prepared food services.

Calculation by ranges:

• The CNAE class of the worker's employer is the same as that of most workers in the destination occupation = 1

• The CNAE group of the worker's employer is equal to that of the majority of workers in the destination occupation = 0.8

• The CNAE division of the worker's employer is equal to that of most workers in the destination occupation = 0.6

• The CNAE section of the worker's employer is the same as that of most workers in the destination occupation = 0.6

• Other cases = 0

Difference between current wages of workers and average wages of workers in the destination occupation

Source: Annual Social Information Report

Tracks:

• Average wage of the destination occupation / worker's wages> 1.2 = 1

• 1.2> Average wage of the destination occupation / wage of the worker> 1.1 = 0.9

• 1.1> Average wage of the destination occupation / worker's wages> 1 = 0.6

• 0.9> Average wage of the destination occupation / wage of the worker> 1 = 0.4

• 0.8> Average wage of the destination occupation / wage of the worker> 0.9 = 0.2

• Other cases = 0

Difference between the Worker's education level and the average education level of the workers in the destination occupation

Source: Annual Social Information Report

Example: Illiterate = 1, Complete Elementary = 5, Doctorate = 11

Calculation by ranges:

• Worker's education level = Average education level of destination workers = 1

• Worker's education level - Average education level of workers in the destination occupation = [-1.1] = 0.6

• Level of education of the worker - Average level of education of the workers in the destination occupation = [-2.2] = 0.2

• Other cases = 0

Proximity between the municipality of the current employer and the majority of workers in the destination occupation

Source: Annual Social Information Report

Zones:

• The worker's municipality is the same as that of most workers in the occupation destination = 1

• The status of the worker is the same as that of most workers in the destination occupation = 0.6

• The worker's region is the same as that of most workers in the destination occupation = 0.3

• Other cases = 0

Relationship between the variation in the number of employees in the destination and origin occupations in the last 5 years • Source: Annual Social Information Report

Zones (origin and destination):

• Variation in the number of employees in the destination occupation in the last 5 years / Variation in the number of employees in the origin occupation in the last 5 years> 1.2 = 1

• 1.2> Variation in the number of employees in the destination occupation in the last 5 years > 1.1 = 0.9

• 1.1> Variation in the number of employees in the destination occupation in the last 5 years > 1 = 0.6

• 0.95> Variation in the number of employees in the destination occupation in the last 5 years > 1 = 0.4

• 0.9> Variation in the number of employees in the destination occupation in the last 5 years > 0.95 = 0.2

• Other cases = 0

Relationship between the variation in the number of employees in the destination and origin occupations in the last year

Source: Annual Social Information Report

Zones (origin and destination):

• Variation in the number of employees in the destination occupation in the last year / Variation in the number of employees in the origin occupation in the last year> 1.2 = 1

- 1.2 > Variation in the number of employees in the **destination** occupation in the last year> 1.1 = 0.9

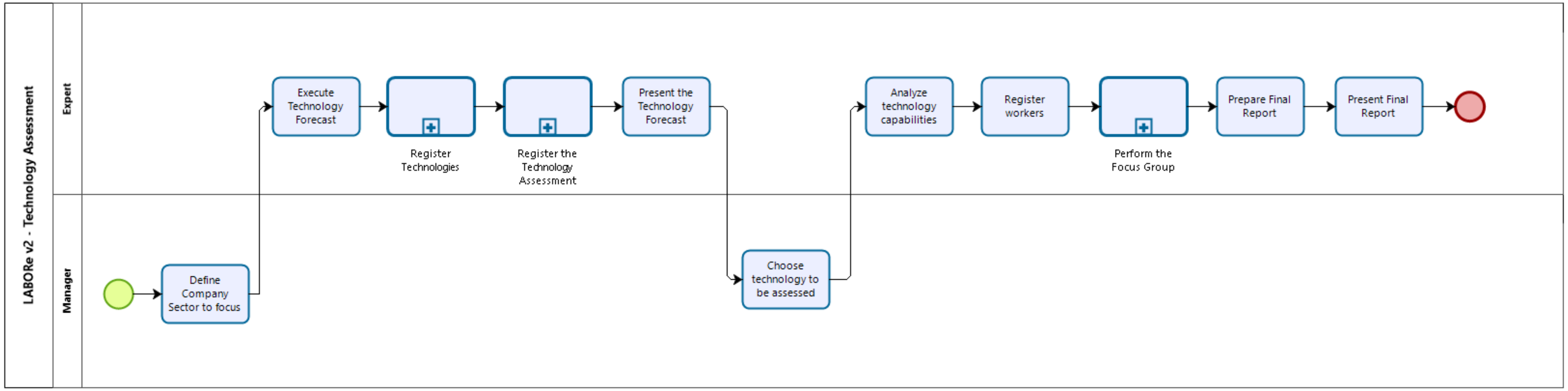
- 1.1 > Variation in the number of employees in the destination occupation in the last year> 1 = 0.6

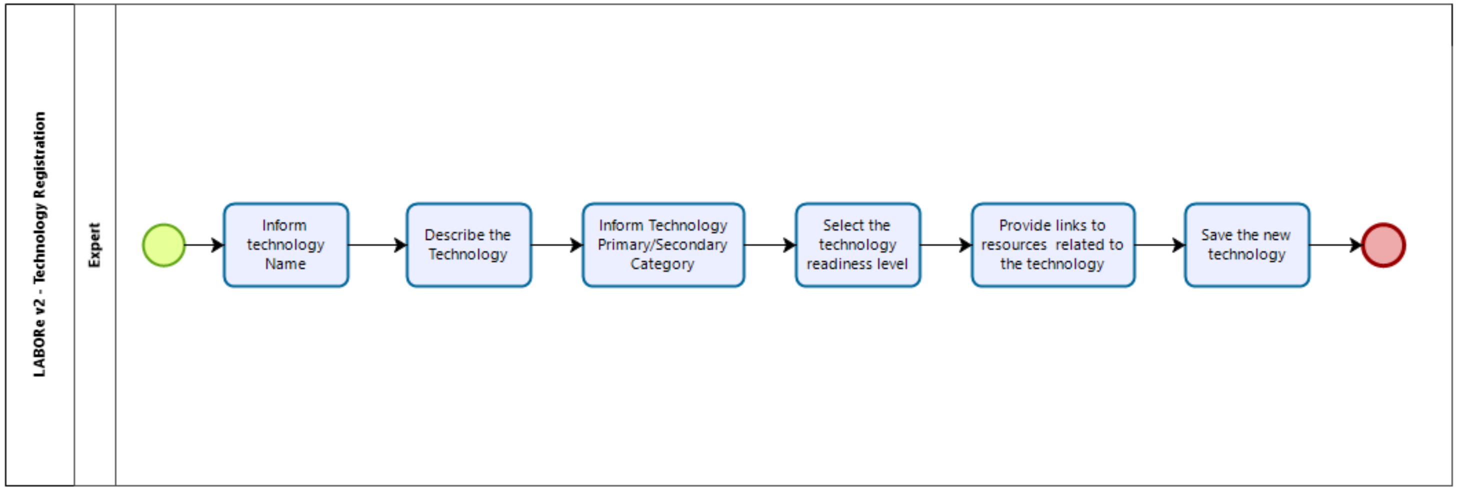
- 0.95 > Variation in the number of employees in the destination occupation in the last year> 1 = 0.4

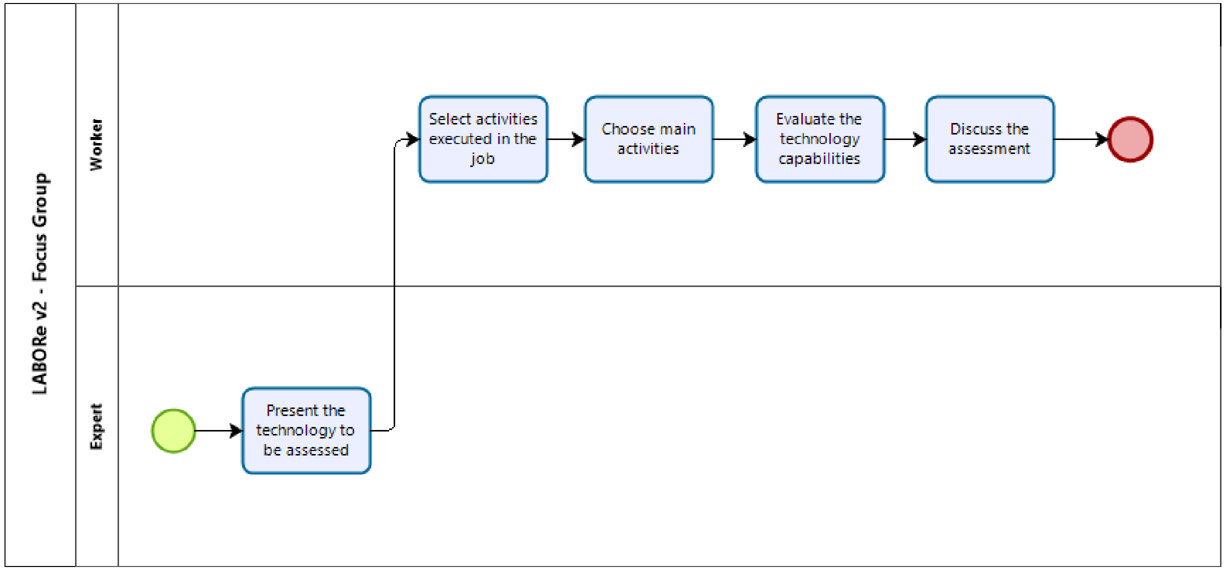
- 0.9 > Variation in the number of employees in the destination occupation in the last year> 0.95 = 0.2

- Other cases = 0

Appendix C: BPMN Activity Diagrams for LABORe v2






LABORe v2 - Focus Group
Worker
Expert
Present the technology to be assessed
Select activities executed in the job
Choose main activities
Evaluate the technology capabilities
Discuss the assessment

Appendix D: Self-Checkout Capabilities

Activity Group	Activity	Automation Level
Communication	Inform the Customer About Product Delivery	High
Control Cash and Values	Verify Authenticity of Received Money Bills	High
Control Cash and Values	Register Products With Cash Value	High
Control Cash and Values	Count Cash	High
Control Cash and Values	Register the Intake of Cash	High
Control Cash and Values	Record the Price of Goods and Services Sold	High
Control Cash and Values	Control Cash Flow	High
Give Information	Inform Deadlines and Days of the Week Defined for Exchange of Goods	High
Receive Sales Values for Products and Services	Consult Price, Rates, and Deadlines List	High
Receive Sales Values for Products and Services	Inform the Client the Amount to be Paid	High
Receive Sales Values for Products and Services	Inform Payment Options	High
Receive Sales Values for Products and Services	Issue the Invoice	High
Serve Customers	Survey Customer Satisfaction	Medium
Communication	Conduct After-Sales Research	Medium
Communication	Conduct Pre-Sales Research	Medium
Communication	Meet Customers' Demands	Medium
Communication	Request Assistance in Case of Accident or Emergency	Medium
Control Cash and Values	Give Change	Medium
Control Cash and Values	Close the Cashier	Medium
Control Cash and Values	Open the Cashier	Medium
Give Information	Inform Ingredients and Validity of Food Products	Medium
Give Information	Promote Sales and Events	Medium
Receive Sales Values for Products and Services	Offer Products and Services to Customers	Medium
Receive Sales Values for Products and Services	Register Goods, Products and Services Using an Optical Reader	Medium
Sell Products	Register Customers	Medium
Communication	Refer Customers to Competent Sectors	Low
Give Information	Consult the Consumer Protection Code	Low
Perform Technical-Administrative Activities	Archive Tax Documents and Invoices	Low
Perform Technical-Administrative Activities	Place Material Orders	Low
Perform Technical-Administrative Activities	Fill Administrative Reports	Low
Receive Sales Values for Products and Services	Pack Products Sold	Low

Appendix E: Result of the analysis of the activities of the Cashier

Activity Group	Activity	% of Participants
Receive Sales Values for Products and Services	Pack Products Sold	100%
Receive Sales Values for Products and Services	Issue the Invoice	100%
Receive Sales Values for Products and Services	Make products and services available at the counter	100%
Receive Sales Values for Products and Services	Inform the Client the Amount to be Paid	100%
Receive Sales Values for Products and Services	Inform Payment Options	100%
Receive Sales Values for Products and Services	Offer Products and Services to Customers	100%
Receive Sales Values for Products and Services	Register Goods, Products and Services Using an Optical Reader	100%
Communication	Meet Customers' Demands	100%
Communication	Request Assistance in Case of Accident or Emergency	100%
Control Cash and Values	Open the Cashier	100%
Control Cash and Values	Give Change	100%
Give Information	Promote Sales and Events	100%
Give Information	Informar a localização de mercadorias e produtos	100%
Perform Technical-Administrative Activities	Participate in Training Courses	100%
Control Cash and Values	Register the Intake of Cash	75%
Control Cash and Values	Register Products With Cash Value	75%
Control Cash and Values	Verify Authenticity of Received Money Bills	75%
Control Cash and Values	Control Cash Flow	75%
Control Cash and Values	Close the Cashier	75%
Give Information	Inform the Public about the Opening Hours	75%
Give Information	Inform the rules and standards set by the company	75%
Give Information	Consult company procedures and standards	75%
Communication	Refer Customers to Competent Sectors	75%
Communication	Provide preferential care to pregnant women, the elderly and the disabled	75%
Perform Technical-Administrative Activities	Archive Tax Documents and Invoices	75%

Activity Group	**Activity**	**% of Participants**
Control Cash and Values	Record the Price of Goods and Services Sold	50%
Control Cash and Values	Count Cash	50%
Receive Sales Values for Products and Services	Consult Price, Rates, and Deadlines List	50%
Perform Technical-Administrative Activities	Control stock of materials	50%
Comunicar-se	Take orders via phone	25%
Comunicar-se	Guide customers via phone	25%
Communication	Conduct Pre-Sales Research	25%
Control Cash and Values	Reimburse the customer for damages	25%
Control Cash and Values	Cash up values from the cashier	25%
Control Cash and Values	Cash up according to limit values	25%
Give Information	Consult the Consumer Protection Code	25%
Give Information	Inform ingredients and validity of food products	25%
Give Information	Inform Deadlines and Days of the Week Defined for Exchange of Goods	25%
Perform Technical-Administrative Activities	Place Material Orders	25%
Perform Technical-Administrative Activities	Fill Administrative Reports	25%
Receive Sales Values for Products and Services	Sell products and services via phone	25%
Perform Technical-Administrative Activities	Fill list of bank checks received	0%
Perform Technical-Administrative Activities	Provide training and refresher courses in the workplace	0%
Communication	Conduct After-Sales Research	0%
Control Cash and Values	Check banck checks received	0%
Receive Sales Values for Products and Services	Stamp documents and objects	0%

Appendix F: Summary of the discussion of the focus group

Activity Group	Activity	Automation Level (Original)	Automation Level (Suggested)	Votes	Comment
Perform Technical-Administrative Activities	Archive Tax Documents and Invoices	Low	Medium	1	If the documents were digitalized, it would be easier to automate this activity.
Control Cash and Values	Control Cash Flow	High	Medium	1	Some protocols and norms of the operation, due to the company's determinations, make the task less automatable. For instance, the Cash Flow envelope must be printed.
Give Information	Promote Sales and Events	Medium	High	1	It is possible to use other means of promotion such as social networks and SMS to complete the promotion of events and automate the activity.
Control Cash and Values	Give Change	Medium	High	1	This automation already exists and can be done. It is already being tested in some pilot stores.
Receive Sales Values for Products and Services	Pack Products Sold	Low	Zero	1	The experience that I had in the USA as a customer shows that it is that client that packs the products sold.
Receive Sales Values for Products and Services	Offer Products and Services to Customers	Medium	High	2	It depends on the client's profile. For some people, the sale done by a human can be better, but for people "100% digital" it can be better to interact with the machine.
			Low	1	The technology needs to be assertive, otherwise, it becomes a notification (e.g. push notifications) that nobody reads. Humans can be better at selling by showing the product and, for that reason, the advisory sale can be more efficient.
Receive Sales Values for Products and Services	Register Goods, Products and Services Using an Optical Reader	Medium	High	1	The participant believes in the capacity of the technology to completely automate this activity.
Communication	Request Assistance in Case of Accident or Emergency	Medium	Zero	2	In general, the self-checkout can even warn about some emergency, but the evaluation and resolution of the situation depends on a human and, in cases of accidents, even more.

Appendix G: Questionnaire for the final evaluation of the model of the 2nd design cycle

Please, answer the questions below according to your view of the test of the methodology for the collaborative assessment of technologies that was tested in the Company X:

1. Capacity of the tested methodology to help those involved in discovering new technologies that are relevant for their sector (5-point Likert scale ranging from very low to very high)
2. Capacity of the tested methodology to help those involved in better understanding the challenges of integrating emerging technologies (5-point Likert scale ranging from very low to very high)
3. Capacity of the tested methodology to help those involved in knowing more about the Self-Checkout technology (5-point Likert scale ranging from very low to very high)
4. Capacity of the tested methodology to help the participants to explore the impact of the Self-Checkout technology on the work of the Cashiers of the Company X's Convenience Stores (5-point Likert scale ranging from very low to very high)
5. Capacity of the system that supports the methodology to help the assessment of the impact of the Self-Checkout technology on the work of the Cashiers of the Company X's Convenience Stores (5-point Likert scale ranging from very low to very high)
6. In your opinion, what are the positive aspects of the methodology/system for the collaborative assessment of technologies that was tested in the Company X? (Open-ended question)
7. And the negative aspects? (Open-ended question)
8. What suggestions for the improvement of the methodology/system would you give? (Open-ended question)

Appendix H: List of publications

#	Title	Type	Publication	Status	Year
1	The future of work: Insights for CSCW	Conference Paper	21st IEEE International Conference on CSCW in Design	Published	2017
2	Working in 2050: A View of How Changes on the Work Will Affect Society	Technical Report	Future LAB	Published	2017
3	LABORe: Collaborative Assessment of Work-Disruptive Technologies	Poster Paper	16th European Conference on CSCW	Published	2018
4	Coordination, Communication, and Competition in eSports: A Comparative Analysis of Teams in Two Action Games	Conference Paper	16th European Conference on CSCW	Published	2018
5	Multi-criteria Analysis applied to the inspection of Aedes Aegypti mosquito breeding places	Poster	44th International Conference on Very Large Data Bases	Published	2018
6	Approaching Future-oriented Technology Analysis Strategies in Knowledge Management Processes	Conference Paper	23rd IEEE International Conference on CSCW in Design	Published	2019
7	A Service Bus for Knowledge Management Systems in Brazilian Federal Government	Conference Paper	23rd IEEE International Conference on CSCW in Design	Published	2019
8	Towards Fact-Checking through Crowdsourcing	Conference Paper	23rd IEEE International Conference on CSCW in Design	Published	2019
9	O Futuro do Emprego: Estimativa do Impacto da Automação no Brasil	Conference Paper	Encontro Nacional de População, Trabalho, Gênero e Políticas Públicas	Published	2019
10	Designing LABORe: a Platform for the Collaborative Assessment of Technological Change in the 4th Industrial Revolution	Conference Paper	IEEE Systems, Man, and Cybernetics	Published	2019
11	O Futuro do Emprego no Brasil: estimando o impacto da automação	Technical Report	Future LAB	Published	2019
12	Healthcare 2030: A view of how changes on technology will impact Healthcare in 2030	Technical Report	Future LAB	Published	2020
13	Initiatives for Gender Equality in Stem Education: the Brazilian case	Conference Paper	13th annual International Conference of Education, Research and Innovation	Published	2020
14	A Framework to Support Integration of Future Studies Methods	Journal Paper	European Journal of Futures Research	Awaiting Reviewer Scores	2020
15	The Impact of the Brazilian Federal Government Decisions on Workers' Exposure to COVID-19	Journal Paper	To Be Defined	Ready to submit	2020
16	Collaboration Challenges of Professional eSports Players	Journal Paper	Internet Research	Submitted	2020
17	Inspection of Aedes Aegypti Breeding Sites in Brazil: Application of Multi-criteria Analysis to Develop an Index	Journal Paper	Journal of Medical Internet Research	Submitted	2020
18	Future of Work in 2050: thinking beyond the COVID-19 pandemic	Journal Paper	Employee Relations	Ready to submit	2020
19	Exploring the Future Impact of Automation in Brazil	Journal Paper	Employee Relations	Published	2021
20	Introduction to the Relation between Technologies and Inequalities: Can Innovations Drive Social Change?	Conference Paper	IV ISA Forum of Sociology	Accepted	2021
21	Labore: Participatory Technology Assessment of Automation Technologies	Conference Paper	IV ISA Forum of Sociology	Accepted	2021
22	Mapeando o impacto da automação no Brasil: o caso de Rio de Janeiro e São Paulo	Journal Paper	Revista Brasileira de Estudos Urbanos e Regionais	Being prepared	2021
23	Towards a Model of Collaborative Technology Assessment	Journal Paper	Technology in Society	Being prepared	2021
24	Percepção do Impacto da Indústria 4.0	Journal Paper	Revista de Administração Mackenzie	Being prepared	2021
25	Automation and worker displacement: towards a model for job transition pathways	Journal Paper	Societies	Being prepared	2021