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AN INFORMATION SYSTEM FOR ASSESSING AND GUIDING INDUSTRY 4.0 STRATEGIES

Pedro António Castela Nolasco



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Dissertation in the context of the Master in Informatics Engineering, Specialization in Software Engineering, advised by Professor João Nuno Lopes Barata, co-advised by Professor Paulo José Osório Rupino da Cunha and presented to Faculty of Sciences and Technology / Department of Informatics Engineering.

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Abstract

The fourth industrial revolution (industry 4.0) is already underway, calling for a profound transformation enabled by digital technologies. The assessment of industry 4.0 maturity and the definition of strategies to redesign business processes and deliver smarter products in the market became priorities for managers. However, the analysis of the state of the art has shown that current maturity models have limitations in assisting digital transformation over time and in fitting with different types of industrial strategies.

This dissertation presents an innovative Industry 4.0 adoption model, named BSC-MM, to implement a continuous diagnosis and execution of industry 4.0 strategies. The development was conducted in a leading paper pulp company listed in the PSI-20 on the Euronext Lisbon stock exchange. The resulting approach (1) extends the balanced scorecard with specific support for industry 4.0, (2) introduces the concept of maturity model fragments, and (3) proposes a web application to operationalize the model.

This thesis describes the design, implementation, and test of the theoretical model and its supporting web application using different methodologies to ensure conformance. The most critical requirements for the development were successfully completed and validated by the case company.

The project results may contribute to a dual goal of increasing maturity models adoption in daily practice and implementing a more resilient and sophisticated strategy in turbulent industry 4.0 environments.

Keywords

Industry 4.0, Digital Transformation, Maturity Models, Balanced Scorecard, Strategy Development, Maturity Model Fragment.

Resumo

A quarta revolução industrial, designada por Indústria 4.0, está em marcha, impondo uma transição estratégica veiculada por tecnologias disruptivas. A avaliação da maturidade da transformação digital, bem como a definição de estratégias para redesenhar processos de negócios e fornecer produtos mais inteligentes no mercado, tornaram-se uma prioridade para os gestores. A revisão de literatura evidenciou que os atuais modelos de maturidade têm limitações para auxiliar a transformação digital ao longo do tempo, e se ajustarem a diferentes tipos de empresas.

Neste trabalho desenvolveu-se um novo modelo de abordagem da indústria 4.0 para as empresas, denominado BSC-MM, com o objetivo de implementar o diagnóstico e execução de estratégias contínuas da indústria 4.0 em empresas. O desenvolvimento do modelo foi conduzido numa empresa de produção de celulose, líder do mercado, listada no índice PSI-20 da bolsa de valores *Euronext Lisbon*. A aplicação do modelo resulta (1) da adaptação do *Balanced Scorecard* para a transformação digital, (2) introduzindo o novo conceito de fragmentos de modelo de maturidade e (3) propõe uma aplicação web para operacionalizar o modelo.

É também apresentada a implementação da aplicação web, em articulação com um conjunto de boas práticas de gestão de projetos relacionadas com o desenvolvimento de software. A aplicação foi testada com recurso a diferentes metodologias por forma a garantir a sua qualidade. Procedeu-se a uma validação final do modelo e da sua aplicação pela empresa caso. O projeto alcançou um duplo objetivo de potenciar a adoção de modelos de maturidade na prática quotidiana das empresas industriais e implementar estratégias mais resilientes e sofisticadas em ambientes turbulentos. O modelo proposto contribui para as empresas definirem, avaliarem e redesenharem continuamente a sua estratégia para atingirem a quarta revolução industrial.

Palavras-Chave

Indústria 4.0, Transformação Digital, Modelos de Maturidade, *Balanced Scorecard*, Desenvolvimento Estratégico, Fragmentos de Modelos de Maturidade.

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Acronyms

API (Application Programming Interface)

BSC (Balanced Scorecard)

CSS (Cascading Style Sheets)

DOM (Document Object Model)

HTTP (HyperText Transfer Protocol)

ISO (International Organization for Standardization)

IT (Information Technology)

JSON (JavaScript Object Notation)

JWT (JSON Web Token)

MM (Maturity Model)

MMF (Maturity Model Fragment)

MVC (Model-View-Controller)

NPM (Node Package Manager)

ORM (Object-Relational-Mapper)

PAAS (Platform as a Service)

PSI (Portuguese Stock Index)

SA (Anonymous Society)

SWOT (Strength, Weakness, Opportunity, and Threat)

UI (User Interface)

URL (Uniform Resource Locator)

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Chapter 1

Introduction

This report documents the work carried out within the curricular unit of Dissertation/Internship, which took place under the supervision of Professor João Nuno Lopes Barata and Professor Paulo José Osório Rupino da Cunha. The dissertation is part of the Master's degree in Informatics Engineering (MEI) with specialization in Software Engineering, in the Department of Informatics Engineering (DEI) of the Faculty of Sciences and Technologies of the University of Coimbra (FCTUC).

This chapter is divided into five sections that demonstrate the overall perspective of the report introducing the context, the motivation of this dissertation, the collaboration company, the success criteria and the report structure.

1.1 Context and Motivation

Industrialization began in the 18th century marking a period of development and transformation from "*agrarian societies in Europe and America into industrialized ones*" [1]. The main characteristics of the First Industrial Revolution were technological ("*the steam engine*"), socioeconomic ("*shift in economic power*"), and cultural ("*workers acquired new and distinctive skills*"). The world continued to develop, with successive advances to a second (electrically-power mass production) and third (automation) Industrial revolutions. The main purpose of these three industrial revolutions was to increase efficiency in the organization, processes, and products [2].

More recently, the technological progress and the increasing difficulties to compete inspired the German government in a new high-tech approach to industry transformations. Their aim was to combine multiple technologies in manufacturing, for example, artificial intelligence, internet of things (IoT), cybersecurity, augmented reality, 3D printing, or smart cloud [3] [4]. The fourth industrial revolution or industry 4.0 had started. Consequently, companies in Europe and in other parts of the globe started to invest in digital solutions and studying how they should align with the organization to add value.



Figure 1.1 Industry 4.0 High-Tech

Assessing the maturity of companies adopting industry 4.0 is a challenge. On the one hand, many self-assessment Maturity Models [5] were developed to evaluate the current state

(readiness) of the organization. On the other hand, each model has different evaluation dimensions [6] and reveal practical limitation: models that don't fit the background scenarios of the company and don't provide strategic planning to the next step after the maturity assessment. Companies need to evaluate how information systems can be adopted in their particular context, but industry 4.0 is a long-term transformation process, therefore, evaluating the company in a single moment in time provides limited assistance to managers.

Performance measurement is key to the management control process, providing feedback on the effectiveness of competitive activities, learning from internal and market-oriented practices, and guiding strategic transformations [7]. The Balanced Scorecard (BSC) proposed by Kaplan and Norton [8] is one of the most popular tools used to envision strategic goals while planning the operational activity at the level of operational objectives and control over their achievement [8]. The Balanced Scorecard draws on the strategy to establish goals requiring that people take actions necessary to arrive at those goals. Therefore, the measures are designed to pull people toward the overall vision and not merely to represent the strategy [8]. Could be interesting to combine tools that measure the current state of the organization (maturity models) with tools that guide transformations over time (BSC).

Assessing and guiding companies in industry 4.0 adoption with the development of an alternative model and a support tool assume a decisive role in this era and is the main motivation of this dissertation.

1.2 Collaborations

This dissertation was developed in close collaboration with the IT department of CELBI - Celulose Beira Industrial, SA.

CELBI is an industry company whose primary activity is the production of paper pulp. It is one of the world's most efficient producers of eucalyptus pulp being the first in Europe and in its industry to receive certification from ISO 50001 - Energy Management System [9]. CELBI is owned by the Altri group. The company is recognized worldwide for the high quality of its product and excellent customer service. Its history dates back to 1962 when the first factory was established. It is listed in the PSI-20, *"a free float market capitalization weighted index that reflects the performance of the maximal 20 most actively traded shares listed on Euronext Lisbon, and is the most widely used indicator of the Portuguese stock market."* [10].

CELBI is developing its strategy for industry 4.0 and needed new tools to assist them in the process.

1.3 Success Criteria

The author considers the dissertation as successful by presenting the following elements: (1) a comprehensive state-of-the-art on industry 4.0, maturity models, and balanced scorecard; (2) a model proposal that can be used at the diagnosis phase (assessing) but also during the industry 4.0 transformation (guiding); (3) implementation of the model in a web application prepared with all the functionalities for the proper functioning defined in the Software Requirements Specification as *"must have"*. Moreover, the model proposal should be presented in the form of a scientific paper, and the supporting tool developed according to best practices of code development and project management instructed in the master's

degree in informatics engineering. CELBI, SA is the entity responsible for assessing the practical results of the dissertation outcomes.

1.4 Structure of the Report

The document is currently divided into eight chapters, which relate to the work performed during the two semesters of the dissertation.

The dissertation evolved in three phases. An initial phase explores the state of the art as well as planning the work (chapter 2 and 3). The intermedia phase designs a solution to address the problems detected with the assessment and guidance of industry 4.0 (chapter 4). The final phase develops and tests the new model in an online tool (chapter 5, 6).

The first chapter introduces the context and motivation of this dissertation. Next, the success criteria are stated, followed by the presentation of the case company and the structure of this dissertation.

The second chapter explores the state-of-the-art, presenting the origin, examples and impact of industry 4.0 on companies. Exposes concepts related to maturity models by revising and comparing 23 maturity models. This chapter also presents foundational concepts related to strategic management and the strategic mapping balanced scorecard tool.

The third chapter explains the method used in the literature review, the contact with the case company, and the project management practices related to the choice of the development lifecycle method, time estimation and risk management.

The fourth chapter includes the proposal for a new model developed to meet the current needs of the industry. This chapter assumes an essential role in summarizing the references found in the literature review and the contacts with the case company. The proposed model expands the Balanced Scorecard with an additional dimension for industry 4.0 and integrates fragments of existing maturity models, according to the specific context of the organization.

The fifth chapter refers to the document of Software Requirements Specification with the identification of functional and non-functional requirements and the stakeholders of the application and their contextualization. This chapter also presents the architecture of the application developed to support the model adoption.

The sixth chapter focuses the tool implementation, explaining the code, the structure, and the elements running in the application. The link for the web application <https://industry-sparks.herokuapp.com/>

The seventh chapter refers to the testing of the application with unit testing, end-to-end functionality and usability. Subsequently is presented the evaluation made by the case company, validating of the proposed model and the first version of the web application.

The eighth chapter exposes the final considerations, and a critical reflection on all the work developed. It closes the dissertation with the limitations and proposals for future work.

Chapter 2

State-of-the-Art

This chapter presents the state-of-the-art, introducing (1) the concepts of industry 4.0, (2) methods of measuring the maturity stage of transformation of organizations (maturity models) and systems to map the strategy of progression of companies over time (balanced scorecard).

2.1 Industry 4.0

The concept of Industry 4.0 was introduced in 2011 by the German government [11]. It can be defined as a strategic initiative to radically transform the industry with High Tech. The technological portfolio of industry 4.0 is vast: autonomous robots, artificial intelligence, internet of things (IoT), cybersecurity, augmented reality, 3D printing, mobile systems integration, smart cloud, or bigdata [3] [4]. Energy efficiency, mobility, sustainability, advanced communications and security are examples of strategic drivers of digital transformation in the industry [12]. In a few years, industry 4.0 captured the attention of European countries that found the opportunity of international cooperation according to a joint set of principles, as represented in the SWOT analysis included in Figure 2.1 [3].

Strength <ul style="list-style-type: none">• Comprehensive framework with broad involvement of policy-makers, industry, science and social partners enables it to push forward I40 at all levels	Weaknesses <ul style="list-style-type: none">• Ensuring actual deployment at shop-floor level, which will become increasingly relevant
Opportunities <ul style="list-style-type: none">• International cooperation opportunities and transferability of I40 platform	Threats <ul style="list-style-type: none">• Balancing between different industrial and sectoral interests

Source: Digital Transformation Monitor

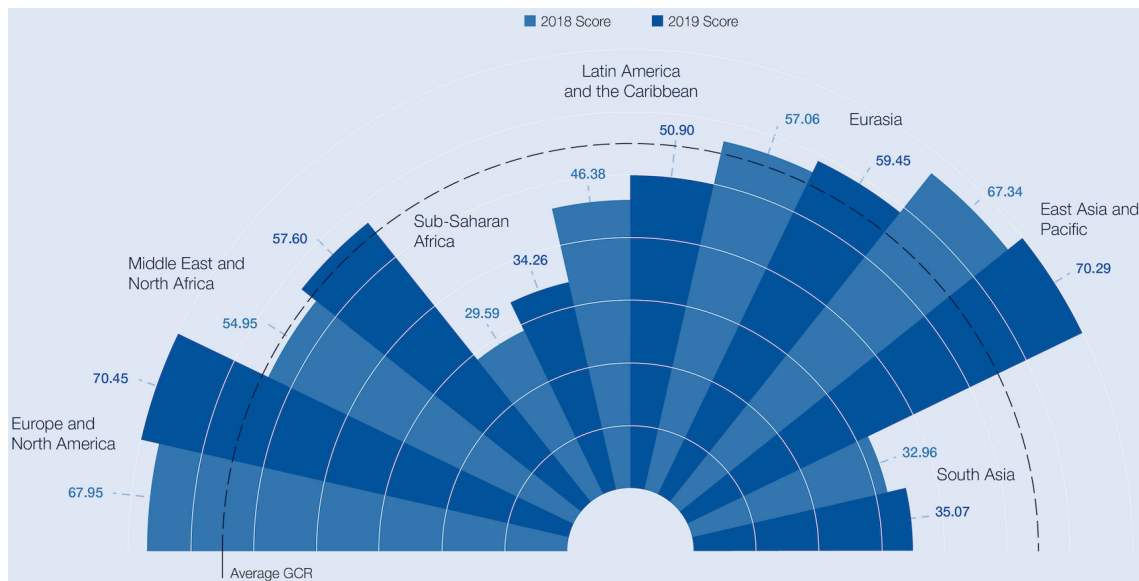
Source: Digital Transformation Monitor [3]

Figure 2.1 SWOT Matrix for Germany's Industrie 4.0

Industry 4.0 has crossed the German borders to other countries [3], similar industry transformation initiatives are competing in different regions of the globe, for example, Industrial Internet in the United States or Made in China 2020. However, " *I4.0 strategy or its*

instruments may not provide the desired results in other countries” [13] meaning that a unique implementation template may not be the best option. Moreover, Figure 2.1 highlights the threats to balance the differences in each sector of the economy.

According to Eurostat [14], the percentage of employees using computers or computerized equipment at work has been continuously growing, reaching 74% in 2018. Moreover, 16% of the employees faced changes in their job tasks as a result of the introduction of new software or computerized equipment. Figure 2.2 reveals that the digitalization of businesses is a global movement [15].



Source: World Economic Forum [15]

Figure 2.2 Tech adoption

Significant investments are being made in industry and universities, aiming to improve competitiveness and develop increased scientific knowledge in information systems and management of new business processes [16]. Operating with new technologies, analysing which ones to integrate with the organization strategy, and apply them to improve business processes and services are some of the main challenges. The impact of digital transformation in industry is noticeable in the following examples where several companies reshaped their structure to attend to *“new technology, customer needs, or other factors shift”* [17]: (1) The development of digital product ecosystems with closer customization to the customer enables the production differentiation with different indicators levels [17]. For example, GE Aviation is an industrial company that produces aircraft engines and collects data from sensors. With the data collected they adjust the engines to different types of planes characteristics to improve the performance of the system; (2) *“Rivalry among competitors”* expansion of capabilities in products and value-added services creates competition on market segments [17]. Babolat is an rackets industry company example that applied sensors on their tennis rackets, allowing players to track their performance in a smartphone application; (3) *“Bargaining power of suppliers”*, new technological suppliers (e.g. google, apple, AT&T) will be integrated into the processes and products of the company [17]. Vehicle production industry integrated new products into their vehicles like the google or apple

assistant. The examples are encouraging, but it is also clear that each organization will need to identify their own action plan.

Industry 4.0 digital transformation requires a strategy. The main challenge is to align the increasingly digital world with the company culture, people, structure, and tasks [18] and to ponder multiple organizational levels: (1) changing from linear to interconnected business operations, shaping how companies operate, collaborate, and compete; (2) adapting to new pressures and demands, yielding new revenue streams *“using demand data and digital technologies to expand more easily into new markets”* and incremental revenue improvements *“such as finding new efficiencies in the core business and using customer data to deepen customer understanding and integration”* [19]; (3) challenging and empowering employees, using smart technologies, and creating new roles with new products and services; improving the customer experience *“from initial research and sales to account management and aftermarket service”* [19].

“Adapt or die” can't be seen as a linear process to all organizations, they will have to search for individual answers to the demands to get a competitive advantage [20]. A digital transformation is intended to evolve the value chain developing new business models [21], adding value to the product and customer. This renewal will have to be worked established on new operating cultures within the organization. The transformation is not restricted to the acquisition of new products; it is an opportunity to reorganize the entire company and adjust its vision [22]. Each country, sector, and company has specificities and, as stated by [23], *“[w]e should 'reengineer' our businesses: use the power of modern information technology to radically redesign our business processes to achieve dramatic improvements in their performance”*.

Section 2.2 presents one of the most popular tools to evaluate the maturity of a company in the digital transformation.

2.2 Maturity Models

Companies need to evaluate digital maturity to fulfil the changes in the customers' needs, and remain competitive [5]. The study of the organization's digital maturity will enable the company to support the transformation process with investments and objectives alignment at a process, cultural and financial levels [24].

Paulk *et al.* [25] define a maturity level as an *“evolutionary plateau”* where an organization intends to achieve a mature process. According to Simić *et al.* [26], digital maturity portrays an organization's readiness and know-how to apply the latest technologies that will lead the company growth. Another concept of maturity is a representation of a distinct skill with evolutionary progress within a company intending to accomplish a planned target from a starting point [27].

Maturity models have different authors presenting original concepts with a common point of maturity assessment in a quantitative way [28]. These models provide a framework to identify the desired development progress using a set of levels or stages [29]. Then, *“rate capabilities of maturing elements”* of an organization's current scenarios and provide improvement guidelines [30]. The existing maturity models use different methods of evaluation as well as different evaluation dimensions [6].

One of the most important maturity models in industry 4.0 is the IMPULS – Industry 4.0 Readiness [31] (used as a foundation for Shift 4.0 the Portuguese model developed by ISQ and IAPMEI [32]). It comes up with the new concept of smart factories dimension to evaluate.

Smart factories are organized production environments with minimal need for human control. In these new environments is possible the cross data through the production systems, information systems, and the end-user in real-time. This maturity model evaluates the bridge between of the physical and digital world that allows greater flexibility at the level of production planning systems and supply chain management. The result from this maturity model is the maturity readiness level of a company to operationalize the exchange of workflow between the physic and digital processes. Figure 2.3 presents the maturity levels of IMPULS (0-5) that are used to identify the company readiness for industry 4.0.



Source: IMPULS Online Self-Check page [31]

Figure 2.3 IMPULS – Industry 4.0 Readiness home page

The IMPULS maturity model uses an online questionnaire in which different information regarding the actual state and the target values of the company in several perspectives is recorded. Examples of questions (from the online questionnaire) to assess readiness in each dimension of the model are included in Figure 2.4.

- | | |
|--|---|
| <p>How is the data you collect used?</p> <ul style="list-style-type: none"> <input type="checkbox"/> Predictive maintenance <input type="checkbox"/> Optimization of logistics and production processes <input type="checkbox"/> Creation of transparency across production process <input type="checkbox"/> Quality management <input type="checkbox"/> Automatic production control through use of real-time data <input type="checkbox"/> Optimization of resource consumption (material, energy) | <p>How would you describe the implementation status of your Industry 4.0 strategy?</p> <ul style="list-style-type: none"> <input type="radio"/> No strategy exists <input type="radio"/> Pilot initiatives launched <input type="radio"/> Strategy in development <input type="radio"/> Strategy formulated <input type="radio"/> Strategy in implementation <input type="radio"/> Strategy implemented |
|--|---|

Source: IMPULS Online Self-Check questions page [31]

Figure 2.4 IMPULS – Industry 4.0 Readiness questions

At the end of the questionnaire, the user has access to a report describing the stage the company is in, following the characteristics and evaluations of the model and a benchmark with other companies of the same industry sector (see Figure 2.5).

Evaluation of Industry 4.0 Readiness Check

Thank you for taking the time to complete the VDMA Industry 4.0 Readiness Check. Your results and your comparison group are outlined below. We also highlight specific measures you can take to improve and expand your Industry 4.0 readiness.

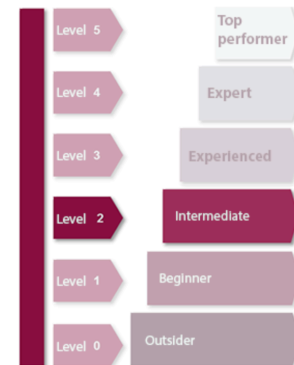
Overall evaluation

Your company is ranked at level 2 in the overall evaluation.

Your readiness scores in the six dimensions of Industry 4.0 are as follows:

- Strategy and organization: Level 3
- Smart factory: Level 2
- Smart operations: Level 2
- Smart products: Level 2
- Datadriven services: Level 2
- Employees: Level 3

Overall (weighted): 2.435 in keeping with level 2



Source: IMPULS Online Self-Check results page [31]

Figure 2.5 IMPULS – Industry 4.0 Readiness final results

The mode of adopting these models is very similar (answer a set of questions grouped in dimensions, then obtaining a maturity level) but the dimensions vary. For example, the PWC – Industry 4.0 Enabling Digital Operations [33] maturity model includes the following dimensions of analysis (each one with a specific set of questions): (1) Offering of digital products and services with a strong customer connection component; (2) Smart sensors complementing integration solutions to create products towards the needs of customers; (3) Fully optimized digital ecosystems that affect the value chain with efficient processes to manage the information of operations, with real-time operations plan available (4) Digital ecosystems value chain integration, passing the limits of the internal operation for suppliers and customers. This is a well-recognized model developed by PWC a valuable consultant company that “provides services to 85% of the Global Fortune 500 companies and more than 100,000 entrepreneurial and private businesses” [34].

The dimensions included in a maturity model and how it assesses the organization should be clear and describe the characteristics factors or questions [35]. Considering the most significant aspects to evaluate in a company, the dimensions defined in each model can have different names and characteristics. Dimensions can address different components of a company, its strategy, technology embedded in its processes, its products and the organization method to integrate external elements with the necessary flexibility [30].

The different stages of a model are designed to identify different phases for the evaluation of the company in the operations related to Industry 4.0 [36]. An example of a staged model is the APM Maturity Model [37], which starts with a benchmarking phase and ends with recommendations (see Figure 2.6).

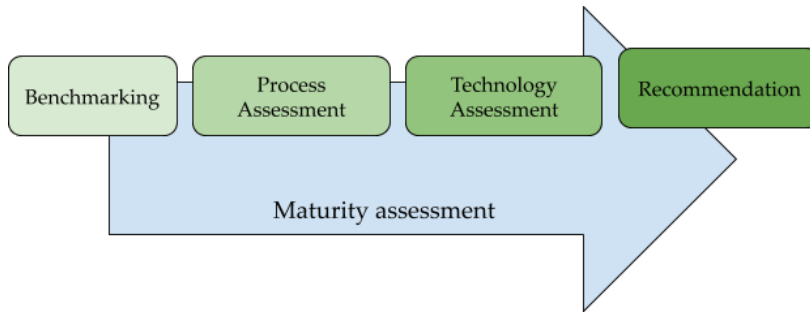
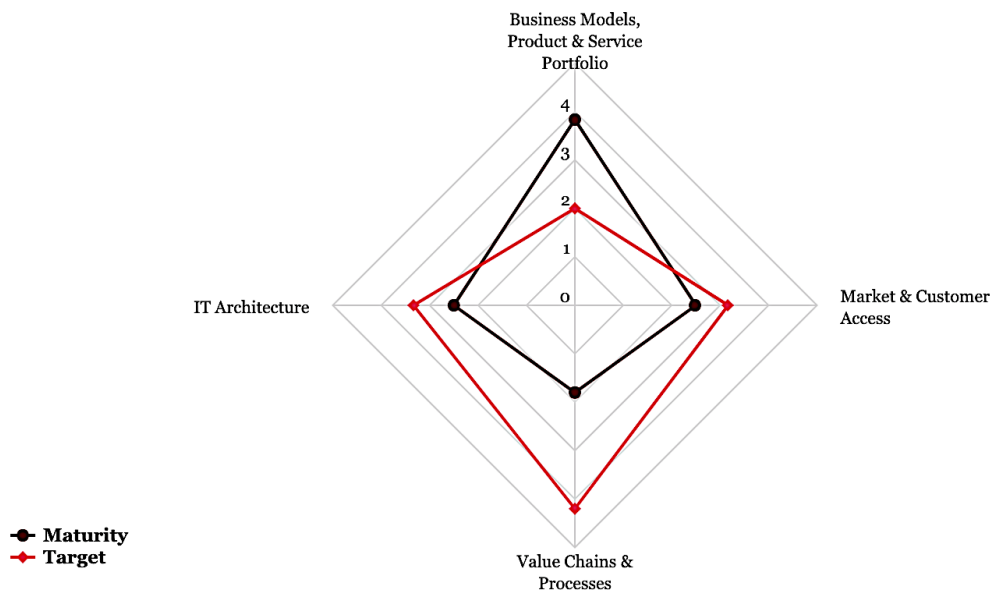


Figure 2.6 APM Maturity Model assessment stages

The resulting evaluation of the maturity model can either focus on the organization in a holistic way (e.g. the overall maturity level of the company), or can be “drilled-down” to each dimension within the model (e.g. dimension maturity level) [36]. The organization can find itself in an early stage in the digital maturity or at its digital transformation peak and be a “digital champion” [38]. There are different ways of working with the data in the maturity models, as well as to present it. For example, Schuhmacher *et al.* [39] determine a final value of maturity calculation formula with the assignment of weight-factors to each dimension that will affect the final result – the overall company maturity is a result of the weighted maturity in each dimension. Results can also appear in graphical formats, such as bar charts or radar charts (where each corner represents a dimension), as illustrated in Figure 2.7.



Source: IMPULS Online Self-Check results page [33]

Figure 2.7 PWC – Industry 4.0 maturity model result

Maturity Models can be developed by academics [40]. These models usually have a solid theoretical background and seek to align theory with practice in organizations [35]. The models can also be developed by practitioners: business consultants (e.g. PwC) or by companies themselves [6]. Apart from the internally developed models, all others are available online in different formats.

In 2018, COTEC, in cooperation with the KPMG consulting company, developed an evaluation system to be able to characterize Industry 4.0 at 18 countries in the European Union, based on data from Eurostat, the World Bank, and The Global Competitiveness Index, [41]. Figure 2.8 shows the results from digital dimensions such as the offer of digital competencies, investment, and finance, technical and innovation ecosystem, regulatory and business environment, strategy, operational and business moulds and implemented I4.0 technologies.

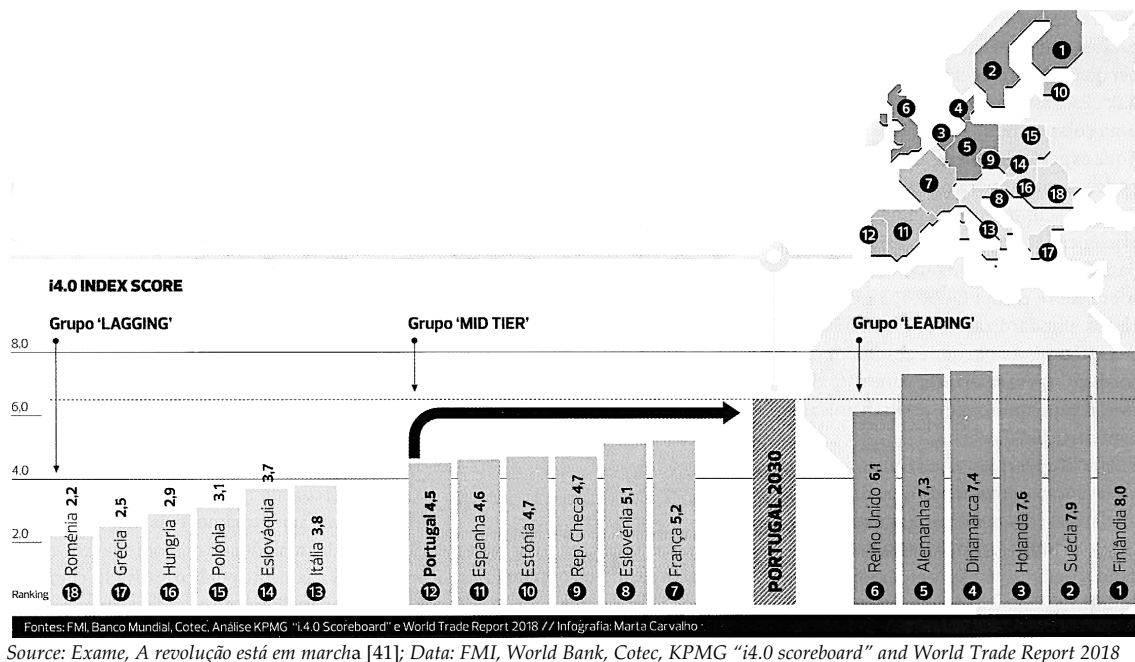


Figure 2.8 Europe I4.0 index score model

Three groups are identified in Figure 2.8: the "Lagging" ones that show some delay in progress for Industry 4.0, the "Mid-Tier" that are in a middle ground, and the "Leading" that are at the top of progress and transformation and should be seen as examples to be taken in consideration. This study predicted the impact of this evaluation, an increase of one point in the index results in a Gross Domestic Product (GDP) growth between 2.1% and 2.4% per capita in 5 years [41].

Government entities from different countries are also developing maturity models based on existing ones, adapting the characteristics to a national level. By evaluating the maturity of the national industry, it is possible to adjust the investment for the development of the sector. Digital documentation and maturity models are being carried out in several countries as the case of France [42], Portugal [32], Spain [43], German [16]. Fath-Allah *et al.* [44] compared several maturity models in terms of digital transformation and services of countries all over the world. The authors concluded that although the models have many similarities, they showed divergences on focus and features not allowing the concretization of a reliable general result.

Maturity Models can have sub-dimensions. The sub-dimensions help the model to focus on specific industry 4.0 technologies or processes that provide a more advanced evaluation of the company maturity readiness level [45][46].

A Global Study of MIT Sloan Management Review and Deloitte's presented results related to the digital transformation applied in different sectors at a global level that would result in different values of digital maturity impact [20]. From this point, it is necessary to look at maturity models, not as a holistic element to all companies, but rather improve know how on the company sector and characteristics. It is up to each organization in the vast offer available to select those maturity models that share the same vision with the desired nuclear strategies and activities [47]. In fact, one of the difficulties pointed to current maturity models is precisely which one to use according to the company strategy. Not all models are possible to apply to all businesses (e.g. the necessities of a major petrochemical are different from a shoe production factory). Also, not all dimensions of the existing models may fit in the organizational vision (e.g. companies have specific strategic objectives and maturity models are developed to be applied in all industry so the evaluation dimension will introduce redundancies).

In this dissertation, a comprehensive assessment of 23 maturity models was made to identify the most usual dimensions in current industry 4.0 maturity models. This study is included in the Appendix A "*Maturity Models 4.0*". Each model was evaluated according to a set of common characteristics: (1) list of dimensions; (2) number of sub-dimensions; (3) list of stages; (4) levels of maturity; (5) the origin; (6) availability of a tool to support its use; (7) how data is presented to the user; and (8) year of publications. All models attempt to analyse and evaluate industry 4.0 maturity. However, the models differ in dimensions, type of sector, type of levels, opening access to the possibility of each company develop its path to study and work on the model they need. The main evaluation of the company readiness for industry 4.0 occurs in two forms: stage phases or dimensional levels. Each company can choose different maturity models going through the dimensions that may interest most, or follow an approach less important for the strategic vision of the company and use a single maturity model. Surprisingly, most of the existing models in the list do not cite or explain what is the advantage of the model, resulting in a proliferation of proposals that may be confusing to the industry.

This literature review allowed to understand the importance of maturity models in industry 4.0 assessment. It was also possible to identify their focus in assessing the "*stage*" of the organization at a precise moment, being difficult to steer long term investments in industry 4.0. Despite their popularity, there are limitations in current maturity models to establish roadmaps tailored to the context of each company [40]. Some maturity models are a poor fit for SMEs or may be too simple to be useful in large enterprises [48]. Additional problems include: (1) shortcomings when dealing with environmental changes (the model is static regarding its dimensions and maturity levels), (2) scant guidance on how to address identified issues, (3) insufficient detail to measure progress over time (e.g. lack of studies showing how an organization can use the maturity model for multiple assessments), (4) deficient theoretical grounding [49], [50], and (5) poor support for social and organizational issues [51].

Sub-chapter 2.3 presents additional work that aims to assist companies during the process of digital transformation.

2.3 Industry 4.0 Frameworks and Roadmap

Maturity model frameworks are a type of tools that can be positioned in-between the models and roadmaps [50]. Maturity Model frameworks appeared to address the current limitations

of maturity models. For example, its descriptive focus (current stage) and the difficulties in meeting the real business needs for SMEs [40]. Kane *et al.* [18] shows that the Industry 4.0 concept is understood differently across industry sectors, thus demanding specific know-how when tailoring existing approaches. This section highlights three examples that aims to provide more specific guidance for organization change over time.

Barata *et al.* [40], after recognizing different flaws in existing maturity models for industry 4.0, presented a Framework industry 4.0 adoption that combines the organizational strategy of the industry sector and the national strategy. They propose a framework with several phases of digital transformation. Work the specifications of the sector and the competitive context (Scenarios) of the organization, "*design-reality gaps of information; technology; processes; objectives and values (through which factors such as culture and politics are manifest); staffing and skills (competencies); management systems and structures; and other resources (e.g., time and money)*". Instead of a prescriptive model, it is intended to detail each dimension based on the processes and services considered more important in the digital ecosystem as well as in the sector. After the design-time, the run-time is the phase of activities adoption associated with the transformation project.

Issa *et al.* [52], defined a way to balance an organization implementation of technology and changes, with business-IT concepts and integration systems. Implementation and deployment of digital transformation are structural elements in the organization. They make use of the CMM to evaluate the digital development of the company. However, the stages of evaluation are defined in different projects existing within the organization. It states that balancing the following 5 pillars "*Strategy, Monitoring and control, Structure and processes, Human resources, and IT*" is possible to increase performance by 30%. The range to be covered by each company is unique and based on criteria that describe a more elaborate knowledge of the company and of the main dimensions with the technologies they intend to develop up to a phase of use case and impact.

Ghobakhloo [53], defines a strategic roadmap for the manufacturing industry designed on industry 4.0 concepts. He focuses on small manufacturers who do not have yet any financial, cultural on fundamental technological elements to advance to Industry 4.0. This study specifies strategies in the short, medium and long term and defines the importance of an organization to evaluate the current state. Proposes a well-designed plan and a description of how it will work in each phase of evolution, thus identifying the needs. Works the marketing strategies issues with the new existing products, the strategies related to human resources, management of information systems, supply chain and background of the sector. In this way, for smaller companies with a simple roadmap can be easier to the entry in Industry 4.0.

Shifting from a "*picture of its readiness state*" (maturity model) to an integrated approach that also monitors transformation over time (how the company evolves), companies will be capable to carry their "*roadmap*" and increase the likelihood of success in Industry 4.0 adoption [52] [53].

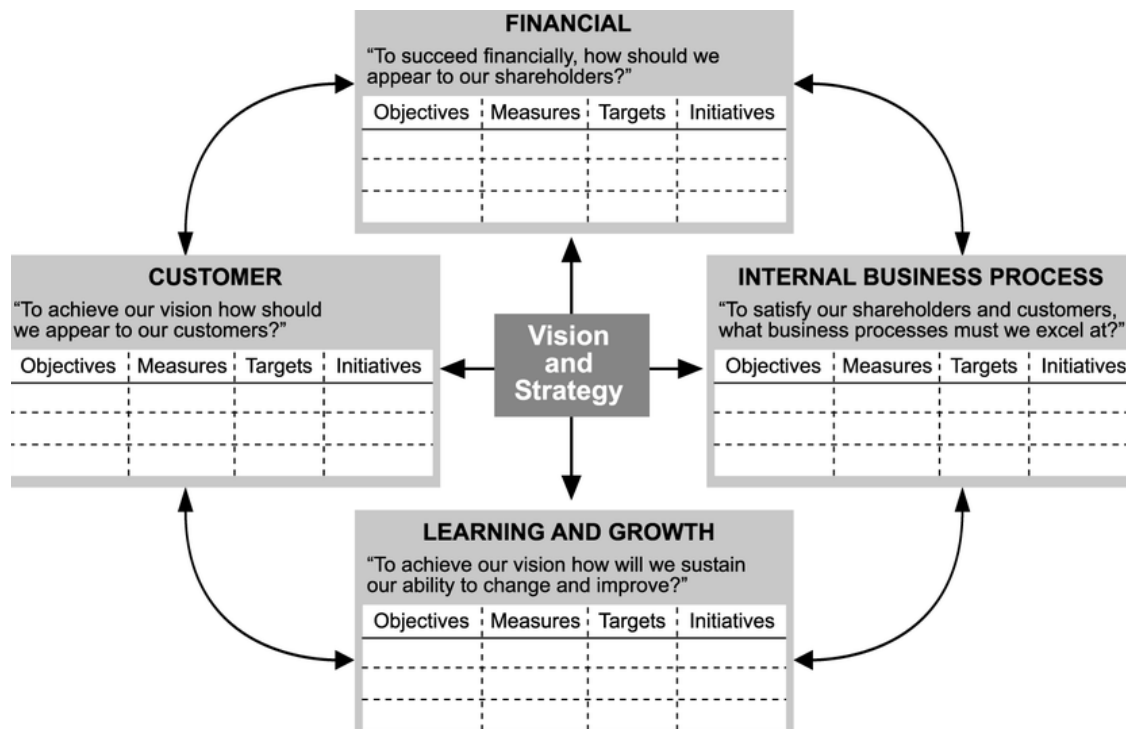
One of the most popular tools to design and monitor a strategy over time is the Balanced Scorecard proposed by Kaplan and Norton [8]. Section 2.4 shows the potential of this tool to extend the literature of frameworks and roadmaps in industry 4.0.

2.4 Creating Roadmaps with the Balanced Scorecard

The increasing changes in the technology portfolio of Industry 4.0 opens new opportunities to compete, but also raises new risks to identify the best investments, requiring maps “supported by dedicated and experienced managers who construct causality in the performance measurement system that is unit-specific, and not just copied from the generic BSC books” [54]. Strategic management is a continuous cooperation process linking knowledge and actions to improve the organization management. As stated by [55] “[b]ecause different strategies have different requirements for success, it follows that performance evaluation should be tailored to strategic orientation”. Competitive strategy concerns the patterns of choice managers assign to which markets to work and how to generate more value for the company buyers than the competitors [55].

Performance measurement is central to the management control process, providing feedback on the effectiveness of competitive activities, learning from internal and market-oriented practices, and guiding strategic transformations [56]. It has three main elements: (1) set performance indicators; (2) measure the performance indicators; (3) take corrective action if not achieve them [56]. Developing an organization approach to a strategic map will enhance business performance [57] [58], a strategic management process will further promote the progress of elaborate architectural structures needed for the growth of a company [59].

The Balanced Scorecard is a solution to assist the organizational strategy and measure the performance over time [7]. To use the Balanced Scorecard, the company has to choose goals that define its strategy. For each goal, the organization must identify metrics to evaluate its state and actions to achieve the desired results (indicators). [60]. The measures are designed to guide people toward the overall understanding of the company strategy [60]. Figure 2.9 presents the Balanced Scorecard presented by R. Kaplan and D. Norton with the identification of the four perspectives.



Source: Using the balanced scorecard as a strategic management system [8]

Figure 2.9 Balanced Scorecard perspectives

The balanced scorecard drives managers to converge on the most critical measures in 4 main perspectives: 1 - “*Customer Perspective: How Do Customers See Us?*” that prioritizes time, quality, performance and service, and cost; 2 - “*Internal Business Perspective: What Must We Excel at?*” that addresses cycle time, condition, employee know-how, and productivity; 3 - “*Innovation and Learning Perspective: Can We Continue to Improve and Create Value?*” that measures the ability to develop and introduce new products rapidly, which the organization assumes will produce the majority of its future sales; and 4 – “*Financial Perspective: How Do We Look to Shareholders?*” that indicates whether the company’s strategy, implementation, and execution are assisting to bottom-line development. This perspective is related to profitability, growth, and shareholder value [60]. Figure 2.10 presents the four perspectives of the Balanced Scorecard that require the identification of strategic goals (each perspective may have one or more goals to achieve).

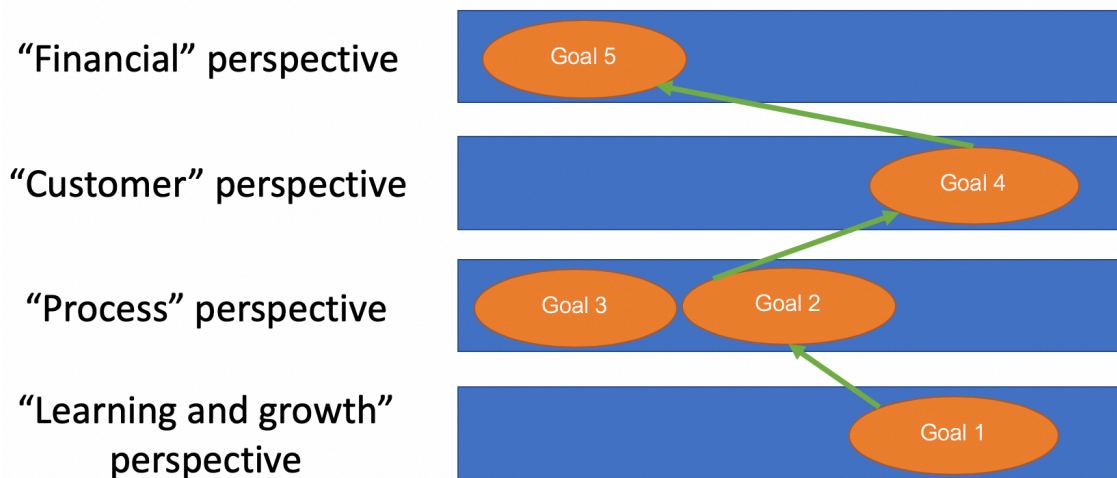


Figure 2.10 Balanced Scorecard representation

For each goal identified by the organization (example of a goal 2 (Figure 2.10) in the “*process perspective*”: decrease the number of software errors; which may affect a goal 4 in the “*customer perspective*”: improve the customer satisfaction index), it will be necessary to identify metrics and initiatives (actions) to achieve them. Figure 2.11 illustrates that process.

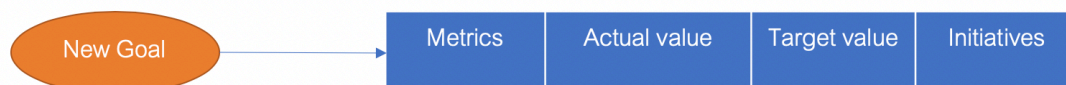


Figure 2.11 Balanced Scorecard goal characteristics

Formalizing this system of causality that determine the terms of strategic goals achievement, makes it possible to assess the organization’s strategic potential [61]. Each goal present in the balanced scorecard has 4 key characteristics to allow a better perception of the vision and strategy of the company: a metric that allows to quantify and establish evaluation parameters to achieve the goal; The current and target value to be able to perceive the evolution or delay of the work necessary to reach the goal; the initiatives that promote the goal.

Recent studies present an integration of the balanced scorecard in Industry 4.0. Szóka [62] that uses the original model and describes the main factors to implement (e.g. automation, motivation of employees) the Industry 4.0 strategy in the four BSC perspectives. Being the balanced scorecard, a support tool must respond to the stakeholder’s digital transformation

challenges. Other authors, extended the Balanced Scorecard model with an additional perspective [63]. Aldea *et al.* [64] shows the combining of BSC with other management tools, in this case with ArchiMate Enterprise Architecture modelling language. Defining high level ArchiMate goals with the help of BSC that develops a more detailed strategy map. These examples confirm that it is possible to create extensions and integrate diverse approaches in the process of developing strategy maps.

2.5 Concluding Remarks

The literature review presented in this chapter confirms the significance of Industry 4.0 for the digital transformation of manufacturing. Companies need new tools to assist them in the assessment (where they are) and guidance (where they want to be). Industry 4.0 varies according to the country, industry, sector, and organizational strategy.

Maturity models are essential tools to assess the organizational readiness and stage for industry 4.0 adoption. Different models have been proposed, but there are also problems. For example, these models are very interesting to identify “*current stage*” and maturity, but fails to assist the companies over time. New proposals are necessary to improve their use in organizations.

The Balanced Scorecard is a popular tool to assist strategy design (goals) and measure its performance, proposing initiatives that guide companies in their transformation. However, the Balanced Scorecard was not made to take advantage of the extensive studies in maturity models and do not measure “*maturity*”. Some studies suggest that the Balanced Scorecard can be adapted with additional perspectives, but cases focusing on industry 4.0 could not be found.

The integration of maturity models in the Balanced Scorecard seems to be a potential approach to assist companies in their industry 4.0 adoption. The integration may be able to simultaneously measure their maturity (repeating assessment over time after) and the transformation process. For example, a company that has low maturity in the digital interaction with their suppliers can propose a development initiative (e.g. a new digital platform) and later measure the maturity changes or the impact of that development in other perspectives of the Balanced Scorecard. However, this combination of maturity models and Balanced Scorecard has not yet been tested in the literature of information systems development.

Chapter 3

Methodology

This chapter presents the work plan and the methodology applied in the dissertation development. Section 3.1 presents the work plan, followed by the literature review process description. The case company that participated in the project is presented in section 3.3. Afterwards, the development of a software tool to assist industry 4.0 adoption is presented. The section concludes with the analysis of risk and the mitigation plan.

3.1 Work Plan

This section presents an overview of the work plan detailing the tasks to be developed during the two semesters, including the literature review, the model to steer industry 4.0 adoption, and the software development. The first phase focused on the literature review about solutions to assess and guide industry 4.0 adoption. The findings were discussed with the company participating in the study, allowing to propose a preliminary solution to test in industry 4.0 adoption.

The original plan for the first half of the internship was:

1. [September 2019, duration 1 month] – Study of the state-of-the-art: industry 4.0 and maturity models.
2. [October 2019, duration 1 month] - Study of the Capability Maturity Model Integration (CMMI).
3. [November 2019, duration 1 month] - Proposal of the model for industry 4.0 strategies.

The following elements were presented at the intermediate presentation: Structure of the model for industry 4.0 strategies (dimensions, possible questions for companies, I4.0 processes, type of inputs); Architecture for an online tool that supports the model implementation; Intermediate report.

The literature review of maturity models identified limitations in the support of the digital transformation of industry. It was also possible to study a number of maturity models, with different formats and purposes. Therefore, creating a new maturity model was excluded from the list of subsequent tasks. The most relevant contribution would be to take advantage of the existing maturity models knowledge and integrate them in a strategic map for industry 4.0 (extending the Balanced Scorecard). Therefore, the literature review also includes a specific section about the Balanced Scorecard. The executed work plan in the first semester evolved to the following steps:

1. Project management _ [5 days];
2. Industry 4.0 state-of-the-art _ [38 days];
3. Maturity Models state-of-the-art _ [34 days];
4. Table to compare the characteristics of the existing maturity models _ [22 days];
5. Industry 4.0 frameworks state-of-the-art _ [13 days];

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6. Digital transformation and digital maturity state-of-the-art _ [26 days];
7. Balanced Scorecard state-of-the-art _ [18 days];
8. Propose an application to integrate Strategies for Industry 4.0: Extending the Balanced Scorecard with Maturity Models. _ [16 days];
9. Mockups for the application _ [5 days].

Table I – Work plan [September-December, 2019] scheduling.

September 2019 phases: 1; 2; 3.						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16 – 1;	17 – 1; 2;	18 – 1; 2;	19 – 1; 2;	20 – 1; 2;	21 – 2;
22 – 2;	23 – 2;	24 – 2;	25 – 2;	26 – 2;	27 – 2;	28 – 2;
29 – 2; 3;	30 – 2; 3;					
October 2019 phases: 2; 3; 4; 5.						
		1 – 2; 3;	2 – 2; 3;	3 – 2; 3;	4 – 2; 3; 4;	5 – 2; 3; 4;
6 – 2; 3; 4;	7 – 2; 3; 4;	8 – 2; 3; 4;	9 – 2; 3; 4;	10 – 2; 3; 4;	11 – 2; 3; 4;	12 – 2; 3; 4;
13 – 2; 3; 4;	14 – 2; 3; 4;	15 – 2; 3; 4;	16 – 2; 3; 4;	17 – 2; 3; 4;	18 – 2; 3; 4;	19 – 3; 4;
20 – 3; 4;	21 – 3; 4;	22 – 4;	23 – 4;	24 – 4;	25 – 4;	26 – 4;
27 – 5;	28 – 5;	29 – 5;	30 – 5;	31 – 5;		
November 2019 phases: 2; 3; 5; 6; 7.						
					1 – 5;	2 – 5;
3 – 5;	4 – 5;	5 – 5;	6 – 5; 6;	7 – 5; 6;	8 – 5; 6;	9 – 6;
10 – 6;	11 – 6;	12 – 6;	13 – 6;	14 – 6;	15 – 2; 6;	16 – 2; 3; 6;
17 – 2; 3; 6;	18 – 2; 3; 6;	19 – 2; 3; 6;	20 – 2; 3; 6;	21 – 6;	22 – 6;	23 – 6;
24 – 6;	25 – 6;	26 – 6;	27 – 6;	28 – 7;	29 – 7;	30 – 7;
December 2019 phases: 3; 6; 7; 8; 9.						
1 – 7;	2 – 7;	3 – 7;	4 – 7;	5 – 7;	6 – 7;	7 – 7;
8 – 7;	9 – 3; 7;	10 – 3; 7;	11 – 3; 6; 7;	12 – 3; 6; 7;	13 – 3; 6; 7;	14 – 3; 6; 7;
15 – 7;	16 – 8;	17 – 8;	18 – 8;	19 – 8;	20 – 8;	21 – 8;
22 – 8;	23 – 8;	24 – 8;	25 – 8;	26 – 8;	27 – 8; 9;	28 – 8; 9;
29 – 8; 9;	30 – 8; 9;	31 – 8; 9;				

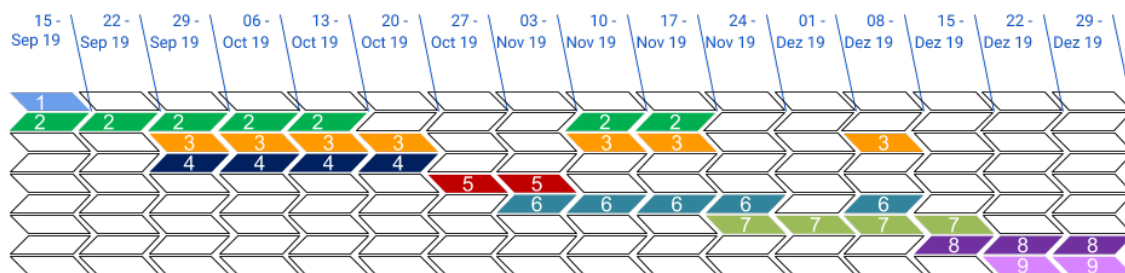


Figure 3.1 Work plan phases by week [15 September – 29 December, 2019]

The initial plan for the second semester aimed at the refinement of the proposed approach and its adoption at CELBI – Celulose da Beira Industrial, SA with the following sequence:

1. [January 2020, duration 2 months] – Development of a web-based solution for assessing industry 4.0 and supporting the transformation process;
2. [March 2020, duration 2 months] – Tests and validation with pilot companies involved with industry 4.0 investments;
3. [May 2020, duration 2 months] – Writing of the thesis and a scientific paper.

The thresholds of success of this dissertation aimed at achieving the following objectives: Online tool for industry 4.0 assessment and guidance; Scientific publication; Final report.

The introduction of the Balanced Scorecard evaluation during the first half of the project did not have an impact in the second semester. The final (executed) work planning was similar to the initial version and proceeded as follows (the number of days summarizes a global involvement in that task, for example, multiple contacts occurred during the project with the case organization, represented as the total number of hours):

1. Conclude the missing elements from the first phase and include the recommendations made by the jury in the intermediate presentation; _ [22 days];
2. Propose the concept of maturity model fragment _ [18 days];
3. Writing of a scientific paper _ [35 days];
4. Contact with manufacturing industry company _ [3 days];
5. Requirements specification, stories and application architecture _ [9 days];
6. First sprint _ [29 days];
7. Second sprint _ [24 days];
8. Third sprint _ [31 days];
9. Validation in a manufacturing industry company _ [1 day];
10. Finish and correct the dissertation document _ [24 days].

Table II – Work plan [January-June, 2020] scheduling.

January 2019 phases: 1; 2; 3; 4.						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1 – 1;	2 – 1;	3 – 1;	4 – 1;
5 – 1;	6 – 1;	7 – 1;	8 – 1;	9 – 1;	10 – 1;	11 – 1;
12 – 1;	13 – 1;	14 – 1;	15 – 1;	16 – 1;	17 – 1;	18 – 1;
19 – 1;	20 – 1; 2;	21 – 1; 2;	22 – 1; 2;	23 – 2;	24 – 2	25 – 2
26 – 2	27 – 2; 3;	28 – 2; 3;	29 – 2; 3;	30 – 2; 3; 4;	31 – 2; 3;	
February 2019 phases: 2; 3; 5.						
						1 – 2; 3;
2 – 2; 3;	3 – 2; 3;	4 – 2; 3;	5 – 2; 3;	6 – 2; 3;	7 – 3;	8 – 3;
9 – 3;	10 – 3;	11 – 3;	12 – 3;	13 – 3;	14 – 3;	15 – 3;
16 – 3;	17 – 3;	18 – 3;	19 – 3;	20 – 3;	21 – 3;	22 – 3;
23 – 3;	24 – 3;	25 – 3;	26 – 3;	27 – 3;	28 – 3;	29 – 5;

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March 2019 phases: 4; 5; 6.						
1 - 5;	2 - 5;	3 - 5;	4 - 5;	5 - 5;	6 - 5;	7 - 5;
8 - 5;	9 - 6;	10 - 6;	11 - 6;	12 - 4; 6;	13 - 6;	14 - 6;
15 - 6;	16 - 6;	17 - 6;	18 - 6;	19 - 6;	20 - 6;	21 - 6;
22 - 6;	23 - 6;	24 - 6;	25 - 6;	26 - 6;	27 - 6;	28 - 6;
29 - 6;	30 - 6;	31 - 6;				
April 2019 phases: 6; 7.						
			1 - 6;	2 - 6;	3 - 6;	4 - 6;
5 - 6;	6 - 6;	7 - 7;	8 - 7;	9 - 7;	10 - 7;	11 - 7;
12 - 7;	13 - 7;	14 - 7;	15 - 7;	16 - 7;	17 - 7;	18 - 7;
19 - 7;	20 - 7;	21 - 7;	22 - 7;	23 - 7;	24 - 7;	25 - 7;
26 - 7;	27 - 7;	28 - 7;	29 - 7;	30 - 7;		
May 2019 phases: 3; 8.						
					1 - 8;	2 - 8;
3 - 8;	4 - 8;	5 - 3; 8;	6 - 8;	7 - 8;	8 - 8;	9 - 8;
10 - 8;	11 - 8;	12 - 8;	13 - 8;	14 - 8;	15 - 8;	16 - 8;
17 - 8;	18 - 8;	19 - 8;	20 - 8;	21 - 8;	22 - 8;	23 - 8;
24 - 8;	25 - 3; 8;	26 - 8;	27 - 8;	28 - 8;	29 - 8;	30 - 8;
31 - 8;						
June 2019 phases: 8; 9; 10.						
	1 - 8;	2 - 9;	3 - 10;	4 - 10;	5 - 10;	6 - 10;
7 - 10;	8 - 10;	9 - 10;	10 - 10;	11 - 10;	12 - 10;	13 - 10;
14 - 10;	15 - 10;	16 - 10;	17 - 10;	18 - 10;	19 - 10;	20 - 10;
21 - 10;	22 - 10;	23 - 10;	24 - 10;	25 - 10;	26	27
28	29	30				

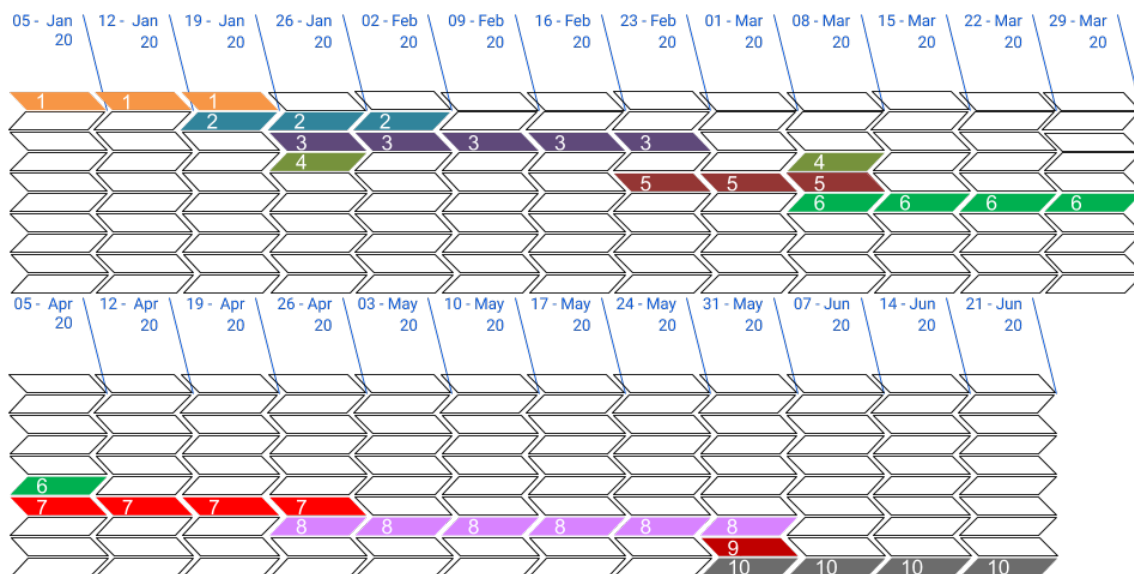


Figure 3.2 Work plan phases by week [05 January – 21 June, 2020]

3.2 Literature Review Process

The literature review was essential for this dissertation because the purpose was to develop a new solution to assess and guide industry 4.0 strategies. It was necessary to evaluate the existing solutions and the gaps found. The review allowed to understand background concepts of digital transformation in industry and identify approaches to assist companies in the assessment and guidance of industry 4.0.

The sources for the review included articles, books, journals, and conference proceedings in the domains of study (specially, information systems). Two main search databases were selected: Google scholar, where it was possible to find a larger set of documents and with different levels of importance and scientific recognition; and Web of Science, returning less results but where the documents are based on more demanding quality criteria. Industry 4.0 is a recent subject joining topics such as the digital transformation, innovative technologies, and redesign business processes, resulting in a growing number of academic researches (Figure 3.3).

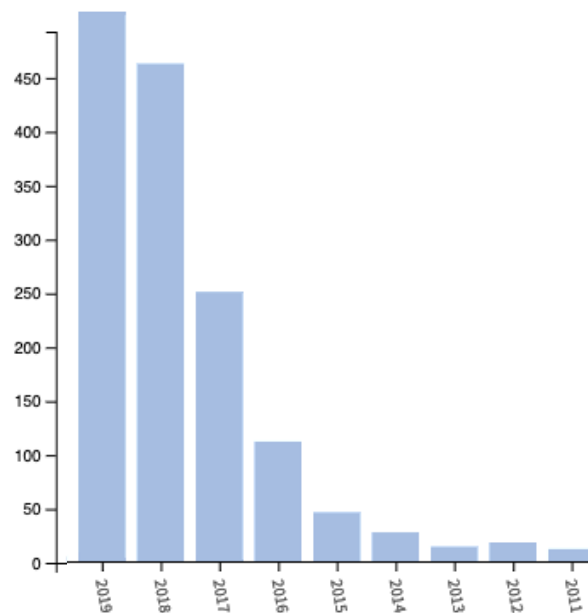


Figure 3.3 Number of "Digital transformation" papers in Web of Science (2019-2011)

The initial search keys used to understand the main concepts of Industry 4.0 and its adoption strategy were:

- *"industry 4.0" AND "state-of-the-art"* (16 700 results in Google Scholar);
- *"industrie 4.0" OR "fourth industrial revolution" AND "strategies"* (31 800 results in Google Scholar) – the concept industry 4.0 usually appears as the fourth industrial revolution and industrie 4.0 (industrie means industry in German);
- *"industry 4.0" AND "maturity model"* (with 1 440 results in google scholar).

The search term *"Digital Maturity"* was also tested during the research process. Figure 3.4 exhibits the interdisciplinary nature of the concept in Web of Science, but the three most relevant areas are clearly computer science, engineering, and business economics.

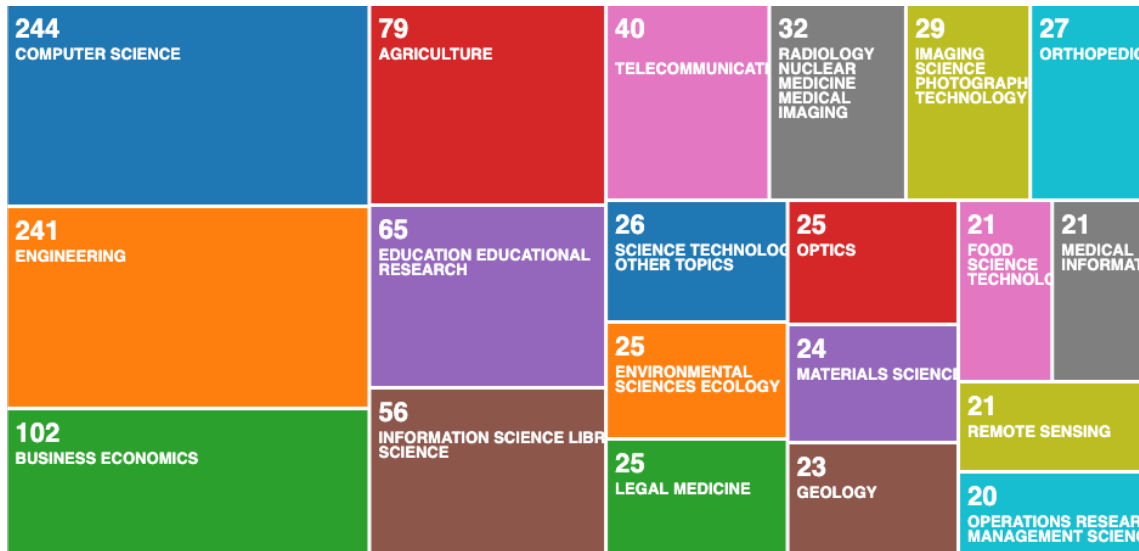


Figure 3.4 “Digital maturity” research areas in Web of Science

In such a wide range of information, was necessary to define the Industry 4.0 thematics of higher interest for the dissertation. This subdivision of the search allowed a better organization, faster access to the documents, and focus on higher importance documentation.

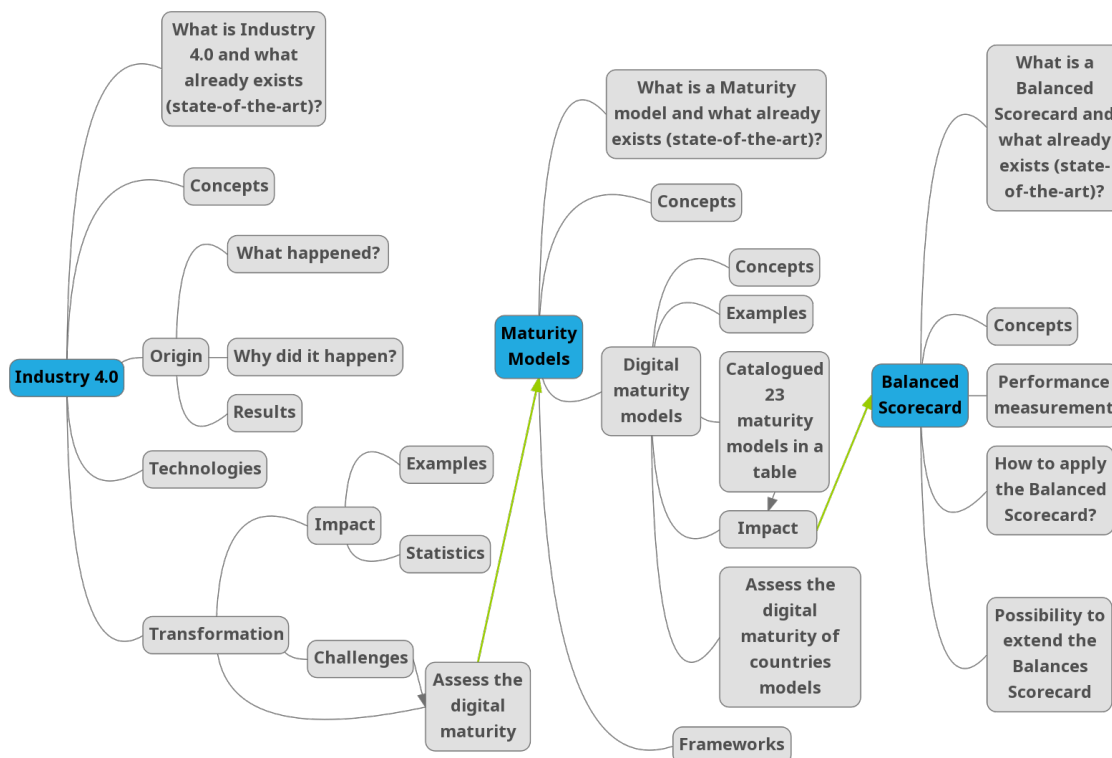


Figure 3.5 Literature review path

Figure 3.5 summarizes the literature review evolution starting from basic industry 4.0 concepts (on the left), the maturity models, and the identification of the Balanced Scorecard as a possible solution to include in the new model. A total of twenty-three maturity models

were tested and classified according to the following characteristics (see Appendix A): (1) list of dimensions; (2) number of sub-dimensions; (3) list of stages; (4) levels of maturity; (5) The Origin; (6) tools to support; (7) how display the data; (8) year.

After the study of maturity models and verify that there were still some missing strategic management topics for the assessment of the companies to Industry 4.0 the research has been reinforced adding to the literature review the Balanced Scorecard. The Balanced Scorecard study was designed to understand the tool and how it could be applied in Industry 4.0 concepts.

3.3 Field Work Presentation

CELBI is an industry company whose primary activity is the production and sell of pulp. The company is one of the world's most efficient producers of eucalyptus pulp being the first in Europe in its industry to receive certification from its Energy Management System following ISO 50001 [9]. It is owned by the Altri group that has several companies framed within the 200 largest national companies. The company is recognized worldwide for the high quality of its product and excellent customer service. Its history dates back to 1962 when the first factory was established. It is listed in the PSI-20, *"a free float market capitalization weighted index that reflects the performance of the maximal 20 most actively traded shares listed on Euronext Lisbon, and is the most widely used indicator of the Portuguese stock market."* [10]. The contact for the project development was the IT manager of CELBI.

The contacts with Altri took place through skype meetings. In the beginning, the objective was to get access to real company data and understand the value of industry 4.0 to them. Multiple artefacts were produced during the data collection tasks. The meetings were also important during the development of the web app. Their feedback was relevant to understand if the proposed model and the application could be useful to the needs of their industry 4.0 adoption. The final meeting included a demonstration of the application with real data to be validated by the IT manager. With an important role to verify the applicability of the project in their challenge to formulate a comprehensive Industry 4.0 strategy that aligns with their major stakeholders' vision.

The fieldwork has taken place in a single industry company, but it is one of the major players in the European paper pulp industry with a long history. The main objective of this process was to understand and answer to some of their challenges in a real case of Industry 4.0 assessment.

3.4 Tool development

A software tool was developed to simplify the adoption of the proposed model in practice, which is the main objective of the dissertation. The case company was essential in this part, offering valuable suggestions, guidance, and real data to understand if the model visualization. The estimations and the project lifecycle are explained as follows.

3.4.1 Estimate Time

Estimate time for software development is a factor to guarantee the success of a project [65]. Estimations enable to organize the work by phases with the requirements defined in the space of time available.

There are 3 different techniques to estimate: analogous, parametric, and definitive [66]. Analogous is also known as top-down and is used when there is still very limited knowledge of the project to measure future activities (a plan and key objectives were already available for this dissertation, therefore, this technique was not selected). The parametric technique is used to estimate the time of the next project based on historical data to calculate (as there is no previous project carried out with similarities, this is not a possible technique). The last is the “definitive”, “often referred to as bottom-up estimating, is a technique in which elements of work are decomposed into smaller components” [66]. This technique proposes to divide and conquer the necessary elements of the project into separate sub-deliverables in development tasks. By making this division, it is possible to make a prediction for smaller elements and consequently improve the accuracy of estimates.

A table was created to apply the bottom-up technique, including the most relevant tasks with the required estimations: best case, most likely case, worst case, and expected case (the table is in Appendix B). Four overall estimations were achieved with this technique [67]:

- Best case: The expected minimum time value;
- Most likely case: The expected time value;
- Worst case: The expected maximum time value;
- Expected case = $([4 * [\text{Most likely case}] + [\text{Worst case}] + [\text{Best case}]) / 6$

Table III – Overall development time estimation.

Tasks	Best Case*	Most Likely Case	Worst Case**	Expected Case
Total	458,13	477	506,87	482,50

* 2% confidence; ** 98% confidence

Estimated time values were essential to define the software development lifecycle and establish a time to develop specific sets of tasks. The work plan was also build based on these values to fit the development of the tool in the remaining project.

3.4.2 Development Lifecycle

This project aimed at the proposal of a new model, therefore, continuous reflection and possible changes were anticipated. Considering the project characteristics, the waterfall lifecycle was discarded due to its lack of flexibility in dynamic environments [68]. It is a project that has a considerable dimension and enough estimated time to divide the project in sprints with the flexibility to establish a pragmatic strategy for the control, tracking and monitoring of the project.

Agile is a process that provides quick and unpredictable responses to the feedback on the development of the application [69]. This approach creates opportunities to reevaluate the direction of the project during the development cycles. Agile methods try to minimize the

risk by developing software in shorter periods, called sprints, which typically spend less than a week to up to four [70]. Each sprint is like a small software project of its own and includes all the tasks required to deploy the small increment of new functionality: planning, requirements analysis, design, coding, testing, and documenting.

There are several agile methodologies [71] that share related ideologies, characteristics and processes. Nonetheless, from the implementation point, each agile has its own specifications, practices, terminology and tactics.

In this dissertation, the development team has a single element, which is also the project manager, influencing the selection of the most suitable methodology. For example, the Kanban framework focuses very much on the direction of the team and that all elements know the state of development and with a list of priorities and categorization stacks but without an evaluation of deadlines and temporal division [71]. Extreme programming agile Framework involves a client that is actively involved with a united team to conduct ongoing planning, testing and rapid feedback to provide frequent work software (this so near client relation doesn't happen in this project situation) [71]. Crystal framework concentrates on people, synergies and skills while working on a group project to adjust them to the work, but this is the development of a project with just one-person [71].

Scrum is a project management framework, from organization to agile development of complex and adaptive products with the highest possible value through various techniques, used since the early 1990s. It is currently used in over 60% of agile projects in Worldwide [69]. As advantages, we can point out that: there is much motivation since programmers want to meet the deadline of each sprint; transparency allows the project to be accompanied by all members of a team; the quality focus is a constant in the scrum method, resulting in fewer errors [70]. It also allows rearranging priorities, ensuring that unfinished sprints get more attention. Scrum seemed to be the most suitable methodology to adapt to this project. However, it is important to state that different practices of Scrum were not followed considering the nature of the team and the project (for example, daily meetings), therefore, a Scrum-inspired development was conducted.

For an expected time of 482 hours of development, there will be 3 sprints that comprise the following steps: 1. Requirements; 2. Design + analysis; 3. Development; 4. Tests; 5. Launch. Before starting each sprint, there is a phase of setting goals for the sprint based on requirements. During each sprint to track the development of the code, there will also be implementation reports (they are in the implementation chapter). At the end of the sprint, there will be a sprint review with an incrementing deploy that is tested. During the development period of each sprint, there is the flexibility of deadlines depending on the work to be done. For the project the expected sprints with the requirements initially defined are as follows:

- [29 days] – Creation of the database and his tables; Create the Node.js server and connect it to the database; Sequelize model creation; Start the Node.js Express routing functions.
- [24 days] – Create the React.js web application front-end; Implement the declarative React route; Implement the “Goal” and Balanced Scorecard related requirements; Navigation bar.
- [31 days] – Implement the Maturity Model Fragments related requirements; Apply a JWT in the Node.js server; Implement the MainPage component (main page of the project showing the BSC with the MMF model); Stylize the front-end.

3.5 Risk Management

Risk assessment is crucial to ensure that the project objectives will be successfully achieved. This risk assessment should be applied and re-evaluated throughout the several phases of the project.

Risk management attempts to assist in project success in the process of identification, evaluation, mitigation, and monitoring possible problems. *“One way of defining “risk” is that risk is a problem that has not happened”* [72], in this way we can define previously risks that we can face in the project. Some concepts concerning risk management are [73]:

- Risk factors: What increases the possibility of happening;
- Risk categories: List of risk categories that should be aware when producing the project management;
- Risk assessment: Understand what can happen;
- Risk prioritization: defines the overall risk factor.
- Risk impact severity: (0-1) Negligible; (1-2) Minor; (2-3) Moderate; (3-4) Serious; (4-5) Critical;
- Risk probability: (0.00-0.10) Remote; (0.10-0.40) Unlikely; (0.40-0.60) Likely; (0.60-0.90) Highly likely; (0.90-1.00) Near certainty;
- Risk control and resolution: How to mitigate it.

To manage risks, it is necessary to reflect on dependencies and external elements that can affect the success of the project. These risks are in the following tables described and showing the probability, impact values, date on which it was identified and what the mitigation and monitoring process is. The following tables describe the most relevant risks found and the mitigation tactics.

Table IV – Risk01 Lack of documentation.

Lack of documentation	
ID:	Risk01
Data of identification	September
Description	The project needs a substantial literature review. Digital transformation has a lot of supporting documentation, but for more specific elements may lack previous research (because a new model is expected to be created and tested).
Impact	Moderate
Probability	Remote
Control and resolution	Use different search tools (google scholar, Web of Science) and different media (online documentation, magazines, books). Support the model proposal with previous studies and feedback from a real case.

Table V – Risk02 Access restriction to documentation.

Access restriction to documentation	
ID:	Risk02
Data of identification	October
Description	Important documentation for specific topics of the dissertation can have restricted access.
Impact	Negligible
Probability	Unlikely
Control and resolution	Send an email explaining the situation to the authors of the document to see if it is possible to have access. Ask the advisors if they have any special access to the document.

Table VI – Risk03 Availability from the organizations.

Availability of the organizations	
ID:	Risk03
Data of identification	November
Description	Companies are interested in collaborating, but they may have overwork at critical moments for research and take a long time to reply
Impact	Serious
Probability	Likely
Control and resolution	Select a case company that is committed in participating in the entire phases of the project. Search for different forms of communication and send with some time in advance the necessary information

Chapter 3

Table VII – Risk04 Requirements modification.

Requirements modifications	
ID:	Risk04
Data of identification	January
Description	The software development lifecycle used is Agile that has sprints. There is the possibility of a major reformulation in the middle of the development of the requirements either by the advisors or by case company.
Impact	Moderate
Probability	Unlikely
Control and resolution	Develop a requirements document for approval at the beginning of the project, including the model that merges Balanced Scorecard and Maturity Models.

Table VIII – Risk05 NPM packages failure.

NPM packages failure	
ID:	Risk05
Data of identification	January
Description	Implement in the application an NPM package that at a later stage of the project development shows problems.
Impact	Serious
Probability	Remote
Control and resolution	Use the fewest packages possible and study them previously.

A risk assessment matrix is a tool that gives a semi-quantitative risk evaluation value [73]. The tool comprises a table that displays two axes. Vertically refers to the impact of the risk and horizontally refers to the probability of this occurring. Table IX shows the Risk assessment matrix of the project where there is no risk with severity and probability highly dangerous for the Project. The ones that have a higher risk are the availability of the organizations and NPM packages failure.

Table IX – Risk assessment matrix.

Critical					
Serious	Risk05		Risk03		
Moderate	Risk01	Risk04			
Minor					
Negligible		Risk02			
Origin	Remote	Unlikely	Likely	Highly likely	Near certainty

This section presented the most important aspects of the methodology. First, a review of relevant literature was conducted to understand the problem of assessing (initial phase where the organization needs to measure its current state) and guiding (after assessing its current circumstance, investments need be taken in new technologies and digital developments, affecting the entire business) industry 4.0. Second, the proposal of an innovative solution to assist industry 4.0 strategies. Finally, testing that model in a real case, using a web application to simplify the process.

Chapter 4

Model Proposal (BSC-MM): Assessing and Guiding Industry 4.0 strategies

This chapter presents the proposed model (named BSC-MM) that seeks to (1) assess and (2) steer companies in Industry 4.0 adoption. The model emerges from contacts with the case company and the literature review in two particular areas: (1) Maturity Models as a form of assessing the digital maturity of a company and (2) Balanced Scorecard as a strategic mapping tool. The Chapter describes the adaptations made to both concepts and its advantage for the dual purpose of evaluating current state of transformation and helping companies over time, since industry 4.0 is a long-term strategic development.

The literature review allowed to identify problems in existing maturity models to support the pace of digital transformation challenges [74]. Different studies point to limitations in existing maturity models such as (1) starting circumstances for Industry 4.0 that do not fit the existing models (very initial stages of development) (2) *“disconnection between maturity models and self-assessment readiness tools”*, and (3) failure to provide tailored support to *“the next step after the maturity and readiness assessment”* [48].

Initial discussions with the case company IT manager confirmed the misfit between generic tools to assess Industry 4.0 maturity (digital maturity models) and their business needs for investing in new technologies. For example, the model could be used to assess their current state, but its utility cease (limited to the AS-IS situation). Moreover, there are multiple maturity models available but not all parts of the maturity models are useful to the company strategy (for example, many models mix several technologies that are not a priority for the case company).

It was clear that a better artefact to assist in crafting Industry 4.0 strategies was needed. To ensure that answer, were sought contributions from maturity models [48], [74] and strategic management [75].

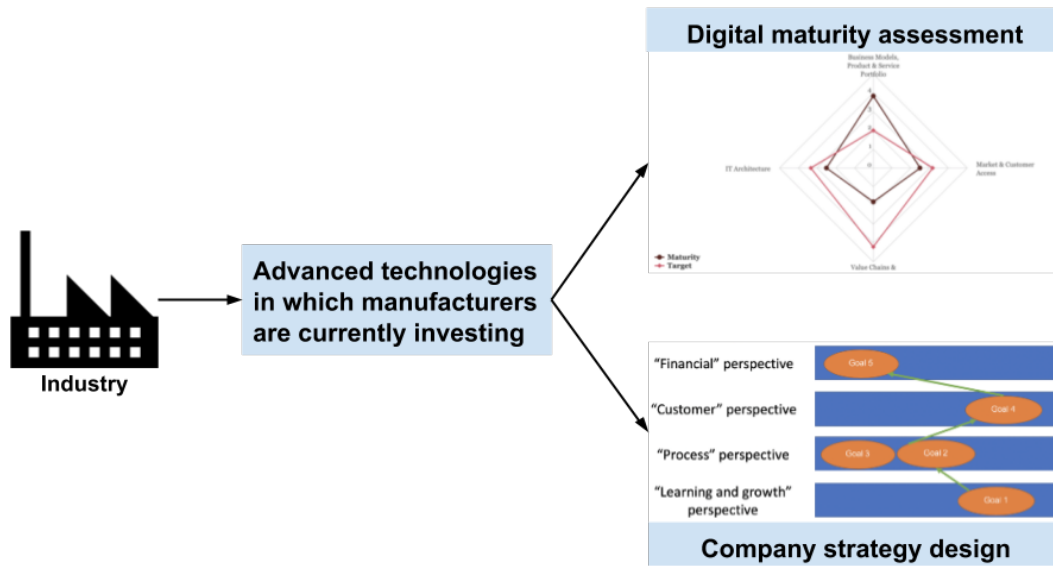


Figure 4.1 The challenge to assess and guide Industry 4.0

According to the IT manager of the case company “we have lots of ideas and potential pilot projects (...) that is important and making experiments can generate valuable knowledge about Industry 4.0 (...) but the ‘part’ that is missing is the creation of our own vision for Industry 4.0, which is much more difficult than importing consultants proposals or trials”.

Figure 4.2 shows the steps that led to the final artefact.

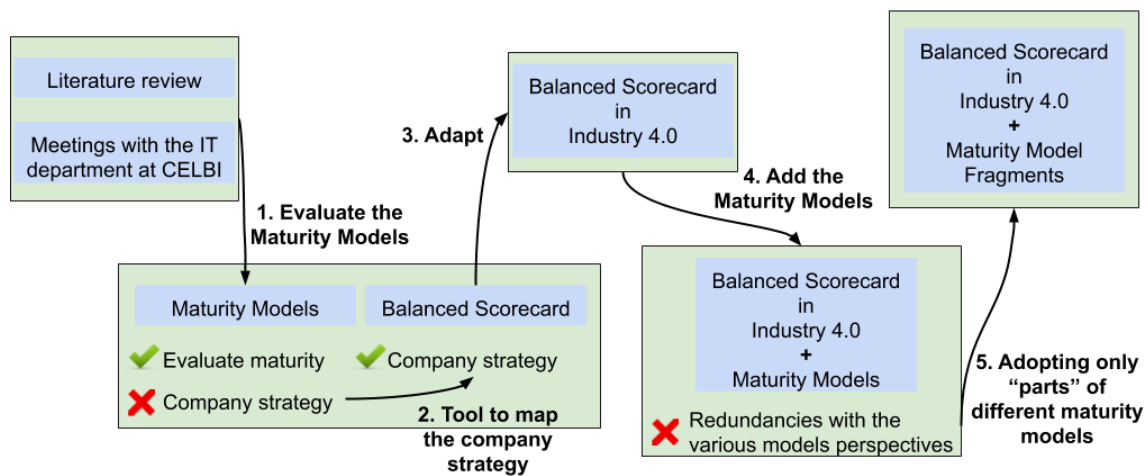


Figure 4.2 artefact development path

The organization was familiar with the use of the Balanced Scorecard tool, so has been made an exploration process of how could it be adapted to better support Industry 4.0 strategies.

The first attempts aimed to incorporate Industry 4.0-specific goals and measures in the four standard perspectives of the BSC. For example: including “Implement IoT in approx. 5000 engines to reduce plant maintenance cost”, in the process perspective, with a connection to “Control variable costs” in the financial perspective. This approach, however, made it difficult to extract the aspects related to Industry 4.0 investments.

The next step investigated the addition of a dedicated Industry 4.0 perspective. This enabled better management of Industry 4.0 goals (in a separate perspective – extending the

traditional Balanced Scorecard), while links to other previously existing perspectives. For example, the Industry 4.0 dimension concentrates all the goals that are supported by technology systems (e.g. robotics, sensing technologies) and can be linked in the strategic map with other goals from the four traditional perspectives.

The separate Balanced Scorecard perspective was interesting but still insufficient. Was claimed that it enabled the Industry 4.0 goals to be elevated to a shared organizational concern, leading to a better understanding of its impact on other goals. However, this modified Balanced Scorecard still lacked in maturity assessment and guidance for concrete initiatives. Figure 4.3 presents examples of the initial models aiming to integrate the BSC for industry 4.0 and maturity.



Figure 4.3 Historical perspective of the artefact development (part 1)

The Figure 4.3 presents (1) the first attempt to extend the BSC with a new Industry 4.0 perspective, (2) later improved to the side dimension because industry 4.0 is transversal to all the other perspectives.



Figure 4.4 Historical perspective of the artefact development (part 2)

Figure 4.4 represents the integration of maturity in each perspective. Although that option seemed possible, it required the creation of a new maturity model to each perspective of the BSC (out of the scope of our research) or selecting a single maturity model for each perspective. Also, the Balanced Scorecard perspectives address significantly different issues, resulting in the adopting of a model with multiple maturity models aligned with the perspectives, which imposes a significant overhead while also potentially introducing redundancies.

Why not adopting only “parts” of different maturity models (which were called fragments) that were deemed relevant for the goals that the company wants to pursue? This approach requires the reflection of industry practitioners about available maturity models and which fragments of which to select to support company goals without endangering model rationale and consistency. Table X to XII show several fragments that can be used from the Industrie 4.0 assessment [76].

Table X – Industrie 4.0 assessment Reply Model part “Strategy & Leadership”.

Strategy & Leadership [76]	(1-5)	
	Actual	Target
The organization has a digital vision to transform because of the new market needs		
Leadership has made an effort to translate the digital vision down to all levels of the organization		
There is a team dedicated to the organization’s digital transformation and change		
There is a business area prioritized for digital investments		
There is a separate budget allocated for adopting digital technologies		

Table XI – Industrie 4.0 assessment Reply Model part “Operations”.

Operations [76]	(1-5)	
	Actual	Target
All production equipment is connected and real time data is available for decision making		
There is one integrated platform which provides complete visibility and can be accessed by multiple users		
It is possible to access all production information remotely		
KPIs are well defined across functions and get updated automatically		
Departments are able to collaborate easily through digital channels		

Table XII – Industrie 4.0 assessment Reply Model part “Customer Experience”.

Customer Experience [76]	(1-5)	
	Actual	Target
The organisation understands how customer demands are changing in the market		
The organisation experiments with multiple digital channels to engage the customers		
Digital technology is used to stay in touch with the customers and to solve their challenges		
Data inputs from customer usage are used continuously for improving solutions and services		

Figure 4.5 presents the final version of the proposed artefact that integrates the BSC and maturity models to manage tailored strategies for Industry 4.0 (called BSC-MM from this point forward). Contrarily to the initial versions presented in Figure 4.4 (each perspective adopted a complete maturity model), the five perspectives may include different fragments to assess the maturity of industry 4.0.

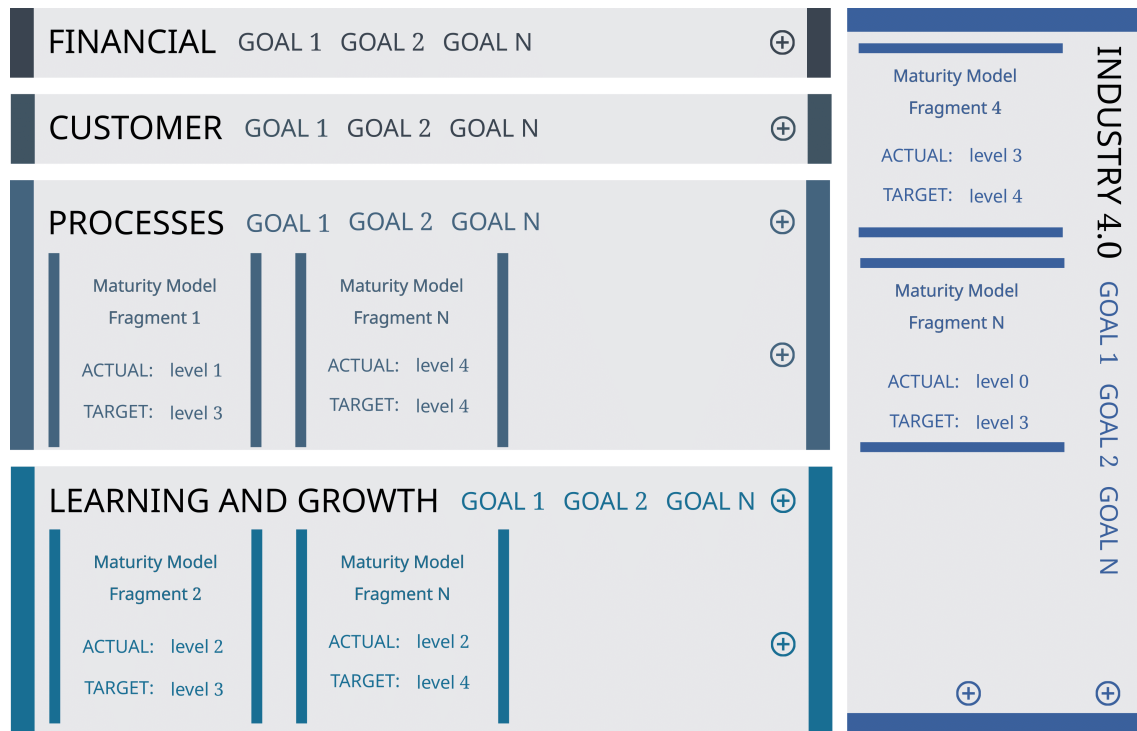


Figure 4.5 BSC-MM: Industry 4.0 navigation (mock-up)

The BSC-MM contains five perspectives for navigating Industry 4.0 strategies, the original four: financial, customer, processes, learning and growth, plus an Industry 4.0 perspective represented vertically on the right of Figure 4.5. Each perspective can have one or more strategic goals defined by the company. Then, linked to each goal, is one or more maturity model fragments that evaluate a particular maturity dimension. For example, vertical integration [77] or leadership [39] are dimensions available in Industry 4.0 maturity models literature that can be selected by the company and will integrate the set of maturity model fragments pertinent to the company strategy.

Each maturity model fragment is characterized by the following elements: (1) identification (the description of what is evaluated and its purpose); (2) related goals (which goals in the BSC-MM can be improved with higher maturity); (3) questions/items (how the measurement is done); (4) maturity level identification (the result of maturity assessment in a specific period).

After reaching a model that potentially could assess maturity (with parts that matter to the company) and point to the future directions of industry 4.0 adoption, measuring its progress over time, the development of a supporting tool was essential. There are several reasons for this development: (1) The proposed model is new. Although extending a popular tool available and well-known to the case company (Balanced Scorecard), it was necessary to include the maturity model fragments (which is also a new concept); (2) Creating a Balanced Scorecard (even with an additional perspective) and then assessing maturity in separate files (e.g. spreadsheets) would be possible but would miss the purpose of an integrated model; (3) A software tool that incorporates the model would be similar to a manual for adopting it – assisting the user with the required information. (4) Finally, the aim is to evaluate industry 4.0 investments over time and the changes that digital transformation allows in all the perspectives (financial, customer, processes, learning). Therefore, a database can simplify the analysis of data and present reports to the top managers.

Table XIII summarizes the synergies obtained in the model development.

Table XIII – Synergies obtained in the model development.

Approach	Advantages for Industry 4.0	Difficulties for Industry 4.0	Synergy
Balanced Scorecard	<ul style="list-style-type: none"> • Future-oriented • Popular tool • Allows measurements over time 	<ul style="list-style-type: none"> • Not developed for digital transformations • Do not include suggestions for actions 	Maturity models assist in the evaluation of current state and ideas for initiatives
Maturity Models	<ul style="list-style-type: none"> • Many proposals available specifically for industry 4.0 • Measure maturity and capacities • Presents ideas for actions (prescriptive) 	<ul style="list-style-type: none"> • Uncommon in companies • The selection of which model to use is problematic • Not all parts of the model are interesting to the company • The company may have other ideas that do not fit in existing models 	The Balanced Scorecard identify the company priorities and only then, the useful parts of models (fragments) are selected by the organization
BSC-MM	<ul style="list-style-type: none"> • Measures the maturity of current state, measure progression over time, and the impact of initiatives (e.g. IT implementations, cloud investments,...) 	<ul style="list-style-type: none"> • New model – only parts are familiar to companies, requiring evaluation and proper training 	Does not discard previous contributions. On the contrary, improves the existing BSC and promotes the selective use of maturity models previously proposed

Chapter 5

Software Requirements Specification and Architecture

This chapter presents the specification guide of the web application requirements, stakeholders contextual design, problem statement, and the needs and constraints for the development tasks. Afterwards, the architecture to be implemented is explained, as well as the quality attributes that will influence its design, and the selected technologies for development.

5.1 Stakeholders with Contextual Design Models

Stakeholders analysis allows the identification of useful interactions in the system. Contextual design models integrate the stakeholders in their organizational environment and help to understand their intentions in the system, preventing system design flaws which would hinder a smooth usage of the system.

The balanced scorecard designed by Kaplan and Norton [8] points to three key categories of stakeholders in its structure, namely, shareholders, customers and employees. The four perspectives would be assigned to its most direct stakeholders, with the financial being associated to shareholders, the customer perspective attributed to customers, internal processes to shareholders and customers and learning and growth perspective to employees. However, the top and intermediate managers are the main responsible for setting and assessing the most appropriate strategy for industry 4.0.

Top managers evaluate the needs of their shareholders, customers, and employees, but also other external entities (e.g. partners, suppliers, or regulatory bodies) and then determine the agreed-on enterprise objectives displayed in the balanced scorecard. The strategic direction of industry 4.0 is then set through prioritization and decision making with control of performance and compliance against established objectives [78]. Strategic governance is a responsibility of the board of directors, under the leadership of the chairperson [79]. IT manager plans, builds, runs and monitors the activities, facing the digital transformation challenges of the company in alignment with the direction set by the governance body, to achieve the enterprise objectives [80]. Therefore, two most critical stakeholders for the web application are identified: the top manager responsible for the governance and the C-level executives. The flow models for these stakeholders are presented in Figure 5.1 and Figure 5.2.

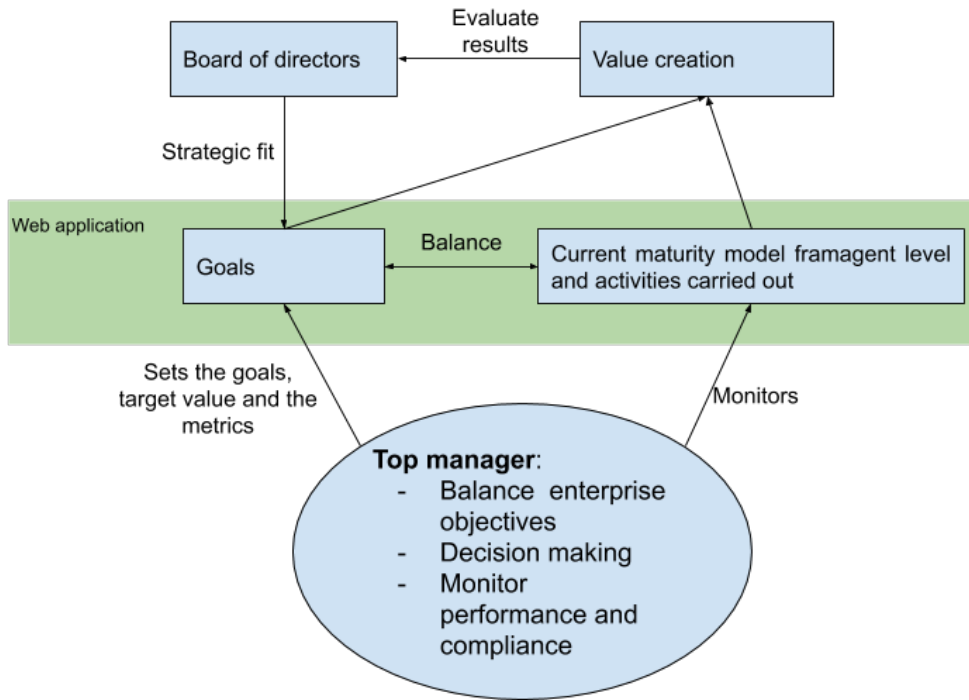


Figure 5.1 Top manager - Flow Model

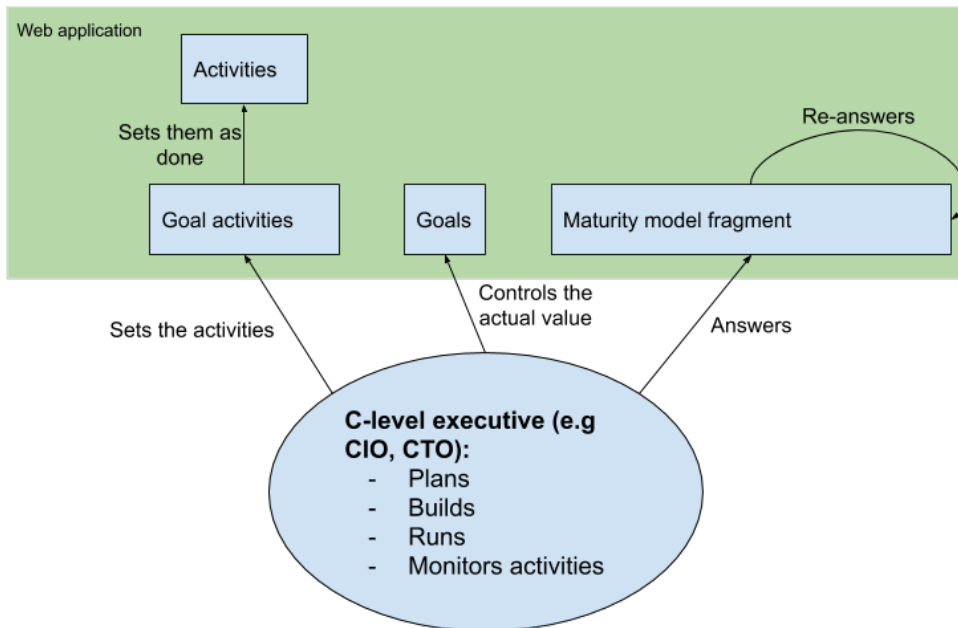


Figure 5.2 C-level executive - Flow Model

Consulting companies are already on their path of Industry 4.0 developing their Industry 4.0 maturity models or frameworks [48] and the main reason is the close contact with chairpersons and managers in the industry 4.0 adoption. The consulting companies are a key content creator stakeholder for the web application, developing the maturity model fragments. They provide theoretical support to the governance challenges and practical knowledge to managers. All the three-stakeholder defined (chairperson, IT manager,

consultant) can have access to the same functionalities of the system. The consultant flow model is presented in Figure 5.3.

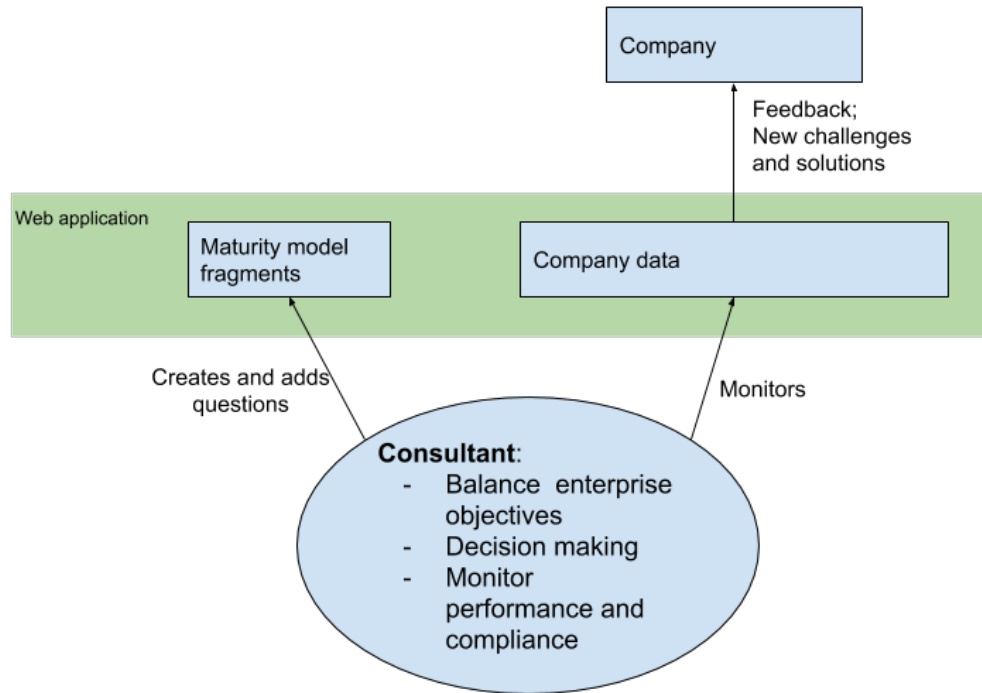


Figure 5.3 Consultant - Flow Model

The identified stakeholders interact with each other, presenting different cultures and job role characteristics, resulting in different cooperation attributes presented in the cultural model [81] (Figure 5.4). The chairperson determine the organization direction [82]. His/her motivation is to add value to the company, guiding managers towards the settings and supporting the company vision. According to D. Ing *et al.* "management effectiveness depends on leaders adequately giving direction, organizing for productivity, handling social issues, and producing results." [82]. The consultant is an external stakeholder that looks for the alignment of the company strategy and the market needs, advising in the definition of the strategic goals and the initiatives towards achieving them.



Figure 5.4 Cultural Model

The three main stakeholders of a system able to assist industry 4.0 adoption were discussed with the case company to validate its selection and analysis. The defined stakeholders have important role in the company digital transformation process. There are other possible stakeholders, for example, the employees to evaluate the indicators of their work/department, however, it was decided that the first version of the web application should focus in the most direct participants in the strategy design.

5.2 Functional Requirements

Functional requirements of the web application represent a function of task or service that the system must perform being described in this chapter as use cases [83]. Each use case is characterized by an ID, an abstraction level, the stakeholders, a priority, a precondition, the main success scenario, one or more extensions, and a post-condition.

As for abstraction levels, these are specified as follows:

- User-goal: Represents the user's primary intention; actions started by the user.
- System: The actions that the system has to perform without the direct intervention of the user.

To indicate priorities, the MoSCoW method [84] is used:

- Must have: Critical requirement for project success;
- Should have: Important requirement, not being critical to the project;
- Could have: Desirable requirement, but unnecessary for the success of the project;

- Won't have: Not critical to project success or not appropriate for now. They will not be included or will be reconsidered later.

Finally, in extensions, the numbering of each item refers to the corresponding item in the main success scenario, in the x.y.z. format. The first number (x) is equal to the number of the main success scenario step to which it applies, and the rest refer to the exception itself (for example, extension 2.1 is the first exception corresponding to item 2. in the main success scenario).

The format chosen to present the use cases is a one-column table style where it is possible to insert the steps of the scenario for each of the use cases in a listed table. Denoting a more aimed to user interface requirements compared to the two-column table and concise and organized within a table compared to RUP Style [83].

To complement each requirement is used a user story. This makes a simple description of the features from the perspective of the user. This text integrates the adapted Scrum software development lifecycle as a popular form of product backlog items.

Table XIV – Use Case Login + user story.

ID:	1
Title:	Login
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	Access the web application
Main success scenario:	1. The user inserts his/her credential in the appropriate fields; 2. The user selects "Login"; 3. The system authenticates the user; 4. Redirects to Main Page.
Extensions:	3.a Invalid login data: 1) The system verifies the credentials don't match; 2) The system displays a login error alert; 3) The system redirects the user to the Login Page. 3.b Servers are down: 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the login page.
Post-condition success:	The user is logged
Stories:	As a non-logged user, I want to log in. I am in the login page, I fill the form with the correct credentials, I press the login button and I will be logged in. After a correct login, I will be redirected to the main page where is the structure of the balanced scorecard with the perspective Industry 4.0 and the selected maturity model fragments.

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Table XV – Use Case Logout + user story.

ID:	2
Title:	Logout
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	The user is logged in
Main success scenario:	1. Press the hamburger-icon button that will open a left navigation bar; 2. Select the option "Logout"; 3. Redirects to Login Page.
Extensions:	(No existing extensions)
Post-condition success:	The user is logged out
Stories: As a logged user, I want to logout. I can be at any page of the application, I press the hamburger-icon and it opens the navigation bar, then press the logout button and I will be logged out. After the logout, I will be redirected to the login page.	

Table XVI – Use Case Add goal + user story.

ID:	3
Title:	Add goal
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	1. Access the web application; 2. User must be logged in.
Main success scenario:	1. In the selected perspective to add a goal, the user selects the button "[perspective] +" on the left corner; 2. The user selects the option "Goal"; 3. Opens a new page on the browser where the user has to fill a form: (1) the goal title; 4. The user has to press "Register Goal" submitting the new goal. 5. The system saves the new goal. 6. The system redirects the user to Goal Data Page;
Extensions:	3.a Servers are down: 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the main page.

Post-condition success:	Goal created and stored in the database The goal with the title appears in the main page in the perspective layer selected
Stories: As a logged user, I want to add a new financial perspective goal. In the main page, I press the button " <i>Financial +</i> " and then appears a dropdown where I select the option " <i>add goal</i> ". Then I am redirected to the add goal page where I fill the form with the title of the goal I want to create and then I press " <i>Register Goal</i> " button. After adding the goal, I will be redirected to the main page where I can see the created goal in the perspective financial of the balanced scorecard.	

Table XVII – Use Case List goals + user story.

ID:	4
Title:	List goals
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User must be logged in
Main success scenario:	1. Press the hamburger-icon button that will open a left navigation bar; 2. Select the option " <i>List answered Goals</i> "; 3. The system gets all registered goals and lists them;
Extensions:	3.a If there are no registered goals: 1) Will appear a message saying " <i>No registered Goals</i> " 3.b Servers are down: 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the main page.
Post-condition success:	A list with all the registered goals with their title appears
Stories: As a logged user, I want to list the created goals. In the main page, I press the hamburger-icon button in the top left corner and then appears a navigation bar where I select the option " <i>List answered goals</i> ". Then I am redirected a page listing all the created goals.	

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Table XVIII – Use Case View goal details + user story.

ID:	5
Title:	View goal details
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User must be logged in
Main success scenario:	1. The user selects a goal pressing his title; 2. The system redirects to the Goal Data Page; 3 The system gets all data of the goal and lists it;
Extensions:	3.a Servers are down: 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the main page.
Post-condition:	The system displays the goal data, his metrics, activities and connections
Stories: As a logged user, I want to access to a created goal data. I have two options: (1) in the list goals page (requirement ID 4) I select the goal; (2) in the main page I press the title of the goal I want to access. After that, I am redirected to the goal data page.	

Table XIX – Use Case Remove goal + user story.

ID:	6
Title:	Remove goal
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User accessed the Goal Data Page
Main success scenario:	1. The user clicks in "Remove" on the bottom of the Goal Data Page; 2. The system removes the goal; 3. Redirects to Main Page.
Extensions:	2.a Servers are down: 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the main page. 3.a Servers are down: 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the main page.

Post-condition success:	Goal removed
Stories: As a logged user and after having already created at least a goal, I want to remove the goal. I access the goal (requirement ID5), next I select the option "Remove". Then I am redirected to the Main Page where I can see that the goal has been removed.	

Table XX – Use Case Edit goal data + user story.

ID:	7
Title:	Edit goal data
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User accessed the Goal Data Page
Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in "Edit"; 2. The system creates a form with an input box and a select box under each of the details with the actual data; 3. The user makes the changes in the form; 4. The user selects "SubmitEdit"; 5. The system saves the edited goal; 6. The data refresh and the user sees new data in the goal.
Extensions:	2.a Servers are down: <ol style="list-style-type: none"> 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page.
Post-condition success:	Goal updated
Stories: As a logged user and after having already created at least a goal, I want to edit the goal data. I access the goal (requirement ID5), next I select the option "edit". Then appears a form where I can edit the data and after that, I press the button "SubmitEdit". In the end, the goal data updates with the newly inserted one.	

Table XXI – Use Case Add metric to goal + user story.

ID:	8
Title:	Add metric to a goal
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant

Priority:	Must have
Pre-conditions:	User accessed the Goal Data Page
Main success scenario:	<ol style="list-style-type: none"> 1. The user fills the form inside the goal with the title "Metrics": (1) Metric title; (2) Description; (3) Actual Value; (4) Target Value. 2. The user clicks "Register Metric" submitting the new metric; 3. The system saves the new metric.
Extensions:	<ol style="list-style-type: none"> 1.a Incorrect data input: <ol style="list-style-type: none"> 1) The system verifies the type input don't match; 2) The system displays input type error alert; 3.a Servers are down: <ol style="list-style-type: none"> 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Goal Data Page.
Post-condition success:	Metric created and stored in the database
<p>Stories: As a logged user and after having already created at least a goal, I want to add a metric to a goal. I access the goal (requirement ID5), next I fill the add metric form and press the button "Register Metric". Then the goal data page is refreshed and I see the created metric.</p>	

Table XXII – Use Case Edit metric inside a goal + user story.

ID:	9
Title:	Edit metric inside a goal
Level:	User-goal
Stakeholder:	<ul style="list-style-type: none"> - Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User accessed the Goal Data Page and created a metric
Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in "Edit metric" on the bottom of the metric; 2. The system creates a form with input boxes under each of the details with the actual data; 3. The user makes the changes in the form; 4. The user selects "SubmitEdit"; 5. The system saves the edited metric; 6. The data refresh and the user sees new data in the metric.

Extensions:	<p>3.a Incorrect data input:</p> <ol style="list-style-type: none"> 1) The system verifies the type input don't match; 2) The system displays input type error alert; <p>5.a Servers are down:</p> <ol style="list-style-type: none"> 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Goal Data Page.
Post-condition success:	Metric updated
<p>Stories: As a logged user and after having already created at least a goal and a metric inside, I want to edit the goal metric. I access the goal (requirement ID5), next I select the button "Edit" inside the metric. Then appears a form in the metric where I can edit the data and after that press the button "SubmitEdit". In the end, the data is updated with the newly inserted one.</p>	

Table XXIII – Use Case Remove metric inside a goal + user story.

ID:	10
Title:	Remove metric inside a goal
Level:	User-goal
Stakeholder:	<ul style="list-style-type: none"> - Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User accessed the Goal Data Page and created a metric
Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in "Remove" on the bottom of the metric; 2. The system removes the metric; 3. The metric list refresh without the metric.
Extensions:	<p>2.a Servers are down:</p> <ol style="list-style-type: none"> 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Goal Data Page.
Post-condition success:	Metric removed
<p>Stories: As a logged user and after having already created at least a goal and a metric inside, I want to remove the goal metric. I access the goal (requirement ID5), next I select the button "Remove" inside the metric. Then the Goal Data Page is refreshed and I see that the metric has been removed.</p>	

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Table XXIV – Use Case Add a new activity to a goal + user story.

ID:	11
Title:	Add a new activity to a goal
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Could have
Pre-conditions:	User accessed the Goal Data Page
Main success scenario:	<ol style="list-style-type: none"> 1. The user selects the react-select box inside the goal with the title “Activities”; 2. Inserts the title of new activity; 3. The user selects “Create [title of the activity]” 4. The user clicks “Register Activities” submitting the new activity; 5. The system saves the new activity.
Extensions:	<ol style="list-style-type: none"> 3.a Already existing activity in the select-box: <ol style="list-style-type: none"> 1) Use case (ID: 9). 4.a Servers are down: <ol style="list-style-type: none"> 1) The system can’t connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Goal Data Page.
Post-condition success:	Activity created and stored in the database Activity stored in the database linking to the goal
<p>Stories: As a logged user and after having already created at least a goal, I want to add an activity to a goal. I access the goal (requirement ID5), next I select the add activity react-select box and write the new activity. Then will drop the option (because the option is new) will appear “create... [new option]” that I press. Then I press “Register Activity” button. in the end, the Goal Data Page is refreshed and I see the created activity.</p>	

Table XXV – Use Case Add an existing activity to goal + user story.

ID:	12
Title:	Add an existing activity to goal
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Could have
Pre-conditions:	User accessed the Goal Data Page

Main success scenario:	<ol style="list-style-type: none"> 1. The user selects the react-select box inside the goal with the title “Activities”; 2. Inserts the title of the activity; 3. The user selects the existing option; 4. The user clicks “Register Activities” submitting the new activity; 5. The system saves the new activity.
Extensions:	<ol style="list-style-type: none"> 3.a Not existing activity in the select-box: <ol style="list-style-type: none"> 1) Use case (ID: 8). 4.a Servers are down: <ol style="list-style-type: none"> 1) The system can’t connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Goal Data Page.
Post-condition success:	Activity stored in the database linking to the goal
<p>Stories: As a logged user and after having already created at least a goal, I want to add an activity to a goal. I access the goal (requirement ID5), next I select the add activity react-select box and write the new activity. Then will drop the option of the react-select box (because the option has already been created and used in another goal) and I select the one that I want to add. Then I press “Register Activity” button. in the end, the Goal Data Page is refreshed and I see the created activity.</p>	

Table XXVI – Use Case Set activity as done + user story.

ID:	13
Title:	Set activity as done
Level:	User-goal
Stakeholder:	<ul style="list-style-type: none"> - Top manager - C-level executives - Consultant
Priority:	Could have
Pre-conditions:	User accessed the Goal Data Page and linked an activity
Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in “Done” on the bottom of the activity; 2. The system updates the activity to “done”; 3. The activity list refreshes without the metric.
Extensions:	<ol style="list-style-type: none"> 2.a Servers are down: <ol style="list-style-type: none"> 1) The system can’t connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Goal Data Page.
Post-condition success:	Activity update to done
<p>Stories: As a logged user and after having already created at least a goal and an activity inside, I want to remove the goal activity. I access the goal (requirement ID5), next I select the button “Done” inside the activity. Then the Goal Data Page is refreshed and I see that the created activity is already not there.</p>	

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Table XXVII – Use Case Add a connection between goals + user story.

ID:	14
Title:	Add a connection between goals
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User accessed the Goal Data Page
Main success scenario:	<ol style="list-style-type: none"> 1. The user fills the form inside the goal with the title "Connections": (1 select-box) Goal; (2 select-box) Type; 2. The user clicks "Register Connection" submitting the new connection; 3. The system saves the new connection.
Extensions:	<ol style="list-style-type: none"> 1.a There no other goals: <ol style="list-style-type: none"> 1) Don't appear de option to add a connection 3.a Servers are down: <ol style="list-style-type: none"> 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Goal Data Page.
Post-condition success:	Connection created and stored in the database
<p>Stories: As a logged user and after having already created at least a goal, I want to add a connection to a goal. I access the goal (requirement ID5), next I define the type of connection in the first connection select-box and the second goal I want to connect in the second connection select-box. Then I press "Register Connection" button. In the end, the Goal Data Page is refreshed and I see the created connection.</p>	

Table XV – Use Case Remove a connection + user story.

ID:	15
Title:	Remove a connection
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User accessed the goal data and created a connection
Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in "Remove" on the bottom of the connection; 2. The system removes the connection; 3. The connection list refreshes without the connection.

Extensions:	2.a Servers are down: 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Goal Data Page.
Post-condition success:	Connection removed
Stories:	As a logged user and having already created at least a goal and a connection inside, I want to remove the goal connection. I access the goal (requirement ID5), next I select the button "Remove" inside the connection. Then the Goal Data Page is refreshed I see that the created connection has already been removed.

Table XXVIII – Use Case Register new maturity model fragment + user story.

ID:	16
Title:	Register new maturity model fragment
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User must be logged in
Main success scenario:	1. Press the hamburger-icon button that will open a left navigation bar; 2. Select the option "Register new Maturity Model Fragment"; 3. Opens a new page on the browser where the user has to fill a form: (1) Maturity model fragment title; (2) Description; (3) Minimum value for ser; (4) Maximum value for set; (5 check-box) Public; (6 select-box) Perspective; 4. The user has to press "Register maturity model fragment" submitting the new maturity model fragment. 5. The system saves the new maturity model fragment. 6. The system redirects the user to the Main Page;
Extensions:	3.a Incorrect data input: 1) The system verifies the type input don't match; 2) The system displays input type error alert; 5.a Servers are down: 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page.
Post-condition success:	Maturity model fragment created and stored in the database

Stories: As a logged user, I want to register a new maturity model fragment. I press the button hamburger-icon in the top left corner and then appears a navigation bar where I select the option *“Register maturity model fragment”*. Then I am redirected to the Add Maturity Model Fragment Page where I fill the form and press the *“Register maturity model fragment”* button. After register the maturity model fragment I will be redirected to the Maturity Model Fragment Data Page.

Table XXIX – Use Case List maturity model fragments + user story.

ID:	17
Title:	List maturity model fragments
Level:	User-goal
Stakeholder:	<ul style="list-style-type: none"> - Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User must be logged in
Main success scenario:	<ol style="list-style-type: none"> 1. Press the hamburger-icon button that will open a left navigation bar; 2. Select the option <i>“List Maturity Model Fragments”</i>; 3. The system gets all user private maturity model fragments or all public ones; 4. Appears a list with all the get maturity model fragments
Extensions:	<ol style="list-style-type: none"> 3.a If there are no registered maturity model fragments: <ol style="list-style-type: none"> 1) Will appear a message saying <i>“No registered maturity model fragments available”</i> 3.b Servers are down: <ol style="list-style-type: none"> 1) The system can’t connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page.
Post-condition success:	A list with all the registered maturity model fragments with their title, description and perspective appears
<p>Stories: As a logged user, I want a list of maturity model fragments. In the Main Page, I press the button hamburger-icon in the top left corner and then appears a navigation bar where I select the option <i>“List maturity model fragments”</i>. Then I am redirected a page listing all the existing maturity model fragments.</p>	

Table XXX – Use Case Search inside list maturity model fragments + user story.

ID:	18
Title:	Search inside maturity model fragments list
Level:	User-goal
Stakeholder:	<ul style="list-style-type: none"> - Top manager - C-level executives - Consultant
Priority:	Could have
Pre-conditions:	<ol style="list-style-type: none"> 1. Access the web application; 2. User must be logged in.
Main success scenario:	<ol style="list-style-type: none"> 1. User has to fill the form on top of the page choosing the search that pretends to do: (1) search by keyword; (2 check-box) perspective; 2. The user has to press “<i>Search Maturity Model Fragment</i>” submitting the search; 3.1 The search with keyword gets all maturity model fragments that have the keyword in the title or description and are user private or public ones; 3.2 The search with perspective gets all maturity model fragments that are from the search perspective and are user private or public ones; 4. Appears a list with all the get maturity model fragments.
Extensions:	<ol style="list-style-type: none"> 3.a If there are no registered maturity model fragments: <ol style="list-style-type: none"> 1) Will appear a message saying “<i>No registered maturity model fragments</i>” 3.b Servers are down: <ol style="list-style-type: none"> 1) The system can’t connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page.
Post-condition success:	A list with all the registered maturity model fragments with their title, description and perspective appears in accordance with the search.
<p>Stories: As a logged user, I want to search in the list of existing maturity model fragments. In page listing all the created maturity models in the top is a search box where I can search by words (in the description of the MMF) of checkboxes to select the maturity model fragments perspectives. In the end, Will be listed the maturity models that match the search.</p>	

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Table XXXI – Use Case View maturity model fragment data + user story.

ID:	19
Title:	View maturity model fragment data
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User accessed the Maturity Model Fragment Data Page
Main success scenario:	1. The user selects a maturity model fragment pressing his title; 2. The system redirects to the Maturity Model Fragment Data Page; 3 The system gets all data of the maturity model fragment and lists it;
Extensions:	3.a Servers are down: 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page.
Post-condition success:	The system displays the maturity model fragment data and his questions.
<p>Stories: As a logged user, I want to access to a created maturity model fragment data. I go to the List of Maturity Model Fragments Page (requirement ID17), next I select the maturity model fragment. In the end, I am redirected to the Maturity Model Fragment Data Page.</p>	

Table XXXII – Use Case Edit maturity model fragment + user story.

ID:	20
Title:	Edit maturity model fragment
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User accessed the Maturity Model Fragment Data Page

Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in <i>"Edit"</i>; 2. The system creates a form with an input box and a select box under each of the details with the actual data; 3. The user makes the changes in the form; 4. The user selects <i>"SubmitEdit"</i>; 5. The system saves the edited maturity model fragment; 6. The data refresh and the user sees new data.
Extensions:	<ol style="list-style-type: none"> 3.a Incorrect data input: <ol style="list-style-type: none"> 1) The system verifies the type input don't match; 2) The system displays input type error alert; 5.a Servers are down: <ol style="list-style-type: none"> 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page.
Post-condition success:	Maturity model fragment updated
<p>Stories: As a logged user and after having already created at least a maturity model fragment, I want to edit the maturity model fragment data. I access the MMF (requirement ID19), next I select the option <i>"edit"</i>. Then appears a form where I can edit the data and after press the button <i>"SubmitEdit"</i>. In the end, the data is updated with the newly inserted one.</p>	

Table XXXIII – Use Case Add a question to a maturity model fragment + user story.

ID:	21
Title:	Add a question to a maturity model fragment
Level:	User-goal
Stakeholder:	<ul style="list-style-type: none"> - Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User accessed the Maturity Model Fragment Data Page
Main success scenario:	<ol style="list-style-type: none"> 1. The user fills the form inside the goal with the title <i>"Add new Question"</i>: (1) Maturity Model Fragment Question. 2. The user clicks <i>"Register Question"</i> submitting the new question; 3. The system saves the new question.
Extensions:	<ol style="list-style-type: none"> 3.a Servers are down: <ol style="list-style-type: none"> 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page.

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Post-condition success:	Question created and stored in the database
Stories: As a logged user and after having already created at least a maturity model fragment, I want to add a question. I access the maturity model fragment (requirement ID19), next I fill the add question form and press the button “ <i>Register Question</i> ”. Then the Maturity Model Fragment Data Page is refreshed and I see the created question.	

Table XXXIV – Use Case Remove a question inside a maturity model fragment + user story.

ID:	22
Title:	Remove question inside a maturity model fragment
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User accessed the Maturity Model Fragment Data Page and created a question
Main success scenario:	1. The user clicks in “ <i>Remove</i> ” on the bottom of the question; 2. The system removes the question; 3. The questions list refresh without the removed question.
Extensions:	2.a Servers are down: 1) The system can’t connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page.
Post-condition success:	Question removed
Stories: As a logged user and after having already created at least a maturity model fragment and a question inside, I want to remove the maturity model fragment question. I access the MMF (requirement ID17), next I select the button “ <i>remove</i> ” inside the question. Then the Maturity Model Fragment Data Page is refreshed and I see that the created question has been removed.	

Table XXXV – Use Case Answer maturity model fragment + user story.

ID:	23
Title:	Answer maturity model fragment
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User must be logged in

<p>Main success scenario:</p>	<ol style="list-style-type: none"> 1. In the perspective that pretends to add a goal the user selects the button "[perspective] +" on the left corner; 2. The user selects the option "Fragment"; 3. The system gets all user private maturity model fragments or all public ones from the selected perspective; 4. Appears a list with all the get maturity model fragments with a button on the bottom "Fill"; 5. The user clicks on the button "Fill"; 6. Opens a new page on the browser where the user has to fill a form with the maturity model fragment questions: (1) Actual Value; (2) Target Value; 7. The user has to press "Submit Answers" submitting the new goal. 8. The system saves the answer. 9. The system redirects the user to the Main Page;
<p>Extensions:</p>	<ol style="list-style-type: none"> 3.a Servers are down: <ol style="list-style-type: none"> 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page. 6.a Incorrect data input: <ol style="list-style-type: none"> 1) The system verifies the type input don't match; 2) The system displays input type error alert; 8.a Servers are down: <ol style="list-style-type: none"> 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page.
<p>Post-condition success:</p>	<p>Maturity model fragment answer created and stored in the database</p> <p>The answer with the maturity model fragment title appears with the results of the answers for the actual value and target value in the Main Page in the perspective layer selected</p>
<p>Stories: As a logged user, I want to answer a maturity model fragment. In the Main Page, I press the button "Industry 4.0 +" and then appears a dropdown where I select the option "fragment". Then I am redirected to a listing Industry 4.0 perspective Maturity Model Fragments Data Page. Then I select the model I pretend to answer and I am redirected to his answer page. I fill the form with the question and after I press "Submit Answers" button. In the end, I will be redirected to the Maturity Model Fragment Answer Data Page.</p>	

Chapter 5

Table XXXVI – Use Case Access to answered maturity model fragment data + user story.

ID:	24
Title:	Access to answered maturity model fragment data
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User answered a maturity model fragment
Main success scenario:	1. The user selects a maturity model fragment answer pressing his title; 2. The system redirects to the Maturity Model Fragment Answer Page; 3 The system gets all data of the maturity model fragment answer and lists it;
Extensions:	3.a Servers are down: 1) The system can't connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main page.
Post-condition success:	The system displays the goal data, his historic data, a data graph and the maturity model fragment questions
<p>Stories: As a logged user, I want to access to an answered maturity model fragment data. In the Main Page, I press the title of the maturity model fragment with the answer that I want to access. After that, I am redirected to the Maturity Model Fragment Answer Data Page.</p>	

Table XXXVII – Use Case Re-answer maturity model fragment data + user story.

ID:	25
Title:	Re-answer maturity model fragment data
Level:	User-goal
Stakeholder:	- Top manager - C-level executives - Consultant
Priority:	Could have
Pre-conditions:	User accessed the Maturity Model Fragment Answer Page

Main success scenario:	<ol style="list-style-type: none"> 1. The user selects a maturity model fragment answer pressing his title; 2. The system redirects to the Maturity Model Fragment Answer Data Page; 3. The user fills a form with the maturity model fragment questions: (1) Actual Value; (2) Target Value; 7. The user has to press “<i>Submit new Answers</i>” submitting the new answers. 8. The system saves the new answers. 9. The system saves the old answers in historic maturity model fragment. 10. The system refreshes the Maturity Model Fragment Page.
Extensions:	<p>3.a Incorrect data input:</p> <ol style="list-style-type: none"> 1) The system verifies the type input don’t match; 2) The system displays input type error alert; <p>8.a Servers are down:</p> <ol style="list-style-type: none"> 1) The system can’t connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page. <p>9.a Servers are down:</p> <ol style="list-style-type: none"> 1) The system can’t connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page.
Post-condition success:	<p>Maturity model fragment answers updated</p> <p>Maturity model fragment answer historic created and stored in the database</p>
<p>Stories: As a logged user and after having already answered a maturity model fragment, I want to re-answer new values. I access the Maturity Model Fragment Answer Data Page (requirement ID24) and then I fill the re-answer form and press the button “<i>Submit new Answers</i>”. In the end, the Maturity Model Fragment Answer Data Page is refreshed and I see the new maturity model fragment level in the data and the old level in the historic list.</p>	

Table XXXVIII – Use Case Remove history maturity model fragment + user story.

ID:	26
Title:	Remove history answered maturity model fragment
Level:	User-goal
Stakeholder:	<ul style="list-style-type: none"> - Top manager - C-level executives - Consultant
Priority:	Must have

Pre-conditions:	User accessed the Maturity Model Fragment Answer Page
Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in “Remove” on the bottom of the maturity model fragment answer data; 2. The system removes the maturity model fragment answer historic; 3. The system removes the maturity model fragment answer; 4. Redirects to Main Page.
Extensions:	<p>2.a Servers are down:</p> <ol style="list-style-type: none"> 1) The system can’t connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page. <p>3.a Servers are down:</p> <ol style="list-style-type: none"> 1) The system can’t connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page.
Post-condition success:	<p>Maturity model fragment answer historic removed</p> <p>Maturity model fragment answer removed</p>
<p>Stories: As a logged user and after having already answered a maturity model fragment and re-answered it, I want to remove a historic level. I access the Maturity Model Fragment Answer Data Page (requirement ID24), next I select the button “Remove” inside the historic answered values. Then the Maturity Model Fragment Answer Data Page is refreshed and I see that the selected historic values have been removed.</p>	

Table XXXIX – Access profile information + user story.

ID:	27
Title:	Access profile data
Level:	User-goal
Stakeholder:	<ul style="list-style-type: none"> - Top manager - C-level executives - Consultant
Priority:	Must have
Pre-conditions:	User must be logged in
Main success scenario:	<ol style="list-style-type: none"> 1. Press the hamburger-icon button that will open a left navigation bar; 2. Select the option “User profile”; 3. Opens a new page on the browser where the user has his personal data (id; first name; last name; email).
Extensions:	<p>3.a Servers are down:</p> <ol style="list-style-type: none"> 1) The system can’t connect with the backend servers; 2) The system displays an error message; 3) The system redirects to the Main Page.

Post-condition success:	Profile data showed
Stories: As a logged user, I want to access my data. In the Main page, I press the button hamburger-icon in the top left corner and then appears a navigation bar where I select the option "User profile". Then I am redirected a page listing all my data in the system.	

The different use cases presented above can be summarized in the following diagram, as well as their access hierarchy.

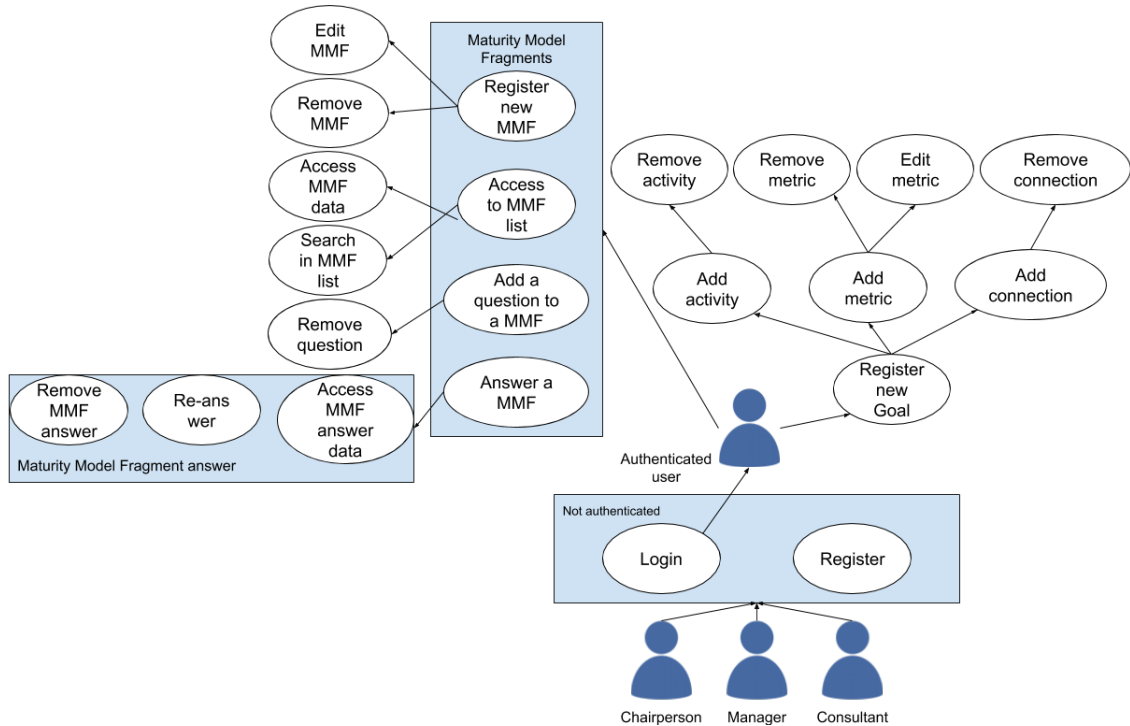


Figure 5.5 Use Case Diagram

5.3 Non-functional Requirements

The non-functional requirements aim to capture and describe general properties about the system, required for the application, and consolidated with quality attributes that will validate them [85]. Usability, data integrity, and security and privacy policies are introduced in this section.

5.3.1 Usability

A functional and usable interface is essential for user interaction. The approach to guarantee a usable interface consists in minimizing the number of menus and options, having simple objects that represent the actions. Since the human error factor can be a threat to the system, it is important to anticipate the multiple ways in which a user can make errors when interacting with the platform. Information about the user actions is crucial for the quality of the feedback to guarantee that the user understands the error and prevent future occurrences.

Examples of usability characteristics include: Use of a navigation bar; Warning alert at the time of wrong information inputs; Select-boxes that makes the selection process faster

instead of entering all the information needed; Inputs with labels that allow the user to recognize the elements required to input.

Two selected usability attributes are detailed in the following two tables.

Table XL – Quality attribute: User can access efficiently to menus.

Stimulus source	Authorized user
Stimulus	Access a function of the application
Environment	Runtime
Artefact	System
Response	Support for efficient navigation within a screen
Measure the response	Task time; Gain of user knowledge.

Table XLI – Quality attribute: User can learn with the errors in inputs.

Stimulus source	Authorized user
Stimulus	Input data
Environment	Runtime
Artefact	System
Response	Recognize and correct user error; Display system state.
Measure the response	Number of errors; User satisfaction; Gain of user knowledge.

5.3.2 Data Integrity

The information used and saved in the system belongs to a set of strategic decisions, with direct impact on the company operations. This information is sensitive for the stakeholders so the web application must assure data integrity. All information entries recorded as valid at the interface and back-end level must correctly pass the information between their respective functions with control mechanisms. Companies have to comply with international laws and standards demanding a reliable platform, protecting the integrity of their sensitive data, and operating along internationally acknowledged guidelines.

An important data integrity attribute is detailed in the following table.

Table XLII – Quality attribute: Maturity model answers historic cannot be lost or modified.

Stimulus source	Authorized user.
Stimulus	Submit an input data.
Environment	Normal mode.
Artefact	Thread on http server.
Response	Show data.
Measure the response	Data loss; Ratio of successful operations to total operations

5.3.3 Security and Privacy Policies

The strategic information is private to the company, so its transmission between the servers and the database has to ensure security. Information control and security is a vital attribute in the application to achieve the trust of stakeholders. It requires protection both within the system and also at the level of the authentication process. All the information security should be ensured and the European Union's terms of data protection and privacy applied [86].

Two selected security attributes are detailed in the following two tables.

Table XLIII – Quality attribute Private maturity model fragments can only be accessed by its creator.

Stimulus source	Maturity model fragment creator.
Stimulus	List maturity model fragments.
Environment	Online.
Artefact	Thread on http server.
Response	Show only public repository.
Measure the Response	Extent to which data/services damaged and/or legitimate access denied.

Table XLIV – Quality attribute Goals maturity model fragment answers information can only be accessible to the account user.

Stimulus source	Non-authorized person
Stimulus	Access profile data
Environment	Online
Artefact	HTTP server
Response	Alert "Make the login"
Measure the response	Ratio of successful operations to total operations.

5.4 Architecture and Development Technologies

The system routes on 2 levels: the front-end of contact with the user and the back-end that controls the logic of the application. The front-end allows the user to have graphic and dynamic access to a set of previously designed functions. The back-end will give the valid functional response of connection to the front-end at the same time that contacts with the database storing system information. The architecture with a server between the front-end and backend assure a safer system avoiding attacks like SQL injection and other vulnerabilities, implement front-end and server-side validations.

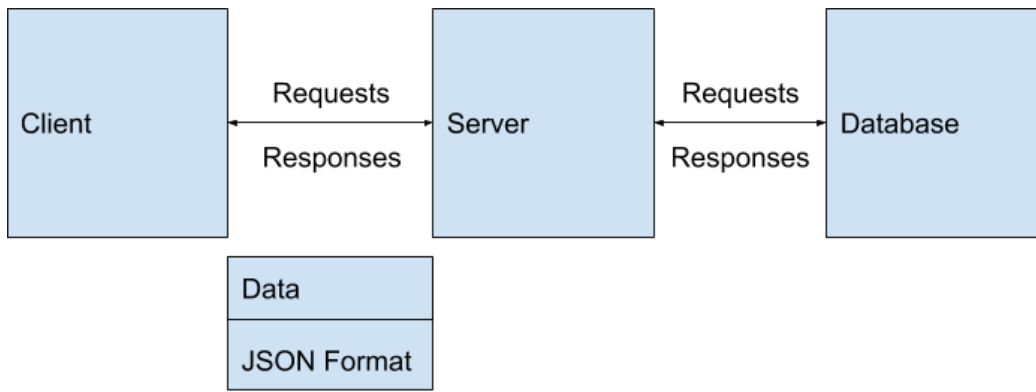


Figure 5.6 Three tiers of the web application architecture

The case company participating in this study did not present specific requirements about the technologies. Therefore, the technology selection was made by the student and then validated by the company.

5.4.1 Client Tier

Client-side development is based in React.js, a browser library which allows developing highly reactive user interfaces [87]. The code is written in JavaScript that executes in the browser which controls what the user sees on the screen and how information change when a button is clicked or when something is registered in an input box. It is about rendering user interface with dynamic data, validating user inputs and communicate with the back-end server. React client sends HTTP requests and retrieves HTTP responses using promise based Axios. React Router is used for control the navigating through URLs and components [88].

React.js is unidirectional data flow (unlike Angular) allowing to have an event by a child component that will affect the parent. After the user interface re-rendering the change of the parent state is reflected in all children, state flows down the components and the events flow up [87]. React.js allows the reuse of components for different system functions with minimum adjustments required since it maintains its property and state. It also has a growing community supporting possible questions and contributing to future evolution of projects in React.js.

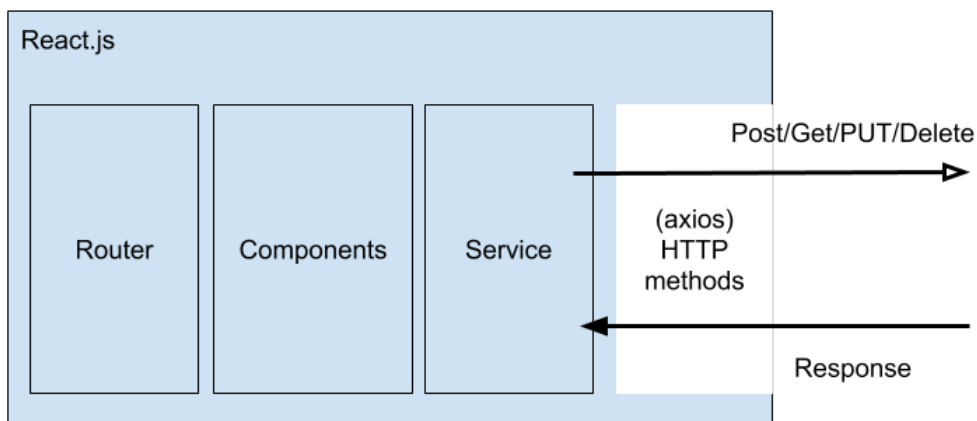


Figure 5.7 Client tier architecture

5.4.2 Business Logic tier and Database Tier

Back-end server development is in Node.js, a JavaScript runtime used to create the server-side. It runs JavaScript out of the browser allowing to conceive a web-server that runs in an internet-connected machine, which accepts requests and sends back responses. Node.js has a package ecosystem able to source modules and get already made packages using Node Package Manager (NPM) an extensive package base [89]. Node.js makes it easier to synchronize the front-end (React.js) and the back-end because both use the same language on the two sides of the application. It is considered scalable and lightweight, using a V8 engine that compiles JavaScript code into machine code instead of using an interpreter that makes it very efficient to real-time application updates [89]. The performance is enhanced by concurrent processing that uses a single thread loop, a no input/output model allows processing for several requests at a time making it highly efficient for answering multiple requests with less CPU usage. But this also brings the problem of CPU bottleneck when there is a heavy computation request: Node.js will set up a block on the other request on the thread causing an overall delay. However, in this application, it will not be a drawback since it does not have a complex computational request (e.g. artificial intelligence algorithms, multiple requests at the same time). It also requires attention to the packages used (some are poorly documented and tested).

Express is a Node.js MVC framework with utility functions to structure and build the application with a set of rules that simplifies writing the server-side code and logic [90]. It is based on Node.js offering the same functionalities; Middleware-based tunnel requests for the functions; has routing and view-rendering. It is easy to customize because it has flexibility. Node.js Express exports REST APIs and communicates with Sequelize ORM to the MySQL database. Sequelize is an object relation map that converts a JavaScript object to a database table transforming JavaScript code to SQL statements without having to build the query.

The database chosen is MySQL presenting top levels of scalability and flexibility with distinct possibilities of hardware to run on them [91]. It is open-source so there is no initial cost for licensing allowing to have support development questions from other users online. Has secure data protection assuring the industry paraments for security. MySQL is easy to maintain, having the possibility of a multiple indexing system. Its high availability allows robust transactional support corresponding to the need to have a system that protects the data integrity.

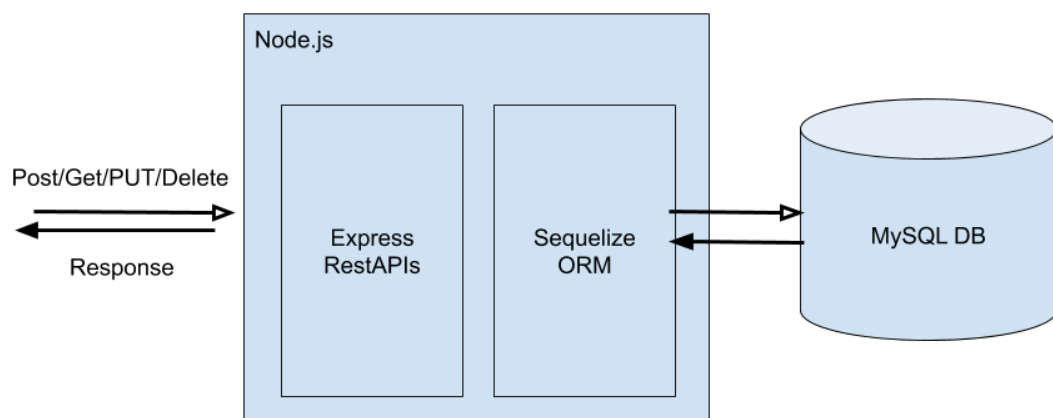


Figure 5.8 Business logic tier and database tier architecture

5.4.3 Heroku Platform as a Service

Heroku is a PAAS (platform as a service) that will host the front-end and back-end of the application [92]. It provides the elements to build, run and scale the application. The core of Heroku is called Dyno: a package that covers a version of the code that the application interacts with. It works like a virtual machine that runs just the application. As the application becomes more used and has more traffic it is possible to scale up horizontally, handling with the number of Dynos [93].

Heroku allows to have the code in GitHub with a live-action functional system online. It is developer-oriented, so the primary way to deploy the Heroku is to get through the version control [93]. This allows to write code locally and, when it is ready to run online, it is expected to push it to Heroku. The application allows immediate feedback and the possibility of deploy it again, with no number of deploys restricted.

Heroku also provides guarantee of integrity and erosion resistance [93]. Heroku also provides a guarantee of integrity and erosion resistance [93]. To package the code and push into Heroku is with the command `git push Heroku master`. That will start by creating the environment the build pack base language where the application runs. Then, compiles into what is called a slug (a compiled version of the application). At that point, adds configurations on add-ons (that is the case of the database services) and bundles all until its release. Those release objects are mutable every time that is a different release or change, it generated newer release so if there is a mistake done is very easy to roll back to a previous version.

ClearDB is the selected addon for MySQL database. It *“uses multi-regional, highly available technology to ensure that your data is not only available when everything works but also when things fail”* [94]. Moreover, it is scalable and provides distinct types of plans that start with a free version. Managed-Cloudant’s big data experts monitor the data twenty-four hours a day assuring the correct control and safety of the operations, which is a non-functional requirement for this project.

Chapter 6

Web Application Implementation

This chapter describes the web application implementation, starting from its main structure. The development logic is introduced, both at front-end and back-end side, as well as the exhibition and explanation of specific parts of code and general organization of the project folders.

This section adopts a tutorial format, assisting the reader in the identification of important elements of the application (e.g. main forms or tables) but also some details of its practical implementation using the selected technologies.

The link for the web application <https://industry-sparks.herokuapp.com/>

6.1 Client-side React.js Implementation

The first step for the development of the React.js application, in the client-side, is to execute the package create-react-app installation (*npm install create-react-app@latest & npm create-react-app client*). This package allows the construction of a standard environment. Using *@latest* in the command assures the installation of the most recent version [95].

The correct organization of project files is an important programming practice in React.js. The client-side code is placed in the directory *"/client/src"*. This location also includes the *app.js* file that makes the route to the components that are in the directory *"/client/src/components"* (all the component files end with the name *.component*).

The *package.json* file has the information that describes the construction of the project and it is inside the client directory (Figure 6.1). The most important construction elements are the dependencies, proxy and scripts. The script *"start : react-scripts start"* allows to run *npm start* on the command line setting up the development environment and opening *http://localhost:3000* to view it in the browser.

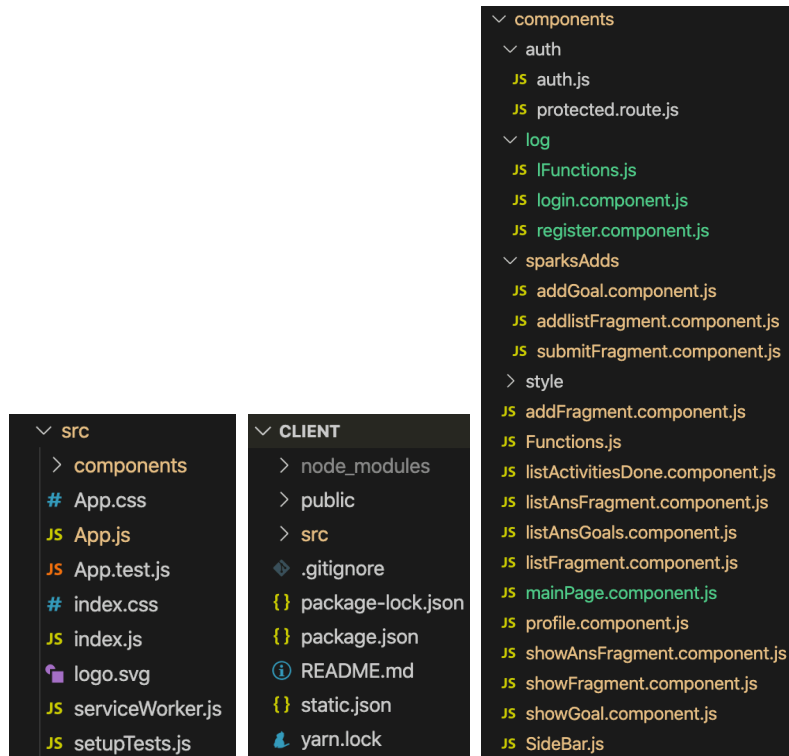


Figure 6.1 Client directory /client/src directory /client/src/components directory

This front-end development in React.js is described in the following five sections: (1) React.js Routing - the routing between URLs and components; (2) Login - the logic of the development behind the Login component implementation examples of code; (3) Main Page – the implementation of the model presented in chapter 4 “*Model proposal*”; (4) Main components – the most important or complex functions from different components in the web application; and (5) Design –the stylistic development of the application involving Bootstrap and CSS.

6.1.1 React.js Routing

The application starts executing in “*client/src/App.js*” where the function *App()* is located: control of a collection of navigational components with react-router-dom. This makes it possible to declare specific accesses to navigate between paths and components in the application [88].

- **BrowserRouter** – “*HTML5 history API (pushState, replaceState and the popstate event) to keep your UI in sync with the URL*” this component allows to use different regular URL paths that are managed by the client-side that is used to serve the same page [88].
- **Route** – “*the most important component in React Router to understand and learn to use well. Its most basic responsibility is to render some UI when its path matches the current URL*” this component allows to define the application components that will be rendered with specific paths [88].

The Route in the system (except the login and register) is managed by a function created in “*client/srs/components/auth/protect.route.js*” that receives the component and the path that the user wants to access. Then, verifies the authorization to access the page. Auth class (path “*client/srs/components/auth/auth.js*”), has the user access control information with a boolean

representing if the user is logged or not and an object with a user JSON Web Token (JWT). This class also has the functions for the set and get values. *ControlRoute* (Figure 6.2) receives the path that the user wants to access and the component referring to that path. If *auth.isAuthenticated()* is true, the user can access and render the component, otherwise, the user is redirected to the login page. This composition allows having the user token that will be needed to validate the back-end along the various paths passed in the component with the name *idParent*.

```

1 export const ControlRoute = ({ component: Component, ...rest }) => {
2   return (
3     <Route
4       {...rest}
5       render={({ props }) => {
6         if (auth.isAuthenticated()) {
7           const id = auth.getIdUserF()
8           return <Component {...props} idParent={id} />
9         } else {
10          return (
11            <Redirect
12              to={{
13                pathname: '/',
14                state: { from: props.location },
15              }}
16            />
17          )
18        }
19      }}
20    />
21  )
22 }

```

Figure 6.2 ControlRoute function

6.1.2 Login

The login is first page of the application that a user has access to (path `/`; Figure 6.3). The inputs for the login form are the email and password. Pressing the “Sign in” button a call to the *onSubmit()* function occurs. *onSubmit()* functions constructs a const with the information of the e-mail and password states and calls another login function imported from `“client/srs/components/log/LogFunctions.js”`, sending the const as a parameter. Axios code is a *“promise based HTTP client request”* [96] where passing the login data as a second parameter, gives a response object of the information (if it has been validated or had any error) of the login that can be used next.

Please sign in

Email address

Password

[Sign in](#)

[Register new user](#)

Figure 6.3 Login page

```

1 export const login = user => {
2   return axios
3     .post('users/login', {
4       email: user.email,
5       password: user.password
6     })
7     .then(response => {
8       sessionStorage.setItem('utoken', response.data)
9       return response.data
10    })
11    .catch(err => {
12      console.log(err)
13    })
14 }

```

Figure 6.4 Login with axios function

The *sessionStorage* concedes access to a session object, the *setItem('utoken',response.data)* assigns *response.data* value to the *utoken* object. A similar function is *localStorage* [97] preventing the stored information from expiring (a characteristic not intended to have in the application). *sessionStorage* is a better option if the user opens a new tab in the browser and no not want to have the same login information stored before.

In the Login Page, there is also a button to route to the page *"/registerUser"* wich as the Register Component. Register Component has a form for setting the registration information. It will call a register with *axios* function in *LogFunctions* function that makes the registration request to the back-end to perform the validation and record the date.

All forms developed for the web application have the input values associated with the value of the component state. The *onChange(e)* function handles event changes as the user enters new values.

```

1 onChange(e) {
2   this.setState({ [e.target.name]: e.target.value })
3 }

```

Figure 6.5 onChange(e) function

6.1.3 Main Page

The user is redirected to the Mainpage (*"/mainpage"*) after a valid login. This page shows the new model for industry 4.0 strategies presented in Chapter 3.

Starting the commit phase in the dom of the application, the method *componentDidMount()* [98] allows to call the functions that will fetch the required data to present and set states shortly after rendering. It is an async function allowing to use *await* in the functions called within it. The initial functions go through *axios.get()* requests for stored user information regarding the goals and maturity model fragments from each perspective.

The *getGoals(Persp)* (Figure 6.6) function needs to have the same parameters used in the component state perspective name, and database perspective name (the defined ones in the application are: *"financial"*; *"costumer"*; *"processes"*; *"lg"*; *"i4"*). The information placed in the

state is a JSON Object that comes from the response of `axios.get()` which in the key `"data"` has a list of the existing goals. The elements are rendered in the application with the `showGoals[perspective]()` functions. (Figure 6.7). The `.map()` function is used to read the list of existing goals.

```

1 getGoals(persp) {
2   return axios
3     .post('/goals/getGoals', {
4       idUser: this.state.idUser,
5       perspective: persp
6     })
7   }
8   .then(response => {
9     this.setState({[persp]: response});
10  })
11 }

```

Figure 6.6 getGoals(perspective) function

```

1 showGoalsFinancial(){
2   return(
3
4     this.state.financial.data.map((go) => {
5       return (
6         <div><Link to={"/ShowG/"+go.id} >
7           {go.goalTitle}
8         </Link></div>
9       );
10    });
11 }

```

Figure 6.7 showGoalsFinancial(perspective) function

Obtaining the maturity model fragments requires reading the lists information. One of the lists include the answers (Figure 6.9) and the other comes with the information of the fragments (Figure 6.8).

```

Array(4) i
▼ 0:
  created: "2020-04-21 15:31:30"
  description: "Ensure that the origin of the wood is known."
  id: 24
  idUser: 1
  maxSet: 4
  minSet: 1
  perspective: "Processes"
  public: 1
  title: "Product and services"
  ▶ __proto__: Object
▶ 1: {id: 26, idUser: 1, public: 1, title: "Manufacturing and o
▶ 2: {id: 29, idUser: 1, public: 1, title: "Organization", desc
▶ 3: {id: 33, idUser: 1, public: 1, title: "Business Models, Pr

```

Figure 6.8 List with the information of the fragments

```

Array(10) i
▶ 0: {id: 10, idUser: 1, idFragment: 23, actValue: 1, propValue: 2, ...}
▼ 1:
  actValue: 1
  complete: 1
  created: "2020-04-17 11:54:31"
  id: 11
  idFragment: 24
  idUser: 1
  propValue: 3
  ▶ __proto__: Object
▶ 2: {id: 12, idUser: 1, idFragment: 25, actValue: 2, propValue: 4, ...}
▶ 3: {id: 13, idUser: 1, idFragment: 26, actValue: 1, propValue: 4, ...}
▶ 4: {id: 14, idUser: 1, idFragment: 27, actValue: 4, propValue: 3, ...}
▶ 5: {id: 15, idUser: 1, idFragment: 28, actValue: 1, propValue: 2, ...}
▶ 6: {id: 16, idUser: 1, idFragment: 29, actValue: 1, propValue: 2, ...}
▶ 7: {id: 17, idUser: 1, idFragment: 30, actValue: 0, propValue: 2, ...}
▶ 8: {id: 18, idUser: 1, idFragment: 32, actValue: 2, propValue: 4, ...}
▶ 9: {id: 19, idUser: 1, idFragment: 33, actValue: 1, propValue: 3, ...}

```

Figure 6.9 List with the information of the user answers

```

Array(4) i
▼ 0:
  actValue: 1
  complete: 1
  created: "2020-04-17 11:54:31"
  description: "Ensure that the origin of the wood is known."
  id: 11
  idFragment: 24
  idUser: 1
  maxSet: 4
  minSet: 1
  perspective: "Processes"
  propValue: 3
  public: 1
  title: "Product and services"
  ▶ __proto__: Object
▶ 1: {id: 13, idUser: 1, public: 1, title: "Manufacturing and op
▶ 2: {id: 16, idUser: 1, public: 1, title: "Organization", desc
▶ 3: {id: 19, idUser: 1, public: 1, title: "Business Models, Pro

```

Figure 6.10 Join of the list of answers in the list of fragments

This chain begins with *getAnswers()* which sets a JSON in the answers component state with the list of all responses to the fragments of maturity models. This JSON is transformed into a list with only the id value of the replied fragments. Next, the function *getFragments()* in which the perspective of the fragments and the list of the ID of the responsive fragments are inserted as a parameter sets in the state referring to each of the perspectives a list with the information of the fragments. Finally, there is a join between the information of the answered fragments and the values of the answers. The *joinfunc()* function is based on a *for()* function that crosses the list of maturity model fragments by perspectives and pushes to a new list the information of the fragments and the user answer values identified with the value *idFragment*. Thus in the function of show fragments, it is already possible to present the values and title (this being also a link with the path *"/showAF/"+go.idFragment* ("go" is the object of the respective list to each of the response of the merged list of the fragment with the

answers). The previously referenced get elements functions continue to operate with `axios.get()`. The final result visible in the web application is in Figure 6.11.

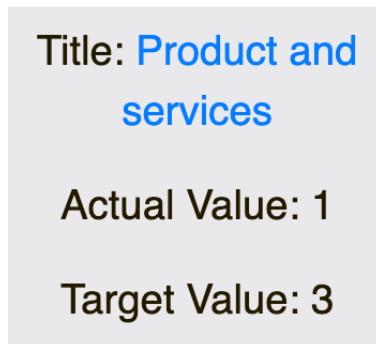


Figure 6.11 Show answered fragment result of joinfunc()

The activities and connections are listed at the bottom of the MainPage, supported on “get” and “show” functions like the ones before-mentioned with different parameters sent in the request and a different approach to the values of the responses that are built.

The MainPage component have more functions like the dropdown buttons that work based on a handle click function in each of the perspectives. They change the value of the `isVisible[perspective]` component state (between 0 and 1), to appear and disappear the dropdown that for the Financial and Customer perspectives gave a link to the path “/registerGoal” while the remaining perspectives had a link to the path “/registerGoal” and “/addlistFragments”.

6.1.4 Main Components

Throughout the application, the user has access to a side navigation bar on the left side. This appears when the user presses the hamburger-icon in the upper left corner. The navigation bar is based on the “react-burger-menu” package. Slide component imported allows to add multiple paths that the user can have access to, these are: “/mainpage”; “/listAnsGoals”; “/listAnsFragments”; “/listFragments”, “/listActDone”; “/registFragment”. The remaining components have functions similar to the previous mentioned but also other important functions presented as follows:

- `handleCheckbox()` – the RegisterFragment component has a form that require a function to handle the input checkbox changes;
- `handleSelectChangeType()` – a function to control the selected option in a select-box;
- `handleSelectChange()` – the ShowGoal component has a select-box to add activities. This select-box is dynamic, allowing the user to create new options. This structure requires importing the creatableselect component from the react-select package. The `handleSelectChange` function handles with this different select-box with the particularity of this being able to receive a list of new options that can already exist or not (Figure 6.12).

Figure 6.12 Dynamic select-box

- ActhandleAnswersChange()* – this is a function used in SubmitFragment component that allows answering in a dynamic form with several questions from a list. It uses the index value of the map to change the value of the objective value with that index in the list. Figure 6.13 presents the dynamic form with 6 examples of questions (a fragment of a maturity model)

Title: Manufacturing and operations

Question 0: Machine and operation system integration (M2M)

Actual Target

Question 1: Equipment readiness for Industry 4

Actual Target

Question 2: Operations data collection

Actual Target

Question 3: Operations data usage

Actual Target

Question 4: Cloud solution usage

Actual Target

Question 5: IT and data security

Actual Target

Figure 6.13 Dynamic form with questions

- edit - the edit of an element inside a component starts by creating a form with the inputs below the values that the user can change and conclude pressing the button "SubmitEdit". The edit metric in ShowGoal component (Figure 6.14) is more complex as it demands to edit a metric in the available list of metrics. The way to only present and edit the chosen element in a list depends on a list of 0 and 1 that determines whether to display the edit (1) or not (0). Then, the editing of the value is based on the function previously presented *ActhandleAnswersChange()*. There is an *onSubmitEdit(idx)* that with *axios.put()* will send a request to update the values in the back-end.

Metrics

The image displays three separate panels, each representing a metric in the ShowGoal component. Each panel has a light green background and contains the following information:

- Panel 1:** Title: test, Actual value: 1, Target Value: 2. It includes an 'Edit' button and a 'Remove' button.
- Panel 2:** Title: test2, Actual value: 3, Target Value: 4. It includes a 'SubmitEdit' button and a 'Remove' button. The values for actual and target are shown in input fields.
- Panel 3:** Title: test3, Actual value: 2, Target Value: 4. It includes an 'Edit' button and a 'Remove' button.

Figure 6.14 Edit metric in ShowGoal component

- Removes – The request `axios.remove()` deletes an element in a component. The element removal is affected by the indexes of the tables in the database: removing a maturity model that has unanswered questions is possible, but other operations (e.g. removing questions with values already inserted) may be limited.
- To pass the data through different components of the application is used two methods. To pass the user JWT is used the props to send when calling the component son that receives it via instance (e.g. father component: “`<Component {...props} idParent={id}>`”; son component: “`this.props.idParent`”). To access specific profiles of goals or maturity model fragments, the data is passed by a dynamic URL (e.g. in the code “`path= “/shogG/:id”`”; in the application “`https://host.herokuapp.com/ShowG/38`”).

6.1.5 Design

The stylistic development of the application involves Bootstrap and CSS. Bootstrap is an open-source framework that simplifies the style production of a component. Figure 6.15 depicts a component function that returns to render a list of existing maturity models. This function has a part of bootstrap called List group that displays a list of content (redirects to the maturity model fragment profile when pressed).

```

1 showMaturityFragments(){
2   return(
3     this.state.fragments.data.map((go) => {
4       return (
5         <p>
6           <a href={"/ShowF/"+go.id} class="list-group-item list-group-item-action flex-column
align-items-start start">
7             <div class="d-flex w-100 justify-content-between">
8               <h5 class="mb-1">{go.title}</h5>
9               <small>{go.created}</small>
10            </div>
11            <p class="mb-1">Description: {go.description}</p>
12            <small>Perspective: {go.perspective}</small>
13          </a>
14        </p>
15      );
16    })
17 }

```

Figure 6.15 showMaturityFragments() function implemented with Bootstrap

Product and services Description: Reduce maintenance costs; Use laser equipment; Reduce the growth periods of eucalyptus. Perspective: I4	2020-04-21 15:31:01
Product and services Description: Ensure that the origin of the wood is known. Perspective: Processes	2020-04-21 15:31:30
Manufacturing and operations Description: Reduce maintenance costs. Perspective: I4	2020-04-21 15:32:19
Manufacturing and operations Description: Ensure that the origin of the wood is known. Perspective: Processes	2020-04-21 15:32:08
Business model Description: Reduce maintenance costs. Perspective: I4	2020-04-21 15:32:38
Culture Description: Reduce maintenance costs. Perspective: I4	2020-04-21 15:32:58
Organization	2020-04-21 15:34:19

Figure 6.16 showMaturityFragments() function implemented with Bootstrap rendered

The CSS development occurred on the MainPage (which includes the main structure of the project). Because of the specificity of the intended graphical objective, it was necessary to stylize implementing CSS code.

The section where the model is located presents 4 different styles that make up the perspectives both at the level of goals and fragments. The application elements also have the characteristic of being dynamic (adjusting text-size, height and length of the boxes to the selected resolution). In the styles there is a division of those who are for horizontal perspectives (Financial; Cost; Processes; Learning & Growth) and those for vertical perspectives (Industry 4.0).

- Horizontal perspective: .grid-container style a table composed of 4 columns with automatic adjusted where maturity model fragment answers goals are being added. Each table element is generated with a <div> within the .grid-container.
- Vertical perspective: .section_i4 stylise the table where the maturity model fragment answers and goals of Industry 4.0 perspective are placed. Wrapping the elements in a <div> will make them render inside the table. The tables for the remaining perspectives expand vertically with new elements while this expands horizontally. To keep visible in the structure scrolling down and up the page, it is used a “position: sticky” style, allowing it to be fixed relative to the rest of the scroll-level structure.

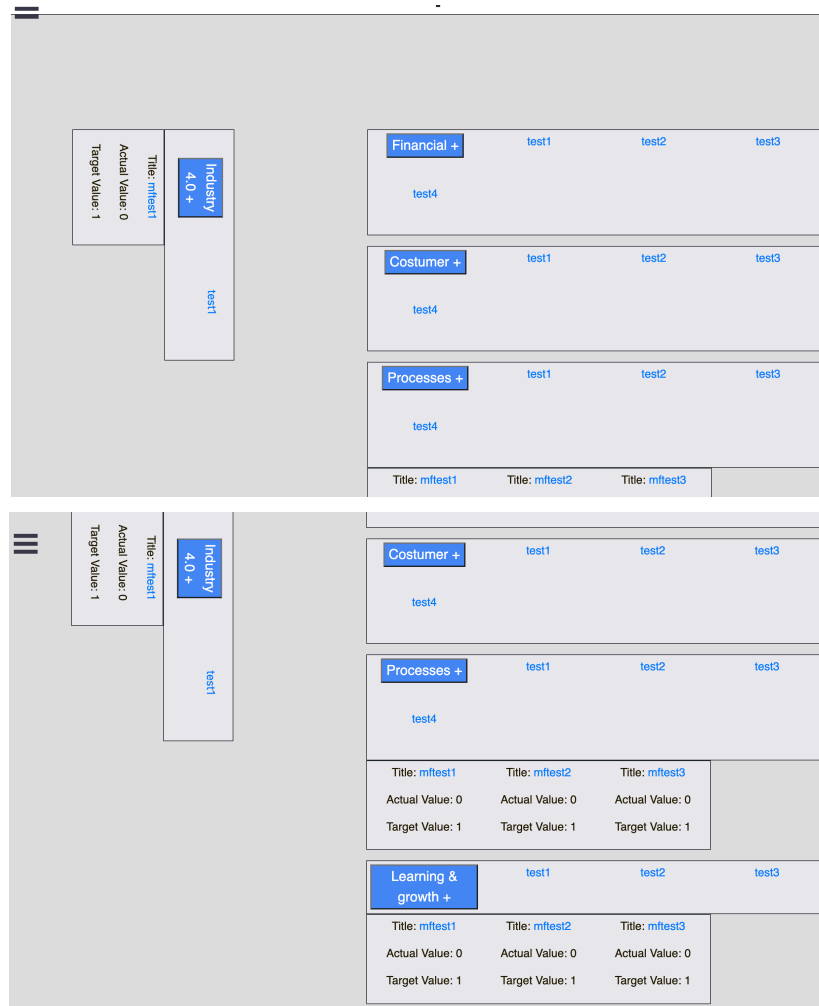


Figure 6.17 Sticky position page scroll-down views

The *ShowAnsFragment* displays a chart with the values (answers) of the maturity model fragment (actual and past values) (Figure 6.18). The main component for this chart is imported from the package react-chartjs-2. The chart is built based on a dataset and in visualization options. The X-axis shows the date. The Y-axis shows the actual and target values of the answers to the maturity model fragment. The display set is also configured with the Y-axis values between the maximum and minimum values defined in the maturity model fragment (e.g. in Figure 6.18 the set is [1,4]).

Chapter 6

Title: Product and services

Perspective: Processes

Public: 1

Description: Ensure that the origin of the wood is known.

Set: [1,4]

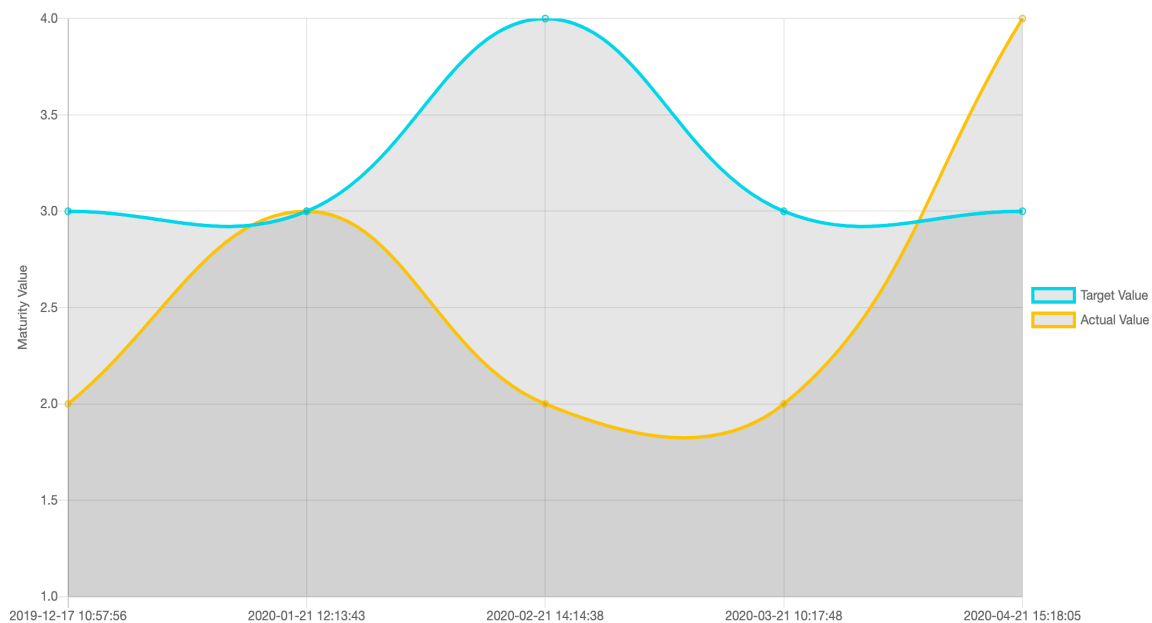


Figure 6.18 Maturity Model Fragment Answers Graph with react-chartjs-2

6.2 Back-end (Express + Sequelize + MySQL)

Two subsections are introduced: the database construction and implementation and the Node.js server. In Node.js with Express and Sequelize ORM the topics are the creation and configuration of the Sequelizer, the construction of the models, and the integration of express routing.

6.2.1 MySQL Database Implementation

The MySQL database was initially developed with XAMPP and phpMyAdmin. Later, in Heroku, the MySQL database is hosted in ClearDB. All the tables in the application have an "id" integer column type which is the primary key being auto-incremented and a "created" text column type that is automatically generated in the yyyy/mm/dd hh:mm:ss format. The database diagram is presented in Figure 6.19, followed by a brief description of the nine main tables.

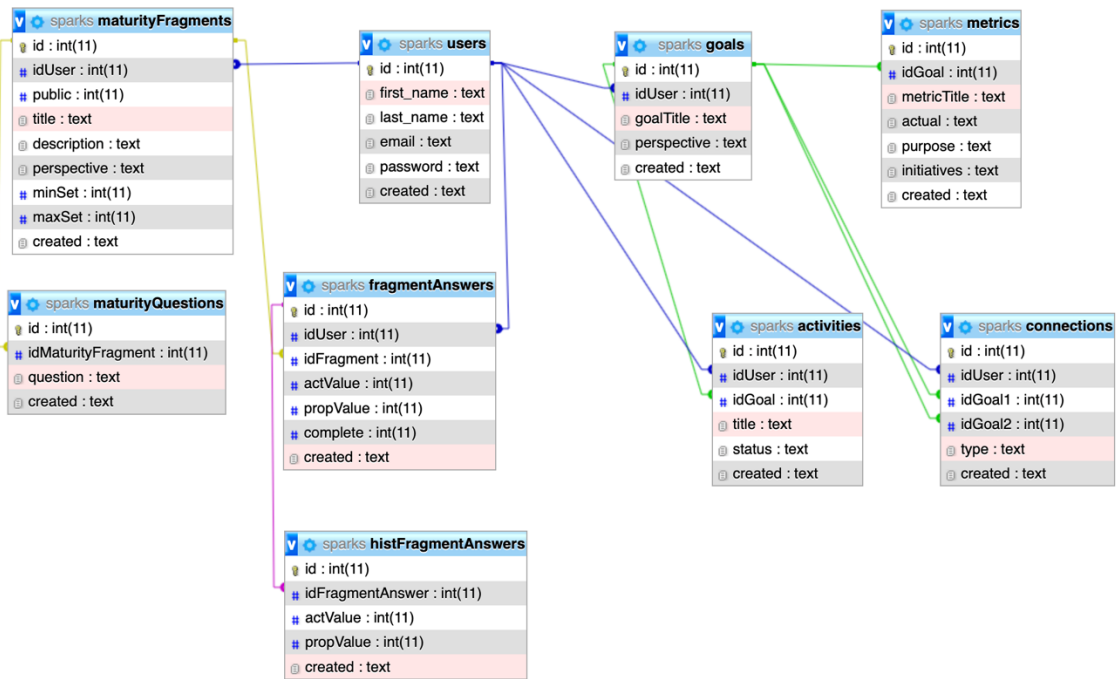


Figure 6.19 Database diagram

The users table has information relating to each user and login credentials and the encrypted password (“id” integer; “first_name” text; “last_name” text; “email” text; “password” text; “created” text). Only one index exists in this table (the primary key).

The goals table has information of the goals defined for each perspective of the model (the columns are “id” integer; “idUser” integer; “goalTitle” text; “perspective” text; “created” text). It has 2 indexes: id (primary key) and idUser.

The metrics table has information relative to the registered goal metrics (“id” integer; “idGoal” integer; “metricTitle” text; “current” text; “purpose” text; “iniciatives” text, “created” text). It has 2 indexes: id (primary key) and idGoal. indexes it to the primary key id of goals, associating each metric to a goal.

The activities table has information relative to the activities associated to each goal (“id” integer; “idUser” integer; “idGoal” integer; “title” text; “status” text; “created” text). It has 3 indexes: id (primary key), idGoal and idUser. idGoal indexes it to the primary key id of goals, associating each activity to a goal. Also, idUser indexes to the primary key id of users, associating each activity a faster access from the user (without having to perform activity -> -> user and only activity->user).

The connections table has information relative to the registered connections associated with the goals (“id” integer; “idUser” integer; “idGoal1” integer; “idGoal2” integer; “type” text; “created” text). It has 4 indexes: id (Primary key), idUser, idGoal1 and idGoal2. idUser indexes to the primary key of users associating each activity with a faster access from the user. idGoal1 and idGoal2 associate each connection to two goals.

The maturityFragments table has the information of the maturity model fragments registered (“id” integer; “idUser” integer; “public” integer; “title” text; “description” text; “perspective” text; “minSet” integer; “maxSet” integer; “created” text). It has 2 indexes: id (primary key) and idUser. idUser indexes to the primary key id of users, associating each fragment to a user who has privileges in that fragment.

The maturityQuestions table has information of the registered questions of maturity model fragments (“id” integer; “idMaturityFragment” integer; “question” text; “created” text). It has 2 indexes: id (primary key) and idMaturityFragment. idMaturityFragment indexes to the primary key id of maturityFragments, associating each question to a maturity model fragment. One maturity model fragment can have multiple questions.

The fragmentAnswers table has information regarding a user response to a maturity model fragment (“id” integer; “idUser” integer; “idFragment” integer; “actValue” integer; “propValue” integer; “created” text). It has 3 indexes: id (primary key), idUser and idFragment. idUser indexes to the primary key id of users, associating the response values to a user. idFragment indexes to the primary key id of maturityFragments, associating each response to a maturity model fragment.

The histFragmentAnswers table has information regarding maturity model fragments responses that have been changed by new ones but that keep in the historic (“id” integer; “idFragmentAnswer” integer; “actValue” integer; “propValue” integer; “created” text). It has 2 indexes: id (primary key) and idFragmentAnswer. idFragmentAnswer indexes to the primary key id of fragmentAnswers, associating an historic answer to maturity model fragment answered.

6.2.1 Node.js Implementation

The Node.js requires the installation of the Express and Sequelize packages (npm install express@latest sequelize@latest). The development of the web application in the back-side has the Sequelize models in the “/models” directory, the route handling methods in “/routes” and the sequelize configuration to the database in “/database”.

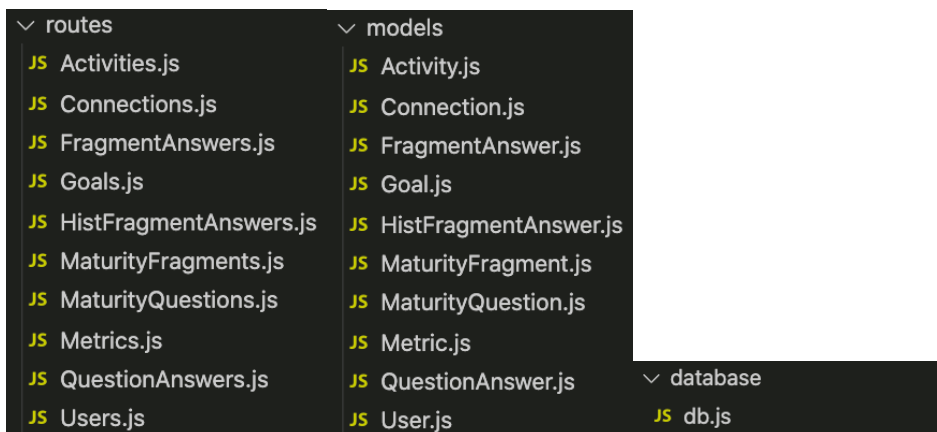


Figure 6.20 /routes directory /models directory /database directory

Sequelize creation is configured with the credentials to communicate with the database. It is implemented as a new Sequelize identifying in the parameters the database, username, password, host, the dialect, and the pool since this is connecting to the database is made from a single process.

```

1 const sequelize = new Sequelize('-database-', '-username-', '-password-', {
2   host: '-host-',
3   dialect: 'mysql',
4   operatorsAliases: false,
5
6   pool: {
7     max: 5,
8     min: 0,
9     acquire: 30000,
10    idle: 10000
11  }
12 })

```

Figure 6.21 Sequelize configuration

Next, the Sequelize models are developed. Sequelize models represent a table in the database and the instances represent a row. This process occurs using a *sequelize.define()*. Each model comprises a name, attributes, and options. The same names existing in the database were selected. The attributes represent columns of the table structure. The options are “*timestamp:false*”, using a DateTime that is timezone independent, allowing a proper sorting of the records.

```

1 module.exports = db.sequelize.define(
2   'goal',
3   {
4     id: {
5       type: Sequelize.INTEGER,
6       primaryKey: true,
7       autoIncrement: true
8     },
9     idUser: {
10      type: Sequelize.INTEGER,
11    },
12    goalTitle: {
13      type: Sequelize.STRING
14    },
15    perspective: {
16      type: Sequelize.STRING
17    },
18    created: {
19      type: Sequelize.DATE,
20      defaultValue: Sequelize.NOW
21    }
22  },
23  {
24    timestamps: false
25  }
26 )

```

Figure 6.22 Goal Sequelize model

Routing in the back-end is handled in Express.js by setting how the URIs endpoint should respond to client requests. Routing methods specify a callback function called when the application receives a request for a specific route and an HTTP method. The HTTP methods used in the web application are:

- *post()* - Used whenever it is necessary to register a new row in a table. Parameters are send in the body of the request and the HTTP method request post is also used.

- `put()` - Used to perform an update of a row on the table. It is called in date editing requirements in application elements.
- `delete()` - Used for removing a row on the table. It is called in element removal requirements in the application.

In addition to request methods, there are route paths that define the endpoints from where requests are handled. The path URL can also be dynamically identifying the route parameters specifying more elements for the request. The returning response may be a JSON object with the data requested or a confirmation message that the requested action was successfully performed. If the function is not completed successfully will return a message with an error confirmation.

Within each method it is possible to add a callback function that behaves like a middleware handling the request. Within each of these functions in the application, there is a logical work. This logical work is supported by Sequelize.

The logging function in the database starts by creating a new value `Date()`. Next, is built a constant with the values that come in the request with `req.body.[element]`. The inside method call `create()` will deal with the built as a synchronous process (creating an object representing the date) and saves it (which deals with mapping a database) in an asynchronous process. The save processes don't need to wait for the request to complete, and when it's done, the callback will be called upon. This callback can finish with success and therefore sends a JSON with the confirmation that the request has been successfully made as a response. But, if there is an error, it will be caught you and the response message will be with the error that has occurred.

```

1 users.post('/login', (req, res) => {
2   User.findOne({
3     where: {
4       email: req.body.email
5     }
6   })
7   .then(user => {
8     if (bcrypt.compareSync(req.body.password, user.password)) {
9       let token = jwt.sign(user.dataValues, process.env.KEY, {
10        expiresIn: 3600
11      })
12      res.send(token)
13    }
14  })
15  .catch(err => {
16    res.send('error: ' + err)
17  })
18 })

```

Figure 6.23 Handle login route request

Functions of request for data begin with a Sequelize find that generates a *SELECT* query. The `findAll` returns all entries in the table, `findOne` returns only the first entry, and `findByPk` that find the entry with that selected primary key. The “*where*” clause is used to restrict the results. Finally, in case an error, a `.catch` occurs that causes the method to end up sending an error message. Otherwise sends a JSON with the requested values from the database.

The edit functions begin with a Sequelize `findByPk` going to fetch the entry by the primary key present to change. An update on the existing values is made, followed by a confirmation message.


```

1 goals.put('/edit', (req, res) => {
2   Goal.findByIdPk(req.body.id).then(function(note) {
3     note.update({
4       goalTitle: req.body.goalTitle,
5       perspective: req.body.perspective,
6     });
7   }).then((note) => {
8     res.sendStatus(200);
9   });
10 })

```

Figure 6.24 Handle edit route request

The *findByIdPk* is used to fetch the entry by the primary key and can be used to remove a single row or destroy multiple rows. The delete operation is affected by the table indexes. To assure that a row is deleted without errors the index relation is an important element to take into account assuring that there is no other row in another table using it as a relation index. If that happens is necessary to delete that other rows first before deleting it. Example of restriction: delete a maturity model fragment with answers is not allowed.

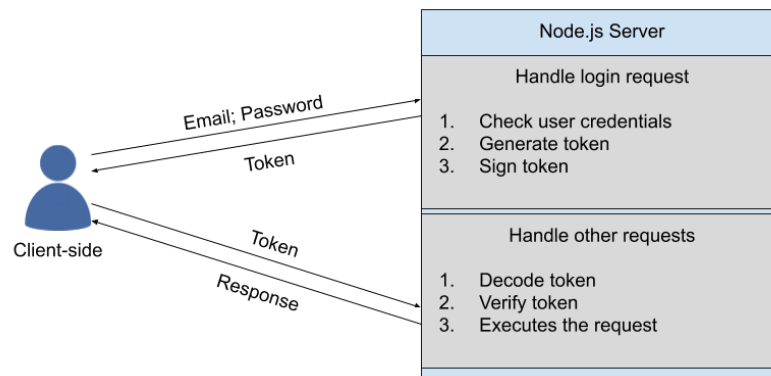


Figure 6.25 JWT mechanism

JWT is used to improve application safety with access restrictions. The confirmation starts in the login. When a request is made to a specific route, a *req.body* is sent with the token to validate and decode. The mechanism is stateless, meaning that generating a new token is independent from the previous one. Therefore, it is possible to restrict the use of specific information to the user to which it belongs. This work with JWT only takes place in the back-end side, avoiding accessing the key by the client-side.

Chapter 7

Testing, Demonstration, and Evaluation

This chapter presents the web application tests, a demonstration of its use according to the proposed model, and the final assessment made by the case company.

The source code was tested after each sprint implementation. This approach aimed to continuously revise the specification of requirements, architecture, and product design. Two main groups of techniques for software testing and quality assurance can be identified: White-box and Black-box, also classified as low-level tests and high-level tests [99]. The testing tools and techniques to be carried out were established according to the needs of a React.js and Node.js project. The tests are considered successful if they meet all the defined acceptance criteria. Therefore, all modules and all interactions of the modules must be tested and the defects found must be corrected, as presented in the next section.

7.1 Testing

This section presents the different tools and methodologies used to test the web application: (1) Unit test; (2) End-to-end testing; (3) Functional tests; (4) Usability tests. Presenting also the results.

7.1.1 White-box Unit Testing

The white-box tests focus on the analysis of the internal structure of the system, being performed in the source code. It is a code-based testing performed by developers that aim to analyse the system after the implementation at the end of each sprint [99]. The testing process uses real values, different input combinations, and seeks to predict the results of an action.

The unit *“is the smallest piece of code software that can be tested in isolation”* [100]. It is tested in full isolation, which *“means separate and apart from the application, and all other units”*[100]. Code that does not meet the requirement of complete isolation will be analysed later in end-to-end or integration test [101].

White-box testing aims to perform different control paths, identifying errors within the boundaries of the system unit. Unit testing was applied to the source code React.js in specific functions within the components: The approach followed for performing this type of tests was focused on three essential levels:

1. Define the possible isolation testing functions with input and output.

The functions in full isolation are: `joinfunc()` and the `_handleclick()` of the MainPage component; `onchange()`, `handleSelectChange()` and `handleCheckboxChange()` belonging to the AddMaturityFragment component; the `joinfunc()` belonging to the ListAnsFragments component; and the `onChange()`, and the `_handleCheckboxChangeP()`,

`_handleCheckboxChangeLG()`, `_handleCheckboxChangeLG4()` of the component `ListFragments`. The purpose of these functions in the application is to control component states with the addition of new elements or events.

2. Configure the testing tool.

The tests are conducted on Enzyme with Shallow rendering API that allows to run and assert the tests. The Shallow rendering API [102] tests the components singularly without being affected by any other component of the application, ensuring that tests aren't indirectly asserting on the behaviour of child components. The main Shallow functions used were `.instance` which can only be called in a wrapper instance to return `ReactComponent` to which one can then call a component method and `.state()` that returns the value of a component state. The most commonly used enzyme functions were the `expect()` that allows check that values meet certain conditions; the `.toBe()` method allows the comparison of values, being these primitives or verifying the identity of object instances; `.toMatchObject()` allows the comparison of JavaScript objects. Figures 7.1 and 7.2 presents examples of functions tested.

```

1 describe ('Unit test MainPage', () => {
2   describe('joinfunc', () => {
3     it('joinfunc perspective Processes 1', () => {
4       const wrapper = shallow(<MainPage />);
5       const instance = wrapper.instance();
6       expect(wrapper.state('mergedP')).toBe(null);
7       instance.joinfunc([{created: "2020-04-21 15:32:08",description: "T1.",id: 26,idUser:
1,maxSet: 4,minSet: 1,perspective: "Processes",public: 1,title: "T1"}],[],[],[{actValue: 1,
complete: 1, created: "2020-04-17 11:57:18", id: 13, idFragment: 26, idUser: 1, propValue:
4}]);
8       expect(wrapper.state('mergedP')).toMatchObject([{actValue: 1, complete: 1, created:
"2020-04-17 11:57:18", description: "T1.", id: 13, idFragment: 26, idUser: 1, maxSet: 4,
minSet: 1, perspective: "Processes", propValue: 4, public: 1, title: "T1"}]);
9     });
10  });
11 });

```

Figure 7.1 Unit testing joinfunc()

```

1 describe ('Unit test addFragment', () => {
2   describe('handleSelectChange to LG', () => {
3     it('checkbox test False-True', () => {
4       const wrapper = shallow(<AddMaturityFragment />);
5       wrapper.find('select[name="selectAMF"]').simulate('change', {target: {name:
'selectAMF', value: 'Processes'}});
6       expect(wrapper.state('perspective')).toBe('Processes');
7       wrapper.find('select[name="selectAMF"]').simulate('change', {target: {name:
'selectAMF', value: 'LG'}});
8       expect(wrapper.state('perspective')).toBe('LG');
9     });
10  });
11  describe('checkbox test False-True', () => {
12    it('select test False-True', () => {
13      const wrapper = shallow(<AddMaturityFragment />);
14      expect(wrapper.state('checked')).toBe(false);
15      wrapper.find('input[name="checkboxAMF"]').simulate('change', {target: {name:
'checkboxAMF', checked: true}});
16      expect(wrapper.state('checked')).toBe(true);
17    });
18    it('checkbox test True-False', () => {
19      const wrapper = shallow(<AddMaturityFragment />);
20      wrapper.find('input[name="checkboxAMF"]').simulate('change', {target: {name:
'checkboxAMF', checked: true}});
21      expect(wrapper.state('checked')).toBe(true);
22      wrapper.find('input[name="checkboxAMF"]').simulate('change', {target: {name:
'checkboxAMF', checked: false}});
23      expect(wrapper.state('checked')).toBe(false);
24    });
25  });
26 });

```

Figure 7.2 Unit test to checkbox

3. Define the testing data and compare the results.

The test checks changes resulting from calling a function affecting the value state of the component. As for the application of events, this occurred with the simulation of clicks on buttons, select-boxes and check-boxes. The data to be tested in the join functions consisted on arrays of JSON objects passed as parameters to which the final result is intended to have impact in the final state value with a join of the arrays by an id. The tests were structured hierarchically by component and then by function. The results were inserted in the following tables with the input value and with the expected output and if the result was equal to the expected. This resulted in a total of 41 cases of unit testing.

```

PASS src/App.test.js
Unit test MainPage
  joinfunc
    ✓ joinfunc Processes 1 (121ms)
    ✓ joinfunc Processes 2 (24ms)
    ✓ joinfunc Learning & Growth 1 (19ms)
    ✓ joinfunc Learning & Growth 2 (19ms)
    ✓ joinfunc Industry4.0 1 (19ms)
    ✓ joinfunc Industry4.0 2 (19ms)
    ✓ joinfunc all 1 (20ms)
    ✓ joinfunc all 2 (20ms)
  _handleClick
    ✓ isVisible Industry4.0 False-True (9ms)
    ✓ isVisible Industry4.0 True-False (8ms)
    ✓ isVisible Financial False-True (6ms)
    ✓ isVisible Financial True-False (8ms)
    ✓ isVisible Customer False-True (6ms)
    ✓ isVisible Customer True-False (5ms)
    ✓ isVisible Processes False-True (6ms)
    ✓ isVisible Processes True-False (8ms)
    ✓ isVisible Learning & Growth False-True (6ms)
    ✓ isVisible Learning & Growth True-False (6ms)
Unit test AddMaturityFragment
  onChange
    ✓ onChange test "" - "test" (3ms)
    ✓ onChange test "test" - "test2" (3ms)
  handleSelectChange to Processes
    ✓ handleSelectChange to Processes (1ms)
  handleSelectChange to I4.0
    ✓ handleSelectChange to I4.0 (2ms)
  handleSelectChange to LG
    ✓ handleSelectChange (4ms)
  checkbox
    ✓ checkbox test False-True (4ms)
    ✓ checkbox test True-False (6ms)
Unit test ListAnsFragments
  joinfunc
    ✓ joinfunc Processes 1 (10ms)
    ✓ joinfunc Processes 2 (8ms)
    ✓ joinfunc Learning & Growth 1 (8ms)
    ✓ joinfunc Learning & Growth 2 (7ms)
    ✓ joinfunc Industry4.0 1 (9ms)
    ✓ joinfunc Industry4.0 2 (7ms)
    ✓ joinfunc all 1 (9ms)
    ✓ joinfunc all 2 (7ms)
Unit test ListFragments
  onChange
    ✓ onChange test "" - "test" (6ms)
    ✓ onChange test "test" - "test2" (5ms)
  checkbox
    ✓ checkbox Processes test False-True (5ms)
    ✓ checkbox Processes test True-False (4ms)
    ✓ checkbox Learning & Growth test False-True (4ms)
    ✓ checkbox Learning & Growth test True-False (4ms)
    ✓ checkbox Industry 4.0 test False-True (5ms)
    ✓ checkbox Industry 4.0 test True-False (6ms)
Test Suites: 1 passed, 1 total
Tests: 41 passed, 41 total
Snapshots: 0 total
Time: 4.989s

```

Figure 7.3 Unit test results

Figure 7.3 shows the test results terminal, including the label of the tested function and the result. On the bottom-right of Figure 7.3 in “Tests:”, is confirmed that 41 tests have passed, allowing to conclude that the application passed with success to the white-box testing phase.

7.1.2 End-to-End Testing

End to end testing is the process of loading the web application in the client-side (browser) and control the communication, synchronization, and tasks performed on the different components and servers that integrate the system [103]. These tests focused on integrating all elements of the application from the React.js client interface to requests to the Node.js server that communicates with the database.

End-to-end test start with the login function, creating a JWT that allow to pass the back-end JWT data restriction. This test focuses on the integration of the different components and intends to evaluate if the interfaces between the multiple modules of the system can communicate correctly.

Cypress was the chosen library for the realization of end-to-end tests enabling the detection of a wide variety of bugs. Cypress tool executes end-to-end test expressions. It also has a test

runner that runs the application in the browser, and provides real-time debugging capabilities for each specification [104]. For every action in the application, it saves a snapshot of the state a snapshot of the UI Figure 7.8 so it's possible to know how things have changed before and after an action has taken place.

End-to-end testing goes through several phases. The initial state starts with a clean database and the application running only with testing user. The *"take an action"* phase follows. In this step, the interaction that the elements are intended to have are written, and lastly, the assertion of the page content.

Cypress requires to install the package (`npm install cypress -save-dev`). This step will create a folder in the directory of the application. In this directory is where is going to be implemented JavaScript file with test configuration. Cypress environment program starts with the command `"node_modules/.bin/cypress open"`.

The main commands used in the Configuration of Cypress in the test are:

- visit – allows access to a URL;

```
1 cy.visit('https://industry-sparks.herokuapp.com/')
```

Figure 7.4 Cypress command visit

- get – allows to get to one or several elements of the DOM;
- click – allows to click on an element of the DOM;
- type – allows to type into a DOM element;
- should – creates an assertion with a chainer (extend from Chai framework with a specific jQuery chainer method) and value. The chainer used in the tests is the *"have.value"* that will verify that the value is as expected;

```
1 cy.get('[name="addGoal"]').click()
2 cy.get('[name="goalTitle"]').type('Reduce operational costs').should('have.value', 'Reduce
operational costs')
3 cy.get('[name="goaladd"]').click()
```

Figure 7.5 Cypress comand get, type, should and click

- route – allows to manage a specific request of the application;

```
1 cy.route({
2   method: 'POST',
3   url: '/maturityFragments/registerFragment',
4 }).as('regFragment')
```

Figure 7.6 Cypress route

- expect – creates an assertion and is used in the application with a *to.include* that allows the comparison of values resulting from requests.

```

1 cy.wait('@regFragment').then((xhr) => {
2   expect(xhr.response.body, 'response body').to.include({
3     'test': 'IA MMF',
4   })
5 })

```

Figure 7.7 Cypress route expect

The screenshot displays the Cypress test runner interface. At the top, it shows 'Tests' with a green checkmark, '1' passed, 'X --' failed, and a total time of '23.45'. Below this, a 'Finds an element' section shows a list of routes:

Method	Url	Stubbed	Alias	#
POST	/goals/registerGoal	No	regGoal	2
POST	/goals/getGoal	No	getGoal	5
POST	/metrics/registerMetric	No	regMetric	1
POST	/activities/registerActivity	No	regActivity	1
POST	/connections/registerConnection	No	regConnection	1
POST	/maturityFragments/registerFragment	No	regFragment	1
POST	/maturityQuestions/registerQuestion	No	regQuestion	1
POST	/fragmentAnswers/registerFragmentAnswer	No	regAnswer	1
POST	/histFragmentAnswers/registerHistFragmentAnswer	No	regHistAnswer	1

Below the routes, the test execution log is visible. It shows a sequence of actions: VISIT localhost:3000, GET input[name="email"], -TYPE test3@test3.com, -ASSERT expected <input.form-control> to have value test3@test3.com, GET input[name="password"], -TYPE test3, -ASSERT expected <input.form-control> to have value test3, GET button[name="si"], -CLICK, and several network requests (XHR) to various endpoints like /users/login, /maturityFragments/getFragment, /fragmentAnswers/getFragment, /maturityQuestions/getMaturityQuestions, and /histFragmentAnswers/getHistFrag. The log also shows WAIT actions and -ASSERT statements for response body expectations, all of which are marked as passed in green. The test concludes with a -CLICK action on a button with class="bm-burger-button".

Figure 7.8 Cypress running the test

Figure 7.8 shows the test results in the Cypress program. It has all the functions, routes and asserts done. The asserts are all in green showing that the test has passed in all the asserts, which allow to conclude that the application passed with success the end-to-end testing.

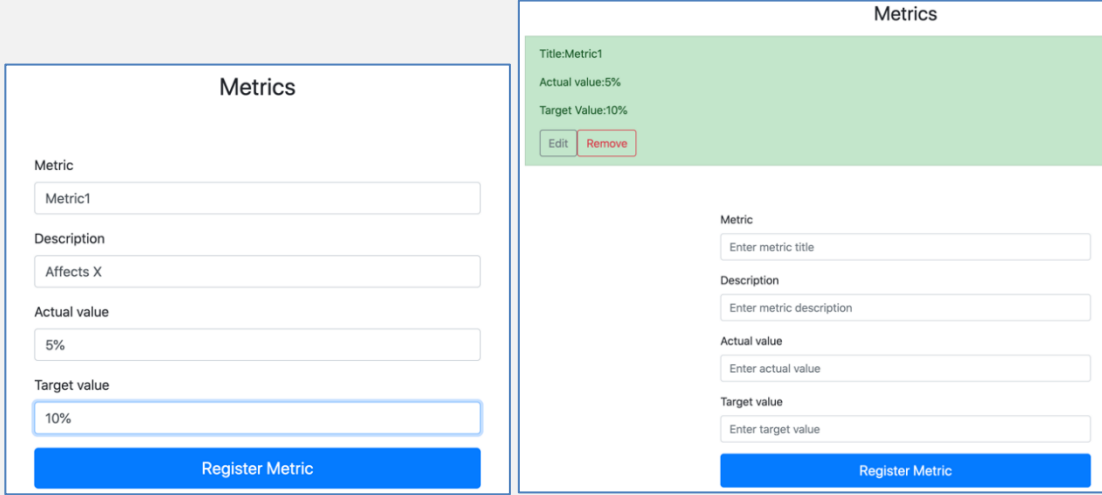
7.1.3 Black-box Functional Testing

This section presents the black-box testing where the test does not go into source code debugging of the application like in the previous ones but resort to operating aspects of functionality and usability [99].

The purpose of functional testing is to ensure that all aspects of the system comply with functional requirements. Each test is written to verify one or more requirements using scenarios and use cases specified by the requirements document.

The tests correspond to the requirements with the highest priority ("Must have."). The results were collected in test cases tables where information of each test execution is. In each table, it is included information about the requirement that is being tested, the steps of the test and the expected result. It is also recorded if the test has passed or failed, as presented in the following example.

Table XLV – Functional testing Add metric to goal.

ID:	8
Title:	Add metric to a goal
Main success scenario:	<ol style="list-style-type: none"> 1. The user fills the form inside the goal with the title "Metrics": (1) Metric title; (2) Description; (3) Actual Value; (4) Target Value. 2. The user clicks "Register Metric" submitting the new metric; 3. The system saves the new metric.
	
<p>Left image: Add metric form Right image: After add metric submit</p>	
Result:	Approved

The tables in the Appendix C with the functional testing were synchronized with the implementation sprints. All the requirements have been checked and approved, concluding the functional testing with success.

7.1.4 Black-box Usability Testing

Usability tests require real people to use the application and provide feedback report [105]. These insights give an external perspective of the application, which is both critical for development and important to assess the real stage of the application. Each of the users performed the test build at the same time a report in which will be described their actions in the guided tasks.

Usability tests report the accomplishment of tasks in a specific scenario. It is verified whether the user can perform the actions or functions that the application allows.

A realistic scenario is important to allow the user to enter within the mind-set of the application. The tasks must be simple, functional and understandable [105]. It is intended that the user report rich information about the experience. These reports may relate to the ease or difficulty of performing the task.

The usability tests were conducted by 5 persons with different backgrounds. The testers qualification areas include management, bank monitor, information systems, and design. The testers did not have any prior knowledge regarding the application.

The introduction states the test purpose, what are the objectives, explain the confidentiality and anonymity of the participation. Before starting the tasks was requested for the testers to fill some individual characterization questions. These questions will make it possible in the conclusions to detect personal characteristics in the use of the application.

A total of 11 tasks were requested:

1. Enter login credentials: Email: "*id@test.com*"; Password: "*test*". Press the "*Sign in*" button.
2. Select the "*Financial +*" button. Select the "*Add Goal*" option. Fill the form: Goal title: "*Reduce operating costs*". Press the "*Register Goal*" button.
3. Fill the form to add a new metric: Metric: "*Current Cost*"; Description: "*Percentage values*"; Current value: "*75*"; Target value: "*80*". Press the "*Register Metric*" button
4. Enter in the Activities text box: Select...: "*Change management software*". Select the "*Create Change management software*" option. Press the "*Register Activities*" button.
5. Select the burger-icon in the upper left corner. A sidebar appears and then select the "*Main Page*" option. Select the "*Industry 4.0 +*" button. Select the "*Goal*" option. Enter in the text box: Goal title: "*Optimize use of artificial intelligence*". Press the "*Register Goal*" button.
6. In the bottom of the page in Connections after "*Optimize use of artificial intelligence*" where it says "*Dependent*" change the type by selecting the option "*Support*". Press the "*Register Connection*" button.
7. Select the burger-icon in the upper left corner. A sidebar appears and then select the option "*Register Maturity Model Fragment*". Fill out the form to register a new maturity model fragment: Maturity Model Fragment: "*IA MMF*"; Description: "*Digital Maturity*"; Minimum value for set: "*0*"; Maximum value for set: "*5*". In the select-box that says Learning and growth change the option to Industry 4.0. Press the "*Register Metric*" button.

8. Fill the form to add a new question to the maturity model fragment: Maturity question: "*Level of processing of data collected based on intelligent systems*". Press the "*Register Maturity Question*" button
9. Press the "Edit" button of the maturity model fragment next to the "*Remove*" button. Change the value: Description: "*Artificial Intelligence*". Press the "*Submit edit*" button.
10. Select the burger-icon in the upper left corner. A sidebar appears and then select the "*Main Page*" option. Select the "*Industry 4.0 +*" button. Select the "*Fragment*" option. Scroll down the maturity model fragments list and select the model with the title "*IA MMF*". Fill the form to submit a response to the maturity model fragment: Current: "2"; Target: "4". Press the "*submit*" button.
11. Fill the form to add new values to maturity model fragment: Current value: "3"; Target value: "4". Press the "*Register Metric*" button.

Results: Appendix D

Table XLVI – Usability test results table.

Identification	Total time (seconds)	Total number of clicks	Success/Error	Difficulty Average
Tester 1	164	29	Sucess	8,90909091
Tester 2	343	65	Sucess	7,54545455
Tester 3	370	53	Sucess	9
Tester 4	348	57	Sucess	8,45454545
Tester 5	272	45	Sucess	8,36363636
Testers Average	299,4	49,5		8,45454545

Table XLV shows the final results obtained from the usability tests of each tester (the full reports are included in the Appendix D. The total time (second column starting from the left) was obtained from the sum of time that took to perform each task. The total number of clicks is the sum of the number of clicks to perform each task. Success/Error represents whether all tasks have been completed successfully (Success) or if there were any that gave an error. The average difficulty is the average value (1 extremely hard and 10 very easy) that each tester assigns to a task. All tasks were successfully completed by all users being a positive element for the usability test. Figure 7.9 and 7.10 presents the results of the remaining elements from the usability test reports.

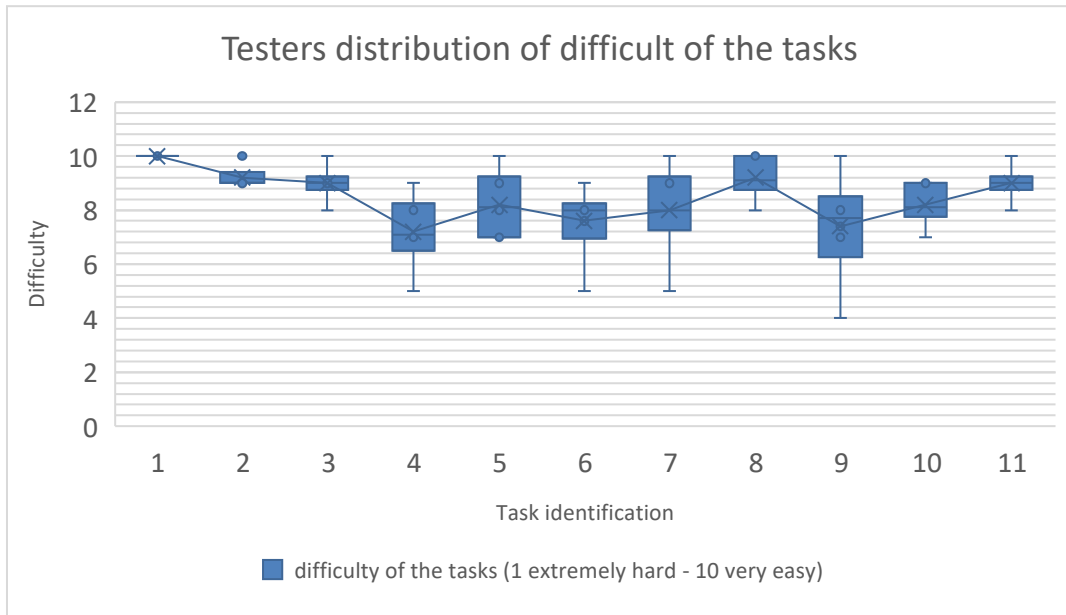


Figure 7.9 Testers distribution of difficult of the tasks graph

Figure 7.9 reveals some differences in the difficulty of execution (results of task 9 are between 4 and 10). The more complex tasks are: task 9 referring to the edit of a maturity model fragment; task 4 which was defined as difficult because it has an unusual dynamic select-box where the user can add new options. The most easily performed tasks are related to fill a form with the specific inputs and press a button to submit values. The number of steps required for each task also has an impact in the results (more steps increases the difficulty).

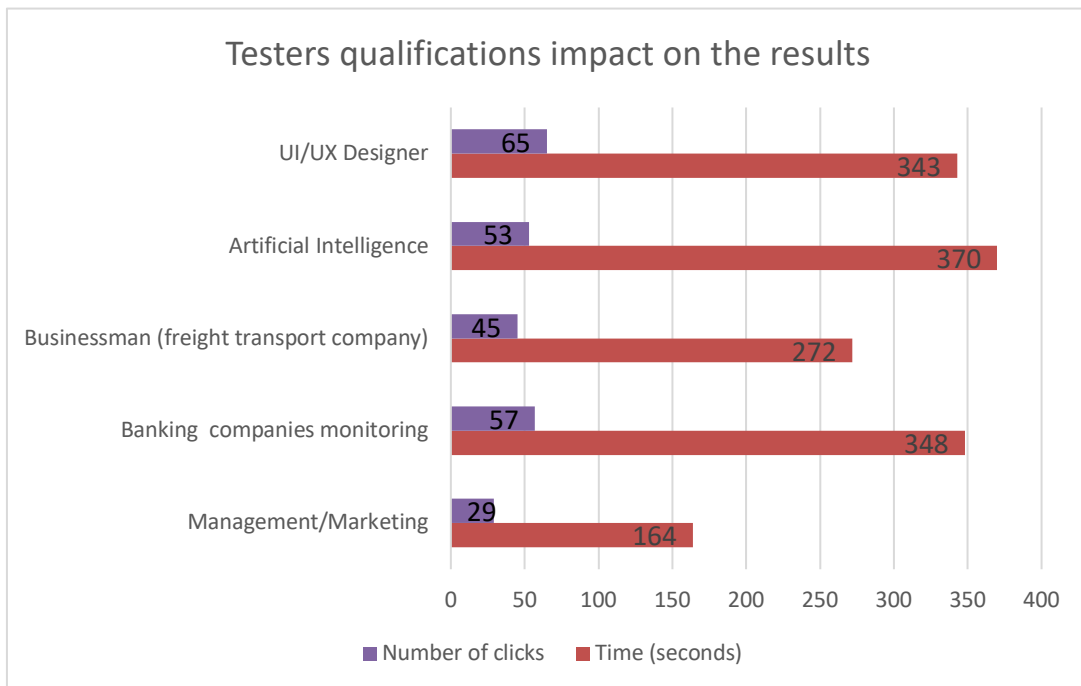


Figure 7.10 Testers qualifications impact on the results chart

The results in Figure 7.10 show how the background testers with higher experience in business and management (with Balanced Scorecard and Maturity Models) perform the tasks in less time and with less clicks than the testers with background in information systems, user interfaces and informatics engineering.

The testers were also asked to submit considerations regarding the complexity of the application and elements to improve. The questions are presented as follows:

1. Have easily and intuitively carried out the proposed tasks? (yes or no question)
2. The system provides the information necessary for the performance of the tasks? (yes or no question)
3. Has the user experience evolved positively over the use of the application? (yes or no question)
4. Does the system inform the user of the actions he is taking? (yes or no question)
5. Does the system have a confusing structure? (yes or no question)
6. How do you describe your experience using the app? (text question)
7. If you could change something in the application what would it be? (text question)

In the final considerations of the usability tests (Appendix D) it was reported that the application could be improved in design and faster navigation (with fewer clicks at the level of the navigation bar). There are also positive aspects such as the case of this being "*Easy, practical and intuitive*".

The testers reports also allowed to identify and correct some of the application flaws (for example, the labels from dynamic select-box to add activities in goal) and identify its adherence to the proposed model. The main corrections occurred in the user interaction design (more understandable design and better-labelled inputs).

All the testers provided a positive feedback about the forms, the dashboard, and the information required to complete the model. The access speed was acceptable as well as the accurate introduction of information. However, it is also possible to conclude that the application may not be straightforward for users with different backgrounds. Moreover, the model requires a significant number of clicks for configuring the model for first use (the goals, indicators, and so on). Only after the industry 4.0 strategy is defined it is possible to find more simple interactions – after the model is created, the user tasks are mainly related with updating maturity evaluations and define initiatives, which is more accessible to regular users. Therefore, a training session prior to the model adoption is essential.

7.2 Demonstration

This section demonstrates the adoption of the proposed model in the organizational setting. The sequence of steps to apply to the proposed artefact are presented as follows (used in the final evaluation made by the case company and also interesting as a tutorial to use the tool):

- Identify the company goals for the five strategic dimensions (or for the additional Industry 4.0 perspective if a traditional BSC is already in use in the organization);

Add "Processes" perspective goal

Goal 1	
Metrics:	
1 – Reduce the waiting time of wooden trucks;	
Target value / Actual value:	
1 – 60 / 120 (minutes)	
1. Ensure in advance that trucks and truckers have documentation in the systems (e.g. registration and internal safety standards); 2. Create a management system on a first-come, first-served basis that guides them to the factory from arrival to departure;	

Figure 7.11 Example of elements necessary to identify each strategic goal

The original Balanced Scorecard guidance is used for the step of adding goals: (1) each goal is associated with a perspective, (2) has a metric, (3) must be measured in the present and identified the target to achieve in the future, and (4) has initiatives aiming to achieve that target.

After identifying all the goals, it is necessary to link them (some goals can influence others, in the same perspective or in different perspectives).

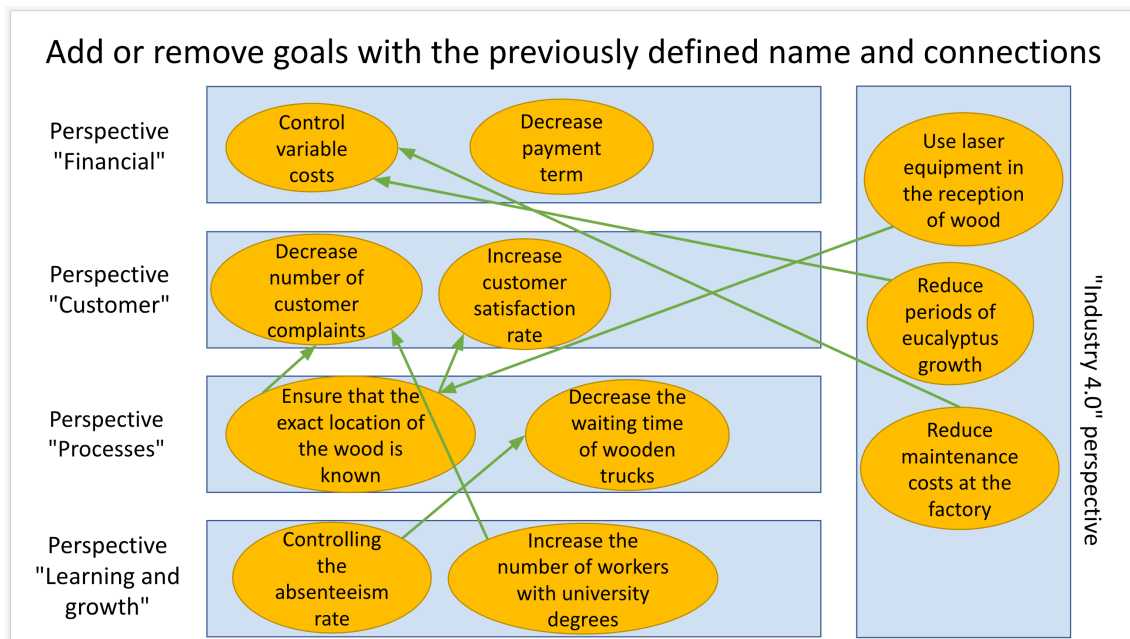


Figure 7.12 Identify the company goals connections

- Identify the most relevant maturity models for the organizational strategy and, for each one, which fragments to adopt (the company selected three examples extracted from 24 maturity models found during this dissertation). Figure 7.13 presents a fragment used by the company (a fragment of the maturity model “The Digital Maturity Model 4.0”).

Industry 4.0; Reduce maintenance costs		
	0 = Completely disagree 1 = Somewhat disagree 2 = Somewhat agree 3 = Completely agree	
Technology	“How much do you agree with each of the following statements?” (0,1,2,3)	
	Current	Ambition
Our technology budget is fluid to allow for shifting priorities	0	2
Our marketing and technology resources work together to co-create our digital technology road map	0	0
We have a flexible, iterative, and collaborative approach to technology development	0	2
We leverage modern architectures (APIs, cloud, etc.) to promote speed and flexibility	1	2
We measure our technology teams by business outcomes not just system up-time	0	2
We use customer experience assets, like personas and journey maps, to steer our technology design	0	2
We use digital tools to promote employee innovation, collaboration, and mobility	2	3

Model: The Digital Maturity Model 4.0 Benchmarks: Digital Business Transformation Playbook

Figure 7.13 Identify the most relevant maturity models fragments

- Create the strategy map and link each goal with the maturity model fragments that can contribute to its sustained performance over time.
- Define the (1) metrics (e.g. number of electric motors with remote monitoring), (2) target (e.g. 50%), and (3) an action plan. For (1) and (2) follow the normal procedure when using a BSC. For (3), take into account the recommendations of the selected maturity model fragments on how to achieve a higher maturity level for the topics at hand. Maturity models are an important source of ideas for the initiatives in industry 4.0 strategy (for example, the company can select actions that aim to achieve a higher level of maturity).
- Evaluate the results of strategy implementation. Refine the association of goals and maturity model fragments. Fragments can be replaced over time, if the desired maturity has been achieved or if the results are not satisfactory.

Figure 7.14 shows the main dashboard of BSC-MM for our case company (the arrows are not yet available in the current version of the tool – added to clarify that there are relations between the goals).

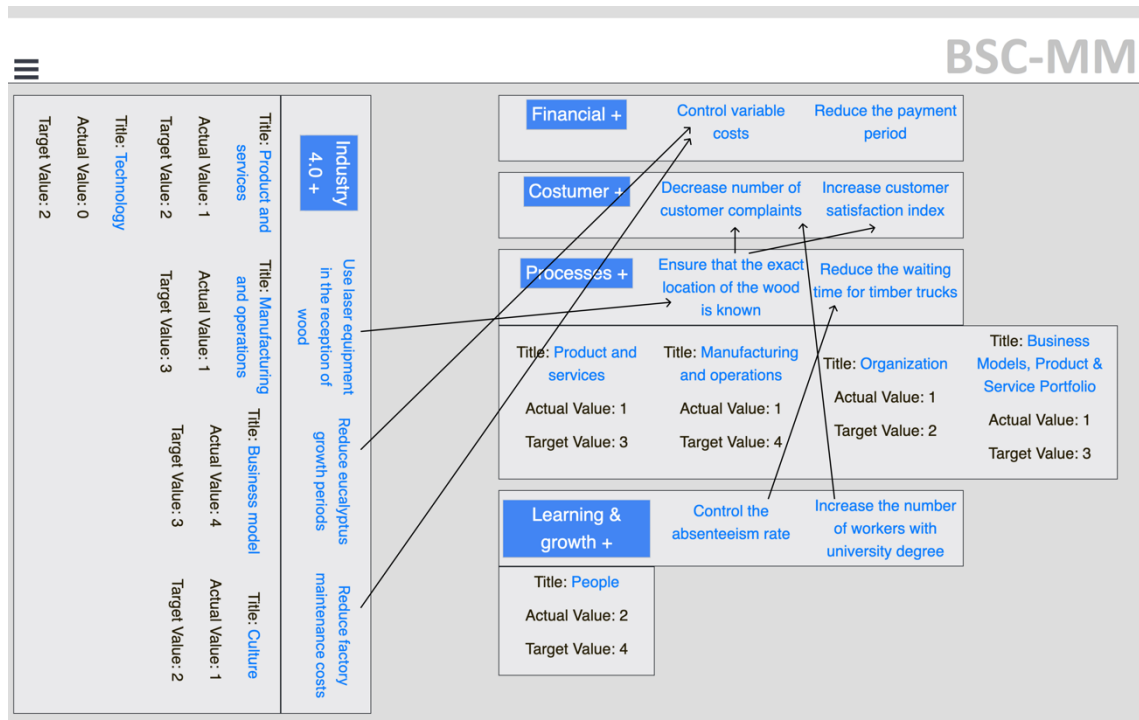


Figure 7.14 BSC-MM instantiation in the paper pulp industry (dashboard with the case company data)

The extract of the strategy map for Industry 4.0 (vertical perspective on the left of Figure 7.14), identifies three main priorities for industry 4.0 investments, namely: (1) “Use laser equipment at the reception of wood” for automatic quality control; (2) “Reduce eucalyptus growth period” using advanced sensor technology, and artificial intelligence algorithms, and; (3) “Reduce factory maintenance costs” taking advantage of predictive maintenance supported by a combination of technologies such as cloud, IoT, 5G, and AI-driven automation [106].

The summary of each maturity model fragment assessment (actual and target stage) is included in the dashboard. Examples of fragments selected are “Product and services” and “Manufacturing and operations” extracted from University of Warwick [35], Business Models, Product & Service Portfolio from PwC [33], or Culture, Organization, and Technology, which are useful parts (according to the case company decisions) of the model proposed by Forrester research [5].

The arrows connect Industry 4.0 strategy goals and other type of goals (e.g., “Reduce factory maintenance cost” associated with Industry 4.0 investments is linked to “Control variable costs” in the financial perspective). A drill down of the goals in each perspective allows to see the actions that need to be done in order to achieve the desired goal and try to reach the target maturity level that may contribute to its performance over time. This feature (arrows connect) interface has not yet been implemented and is defined as future implementation work.

The “Processes” perspective presented in Figure 7.14 (on the right; the “plus sign” button is used to add goals to that perspective or maturity fragments below) includes two strategic goals related to knowing the location of wood (the most important raw material for the company that needs to be traced) and reduction of waiting time when delivering the wood. Each of these two goals has indicators, following the traditional BSC adoption but also have four maturity model fragments selected by the company to improve the goal achievement.

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This contrast of “*company goals*” and “*mature practices*” provides a richer evaluation of the strategy, for example, the metrics related to the two goals may be compliant to what is expected (e.g. the average waiting time is below 30 minutes) but the maturity evaluation may have a different result – maturity evaluates the possibility to sustain the indicators over time in the desirable stage, while the traditional BSC indicators are usually addressing the present moment of the organization.

Question 0 - Awareness of 'As a service' business model

Actual Value Target Value

Question 1 - Data driven decisions

Actual Value Target Value

Question 2 - Real-time tracking

Actual Value Target Value

Question 3 - IT supported business

Actual Value Target Value

submit new answers

Historic:

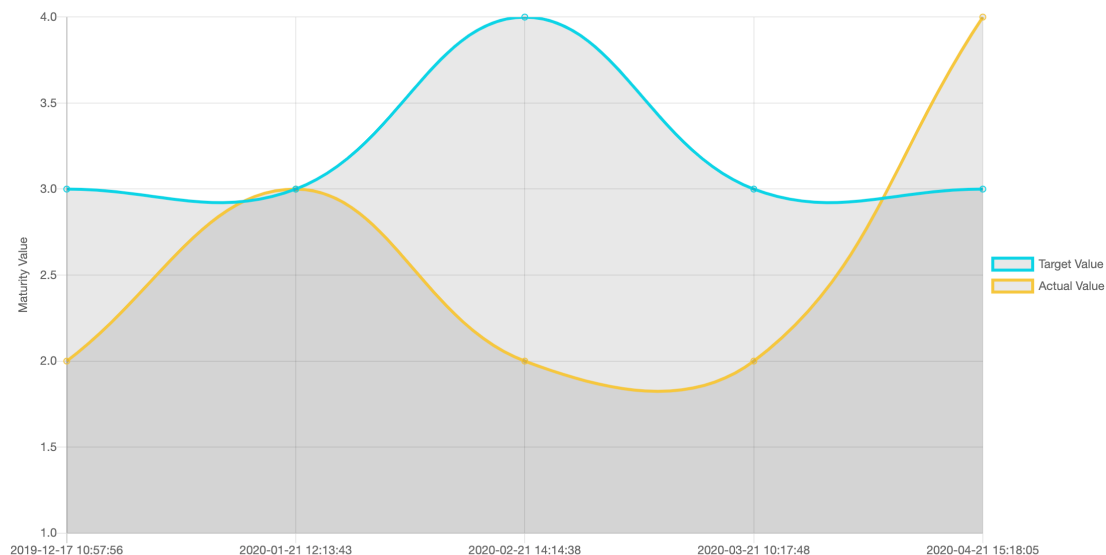


Figure 7.15 Supporting Tool Interface Example
(maturity model fragment with four questions and visualization of the measurement over time)

Figure 7.15 presents the web form used to fill new data in a specific maturity model fragment (on the top, using four questions selected by the company) and the evolution of the actual (orange) and target value (blue). The subsequent identification of BSC-MM initiatives (not prescriptive, as happens in current maturity models, but as a suggestion of practices that must be discussed in the organization) uses only the useful fragments. By “*useful*”, means the part of the original maturity model tailored to the company strategy, obtaining commitment from the managers in their Industry 4.0 navigation map.

7.3 Case Company Evaluation

The meetings with the IT department at CELBI were crucial for the development of the model and its supporting web application. Several meetings occurred during the project development. This section summarizes the final test and validation.

This final stage of the dissertation aimed to confirm the potential and value of the model to design and steer industry 4.0 strategies in a real organization, and ensure an independent assessment without pre-defined tasks (as happened with the usability tests). The application was hosted online and running in a production environment.

The final meeting was scheduled via Skype with screen sharing to access the user's behaviours within the system. In the beginning, a live demonstration was performed. The demonstration used real data and aimed to present the latest features of the system as a tutorial before the final test performed by the company.

The participants started a new and empty account. The IT manager had the possibility to ask questions during the final test, for example, to assist in the selection of goals that could be related to each perspective. The steps were:

1. Added a goal with the title "*Ensure that the exact location of the wood is known*" in the process perspective. After adding the goal, he asked about the various elements possible to add within it (metrics, activities and connections);
2. Added a metric (within the goal recorded in 1) with the title "*Know the exact location of the wood*", with the description "*Ensure that the exact location of the wood is known (FSC certifying entities)*";
3. Added an activity (within the goal registered in 1) with the title "*Monitor wood traceability from its origin (land/plot)*";
4. Accessed the navigation bar, in which he asked a summary of what each of the components presented;
5. He returned to the main page and created a new goal with the title "*Decrease number of customer complaints*" in the customer perspective. He registered this goal to test the functionality of connections between goals;
6. Created a dependency connection between the goal "*Ensure the exact location of the wood is known*" and "*Decrease number of customer complaints*";
7. Accessed the registration page for maturity model fragments without having registered any, the point was to see the elements that were necessary to register a maturity model fragment;
8. Next, he tried to answer a maturity model fragment in the Industry 4.0 perspective. Having responded to the maturity model fragment "*Technology*";
9. After submitting the form and being redirected to the answer maturity model fragment page, he answered the questions again to verify the values to be recorded in the history and appear in the maturity level progression graph.

No bugs or problems were detected during the final test. The IT manager affirmed that the application was quick and "*engaged user experience*". He underlined that, for a first version of the application proposing an innovative model, the system presented all the required elements and an advanced structure without major flaws.

The IT manager was very interested in how the values of the maturity model fragments could be analysed (e.g. trends, relation with the initiates) and the value that this would bring to the analysis of the company's maturity in a digital transformation process. He said that trends could also be developed for the metrics (only the maturity assessment had charts at this stage). The user also reported some difficulties to record activities using the dynamic select-box.

The IT manager presented suggestions regarding the benchmark of a company's maturity values to compare with the rest of the industry (similar to online maturity models – adding

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more organizations to the platform would allow comparing the results, however, much more values are necessary to allow this comparison) and the implementation of templates to make it is easier to introduce default information (for example, goals suggested for each perspective). These suggestions are also aligned with the need previously identified to create more help to the users (e.g. videos, templates). Although the Balanced Scorecard is a popular tool, it is usual to conduct a training session before adopting it in the organization, therefore, a similar procedure needs to be followed in this case.

In a final phase of the meeting, the IT manager validated the application as *“useful for a company in digital transformation process”*.

Chapter 8

Final Considerations

This chapter sets out the final considerations on the work done, listing the major obstacles encountered, presenting a critical reflection on the complete process, stating the limitations in the proposed model and the web application development, and suggesting opportunities for future work.

8.1 Conclusion

This master's dissertation presents a new Industry 4.0 model for companies, named BSC-MM, to implement a continuous diagnosis and execution of industry 4.0 strategies. The dissertation was conducted in a leading paper pulp company listed in the PSI-20 on the Euronext Lisbon stock exchange. The contact with the case company allowed access to real data and feedback from their experts. The insight gathered in the company intervention were important to confirm that the model is useful to evaluate the maturity and guide strategic decisions on industry 4.0.

The work carried out was divided into five stages, namely, (1) literature review, (2) model proposal, (3) Software Requirements Specification and architecture, (4) implementation, and (5) testing.

The literature review enabled the understanding of Industry 4.0 adoption and the impact that technologies have on the competitiveness. Moreover, different maturity models were compared. However, it was also clear that companies have differences and "*template models*", although important assessment, are limited for the long-term support. It was possible to confirm that new solutions to assist industry 4.0 adoption were possible and desirable.

A new model was developed in cooperation with a major industrial company (CELBI - Celulose da Beira Industrial, SA). Their participation allowed to clarify the limitations of maturity models and identify a strategic management tool that they were already familiar with: balanced scorecard. The integration of both concepts was made as follows: (1) the balanced scorecard was not made for Industry 4.0, therefore, an additional perspective was added and (2) not all the dimensions of maturity models are relevant to company characteristics, therefore, only relevant parts or fragments are used.

The next phase concerns the development of a software solution to support the operationalization of the new model. The software requirements specification preceded the web application development. A total of 27 functional requirements were characterized by an ID, an abstraction level, the stakeholders, a priority, a precondition, the main success scenario, one or more extensions, a post-condition and a story. Twenty two were considered critical to the success of the project ("*must have*") and 5 desirable ("*could have*"). Moreover, the design of the software architecture was established in two units, front-end (implemented in React.js) and a back-end (implemented in Node.js with Express and a MySQL database).

The implementation followed, describing the logic of development, with the exhibition and explanation of specific parts of code. The application was developed in JavaScript with a MySQL database and also hosted in Heroku a Platform as a service (PAAS). The development has followed a methodology inspired in SCRUM adapted to a single element.

Finally, the model and its supporting tool were tested. The final test found no errors and all functional requirements were validated by the testers. Still, to complete the testing process, both the model and the application were validated by the case company. Their feedback was positive and encouraging. All the main deadlines have been met and all the functionalities defined in the SRS have been implemented.

The proposed model has solid foundations in the literature and the initial version of the web application can assist companies in a comprehensive industry 4.0 strategy. The outcomes of this work may help companies evaluating how their actions (e.g. IT investments, software development projects) are contributing to (1) increase the company maturity in industry 4.0 and (2) achieve the desired organizational goals.

Considering the novelty of this topic, a scientific paper was written with the title "*Crafting Strategies for Industry 4.0: Extending the Balanced Scorecard with Maturity Model Fragments*". The original plan was to submit the paper to the 29th International Conference on Information Systems Development, unfortunately postponed to 2021 due to COVID-19. It was then decided to extend the first version of the paper and send it to a journal indexed in Web of Science. The paper has passed the initial screen by the editor and is currently under review.

8.2 Study limitations

The main goals and the success criteria for this work have been accomplished. However, there are also limitations to consider.

First, a broader generalization of the results requires testing of the approach and the model in companies of different industries and sizes. The IT department of the case company has the skills and the motivation to adopt the new tool but smaller organizations or different sectors of the economy may face different challenges, including finding suitable many maturity models.

Second, in spite of the various iterations in refining the model, and its apparent fit with the problem of the case company, only a longitudinal study (involving the observations of the results over a longer period of time) can provide a full evaluation of its effectiveness in helping successfully craft an Industry 4.0 strategy.

Third, maturity models have internal consistency, so mixing and matching fragments from different ones must be made with extreme care. When selecting a fragment from a given maturity level, it is critical to ensure that any preconditions are met by the company (e.g., one cannot quantitatively manage without reliable KPI collection). Maturity levels from different models may not be aligned, so a common characterization is required.

Fourth, there are other possible stakeholders, for example, the employees to evaluate the indicators of their work/department, however, this was the first version of the web application focusing in the most direct participants in the strategy design. There is still much to be improved in new application features. Suggestions for future work are made in the report.

Despite the inherent limitations, the knowledge obtained during this demanding process of both model and tool development, contacts with a major company, and writing of a paper was extremely rewarding and positive.

8.3 Future Research/Development

A new model to adopt industry 4.0 was proposed and the requirements of the web application were implemented and tested. However, there are always opportunities for future improvements, namely:

- Benchmarking of the company's maturity (from the maturity model fragments) contrasting with the rest of the industry (similar to online maturity models). This possibility will require changing the application to be accessible by multiple companies;
- Creation of an online maturity model portfolio to facilitate their identification and adoption by organizations. A wider database of fragments may give more visibility to existing maturity models and facilitate the company selection;
- Improve the graphical interface of the web application, making it more appealing and intuitive, according to the recommendations made in the testing phase;
- Include other types of stakeholders in the next version of the web application (for example, the employees to evaluate the indicators of their work/department);
- Continue studying the model adoption in the case company and in other organizations with different sizes, and in distinct sectors of the economy.

Industry 4.0 is a long-term challenge to industries. Proposing an innovative way of adapting maturity models and balanced scorecard can assist companies in the definition of strategies, and continuous improvement of their processes supported by digital technologies.

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Appendices

Appendix A Review of Maturity Models for Industry 4.0

A review of Maturity Model for Industry 4.0 table

	Dimensions / maturity items	# Sub Dimensions	Stages/Levels (segment)	Levels of Maturity	Origin	Tool to support	Link	Form of displaying information	Year
IMPULS – Industrie 4.0 Readiness	Strategy and organization; Smart factories; Smart operations; Smart products; Data-driven services; Employees	13	Not staged	0 (min) - 5 (max)	Professional (Impuls Foundation of VDMA)	Online Questionnaire	Tool - https://www.industrie40-readiness.de/?lang=em ; Document - https://industrie40.vdma.org/documents/4214230/26342484/Industrie_40_Readiness_Study_1529498007918.pdf/0b5fd521-9ee2-2de0-f377-93bdd01ed1c8 [last accessed 10-02-2020]	Weights; Level in each dimension	2015
PWC maturity model - Industry 4.0	Digital business models and customer access; Digitization of product and service offerings; Digitization and integration of vertical and horizontal value chains; Data & Analytics as core capability; Agile IT architecture; Compliance, security, legal & tax; Organization employees and digital culture	0	1. Digital Novice; 2. Vertical Integrator; 3. Horizontal Collaborator; 4. Digital Champion;	Are Stages	Professional (PWC)	Online Questionnaire	Tool - https://i40-self-assessment.pwc.de/i40/landing/ ; Document - https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf [last accessed 10-02-2020]	Radar chart (n dimensions); Stage in the Maturity Model	2016
Shift 4.0	Strategy and organization; Smart factories; Smart operations; Smart products; Data-driven services; Employees	18	Not staged	0 (min) - 5 (max)	Governmental	Online Questionnaire	Tool - https://i40-self-assessment.pwc.de/i40/landing/ ; Document - https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf [last accessed 10-02-2020]	Weights; Level in each dimension	2019

	Dimensions / maturity items	# Sub Dimensions	Stages/Levels (segment)	Levels of Maturity	Origin	Tool to support	Link	Form of displaying information	Year
Three stage maturity model in SME's toward industry 4.0	Are perspectives of the stages (market, product, process, and value network)	-	1. Envision; 2. Enable; 3. Enact	1 (min) - 5 (max)	Academic (Journal of Industrial Engineering and Management)	No	Document - https://www.researchgate.net/publication/311780363_Three_stage_maturity_model_in_SME's_toward_industry_40 [last accessed 10-02-2020]	Descriptive	2016
Development of a Digitalization Maturity Model for the manufacturing sector	Strategy; Processes; Technologies; Products & Services; People	0	1. Digitalization maturity assessment; 2. Process related analysis; 3. Activity based requirements	0 (min) - 3 (max)	Academic (University of Applied Sciences and Arts of Southern Switzerland)	Questionnaire	Document - https://www.researchgate.net/publication/327065365_Development_of_a_Digitalization_Maturity_Model_for_the_Manufacturing_Sector [last accessed 10-02-2020]	Radar chart (n dimensions); Overall Maturity Level (OML) calculated	2018
A Maturity Model for accessing Industry 4.0 readiness and maturity of manufacturing enterprises	Strategy; Leadership; Customers; Products; Operations; Culture; People; Governance; Technology	0	Not staged	1 (min) - 5 (max)	Academic (Fraunhofer Austria Research GmbH; ienna University of Technology, Institut of Management Science)	Questionnaire	Document - https://www.sciencedirect.com/science/article/pii/S2212827116307909 [last accessed 10-02-2020]	Radar chart (n dimensions);	2016
SIMMI 4.0 – A Maturity Model for Classifying the Enterprise-wide IT and Software Landscape Focusing on Industry 4.0	Vertical integration; Horizontal integration; Digital product development; Cross-sectional technology criteria	0	1. Basic digitization level; 2. Cross-departmental digitization; 3. Horizontal and vertical digitization; 4. Full digitization; 5. Optimized full digitization	-	Academic (Technische Universität Dresden; University of Applied Sciences Heilbronn)	None	Document - https://www.researchgate.net/publication/311780363_Three_stage_maturity_model_in_SME's_toward_industry_40 [last accessed 10-02-2020]	The actual stage of the company	
M2DDM – A Maturity Model for Data-Driven Manufacturing from University Stuttgart	-	-	0. Nonexistent IT Integration; 1. Data and System Integration; 2. integration of Cross-Life-Cycle Data; 3. Service-Orientation; 4. Digital Twin;	-	Academic(Graduate School advanced Manufacturing Engineering, University of Stuttgart)	None	Document - https://www.sciencedirect.com/science/article/pii/S2212827117304973 [last accessed 10-02-2020]	The actual stage of the company	2017

	Dimensions / maturity items	# Sub Dimensions	Stages/Levels (segment)	Levels of Maturity	Origin	Tool to support	Link	Form of displaying information	Year
HADA advanced digital selfdiagnostic tool Ministerio de economía, industria y competitividad	Business and Market Strategy; Processes; Organization and People; Infrastructures; Products and services	16	Not staged	0 (min) - 10 (max)	Governmental	Online Questionnaire	Tool - https://hada.industriaconectada40.gob.es/hada/register ; Document - https://hada.industriaconectada40.gob.es/hada/data/manual/Manual_usuario_HADA.pdf [last accessed 10-02-2020]	Benchmarking Radar chart (n dimensions); Level in each dimension	2016
A maturity assessment approach for conceiving context-specific roadmaps in the Industry 4.0 era	Governance; Technology; Connectivity; Value creation; Competences	0	1. Creation of awareness; 2. Definition of scope; 3. Data collection; 4. Evaluation and solution selection; 5. Debriefing	1 (min) - 6 (max)	Academic (Aalborg University, Denmark; Brandenburg University of Technology, Germany)	Questionnaire	Document - https://www.sciencedirect.com/science/article/pii/S1367578819300409 [last accessed 10-02-2020]	Radar chart (n dimensions)	2019
Digital Maturity Model (Deloitte)	Customer; Strategy; Technology; Operations; Organization & Culture	28	1. Imagine; 2. Deliver; 3. Run	-	Professional (Deloitte)	Documentation	Document - https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Tech-Telecommunications/deloitte-digital-maturity-model.pdf [last accessed 10-02-2020]	-	2018
Maturity Levels For Logistics 4.0 Based On NrW'S Industry 4.0 Maturity Model	Flow in purchasing logistic; Flow in internal logistics; Distribution logistic; Logistics subsystems	0	Not staged	1 (min) - 5 (max)	Academic (University of Maribor, Faculty of logistics in Celje, Slovenia)	Documentation	Document - https://www.researchgate.net/publication/329371288_Maturity_Levels_For_Logistics_40_Based_On_Nrw'S_Industry_40_Maturity_Model [last accessed 10-02-2020]	Actual level in each dimension	2018
Reifegradmodell Industrie 4.0. Unternehmen durch Industrie 4.0 stärken	Dimensions data; Intelligence; Digital transformation	23	1. Initial situation; 2. Potencial	0 (min) - 10 (max)	Professional (OÖ Wirtschaftsagentur GmbH)	Documentation	Document - https://research.fh-ooe.at/data/files/publications/5376_Reifegradmodell_I40.pdf [last accessed 10-02-2020]	3 dimensional table with the level in each dimension	2016
DREAMY (The Digital Readiness Assessment Maturity Model)	Monitoring & control; Technology; Process; Organization	0	1. Design & engineering; 2. Production Management; 3. Quality Management; 4. Maintenance management;	1 (min) - 5 (max)	Academic (Politecnico di Milano)	Online Questionnaire	Tool - https://www.testindustria40.com/ ; Document - https://www.alpine-space.eu/projects/smart-space/results/wpt3/smart-space sv7 dreamy assessment and	Radar chart (n dimensions)	2017

Dimensions / maturity items	# Sub Dimensions	Stages/Levels (segment)	Levels of Maturity	Origin	Tool to support	Link	Form of displaying information	Year
		5. Logistics Management; 6 - Supply chain management				_testindustria4.0_politecnico.pdf ; [last accessed 10-02-2020]		
Development of an Assessment Model for Industry 4.0: Industry 4.0-MM	0	Not staged	0 (min) - 5 (max)	Academic (Middle East Technical University)	Documentation	Document - https://www.researchgate.net/publication/319640255_Development_of_an_Assessment_Model_for_Industry_40_Industry_40-MM [last accessed 10-02-2020]	Actual level in each dimension	2017
An Industry 4 readiness assessment tool	37	Not staged	1 (min) - 4 (max)	Academic (University of Warwick)	Documentation	Document - https://warwick.ac.uk/fac/sci/wmg/research/scip/reports/final_version_of_i4_report_for_use_on_websites.pdf [last accessed 10-02-2020]	Actual level in each sub-dimension	2018
APM Maturity Model (Asset Performance Management Maturity Model)	0	1. Benchmarking; 2. Process Assessment; 3. Technology Assessment; 4. Recommendation	0 (min) - 4 (max)	Professional (Capgemini)	Documentation	Document - https://www.capgemini.com/wp-content/uploads/2017/08/asset_performance_management_maturity_model_paper_web_version.pdf [last accessed 10-02-2020]	Actual level in each dimension	2018
The Connected Enterprise Maturity Model from Rockwell Automation	-	1. Assessment; 2. Secure and upgraded network and controls; 3. Defined and organized working data capital (WDC); 4. Analytics; 5. Collaboration	-	Professional (Rockwell Automation)	Documentation	Document - https://literature.rockwellautomation.com/idc/groups/literature/documents/wp/cie-wp002_en-p.pdf [last accessed 10-02-2020]	-	2014
Industrie 4.0 Maturity Model	0	1. Computerization; 2. Connectivity; 3. Visibility; 4. Transparency; 5. Predictability; 6. Adaptability	1 (min) - 6 (max)	Professional (infosys)	Documentation	Document - https://www.infosys.com/services/engineering-services/white-paper/documents/industry-4.0-real.pdf [last accessed 10-02-2020]	Actual level in each dimension	2018
VTT Model of Digimaturity (VMoD)	0	1. Understand your organization's digimaturity level; 2. Select potential improvement steps	1 (min) - 4 (max)	Professional (VTT Technical Research Centre of Finland)	Online Questionnaire	Tool - https://digimaturity.vtt.fi/ ; Document - https://www.researchgate.net/publication/315103718_VTT_Model_of_Di	Radar chart (n dimensions)	2017

	Dimensions / maturity items	# Sub Dimensions	Stages/Levels (segment)	Levels of Maturity	Origin	Tool to support	Link	Form of displaying information	Year
							gimaturity [last accessed 10-02-2020]		
Stages in Digital Business Transformation: Results of an Empirical Maturity Study	Customer Experience; Product Innovation; Strategy; Organization; Process Digitization; Collaboration; Information Technology; Culture & Expertise; Transformation Management	25	1. Promote & Support; 2. Create & Build; 3. Commit to transform; 4. User-centered & elaborated processes; 5. Data-driven enterprise;	-	Academic (University of St. Gallen)	Questionnaire	Document - https://pdfs.semanticscholar.org/d416/aa50e0eb6abb3f5e6e5fa071931f9a494d28.pdf [last accessed 10-02-2020]	-	2016
dStrategy Media Introducing the dStrategy Digital Maturity Model	Human Resources; Technology Resources; Data Strategy; Content Strategy; Channel Strategy; Social Business Strategy;	0	-	0 (min) - 3 (max)	Professional (dStrategy Media)	Documentation	Document - https://www.onlineauthority.com/blog/introducing-dstrategy-digital-maturity-model/ [last accessed 10-02-2020]	Radar chart (n dimensions)	2014
Forrester The Digital Maturity Model 4.0	Culture; Technology; Organization; Insights;	0	-	0 (min) - 84 (max)	Professional (Forrester)	Documentation	Document - https://forrester.nitro-digital.com/pdf/Forrester-s%20Digital%20Maturity%20Model%204.0.pdf [last accessed 10-02-2020]	Actual level in each dimension	2016

Appendix B Estimation Bottom-up Form

Individual tasks estimation table

Tasks	Best Case	Most Likely Case	Worst Case	Expected Case	Assumptions
Login React.js	4	5	9	5,50	Must have requirement; Front-end.
Login Node.js	6	7	10	7,33	Must have requirement; Back-end.
Logout	3	5	7	5,00	Must have requirement; Front-end; Back-end.
Add goal React.js	7	9	12	9,17	Must have requirement; Front-end.
Add goal Node.js	8	10	12	10,00	Must have requirement; Back-end.
List goals React.js	6	7	8	7,00	Must have requirement; Front-end.
List goals Node.js	5	7	8	6,83	Must have requirement; Back-end.
View goal details React.js	6	8	10	8,00	Must have requirement; Front-end.
View goal details Node.js	7	8	10	8,17	Must have requirement; Back-end.
Remove goal React.js	6	8	9	7,83	Must have requirement; Front-end.
Remove goal Node.js	7	8	10	8,17	Must have requirement; Back-end.
Edit goal data React.js	8	9	10	9,00	Must have requirement; Front-end.
Edit goal data Node.js	8	8	10	8,33	Must have requirement; Back-end.
Add metric to a goal React.js	7	6	9	6,67	Must have requirement; Front-end.
Add metric to a goal Node.js	7	7	9	7,33	Must have requirement; Back-end.
Edit metric inside a goal React.js	6	7	9	7,17	Must have requirement; Front-end.

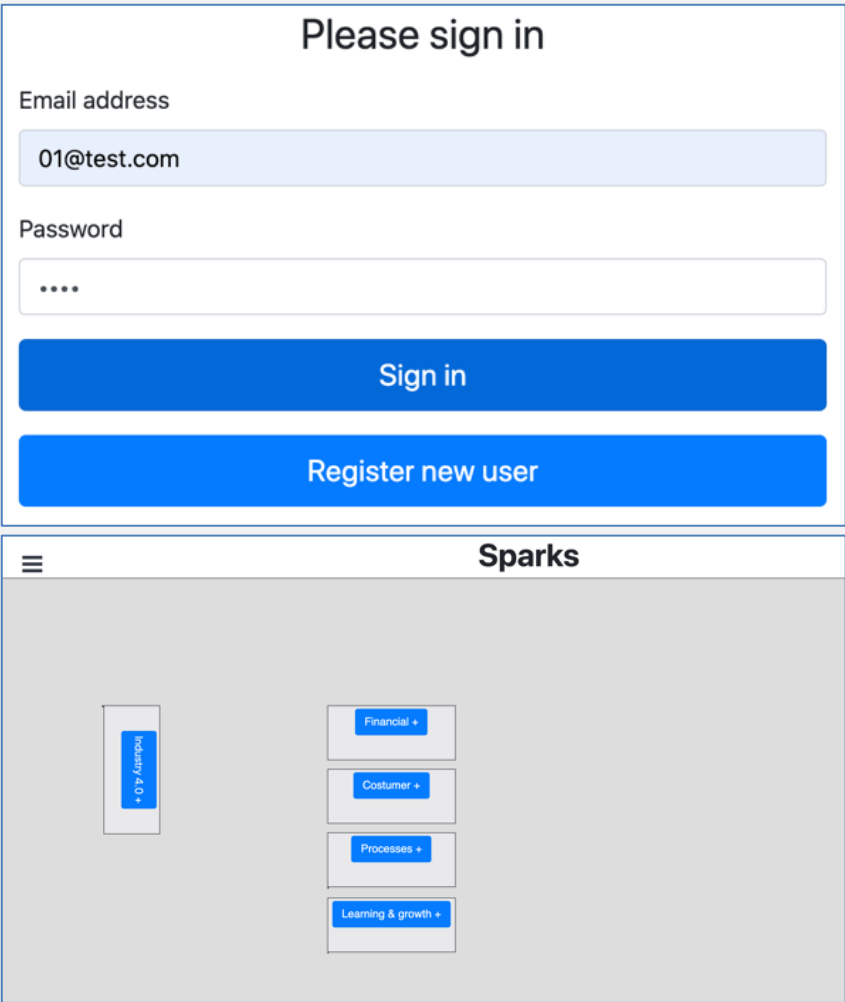
Tasks	Best Case	Most Likely Case	Worst Case	Expected Case	Assumptions
Edit metric inside a goal Node.js	7	8	9	8,00	Must have requirement; Back-end.
Remove metric inside a goal React.js	6	7	9	7,17	Must have requirement; Front-end.
Remove metric inside a goal Node.js	7	8	9	8,00	Must have requirement; Back-end.
Add a new activity to a goal React.js	7	8	8	7,83	Could have requirement; Front-end.
Add a new activity to a goal Node.js	6	7	8	7,00	Could have requirement; Back-end.
Add an existing activity to goal React.js	6	7	9	7,17	Could have requirement; Front-end;
Add an existing activity to goal Node.js	6	7	9	7,17	Could have requirement; Back-end.
Set activity as done React.js	4	6	7	5,83	Could have requirement; Front-end.
Set activity as done Node.js	5	7	8	6,83	Could have requirement; Back-end.
Add a connection between goals React.js	6	7	9	7,17	Must have requirement; Front-end.
Add a connection between goals Node.js	6	8	9	7,83	Must have requirement; Back-end.
Remove a connection React.js	4	5	8	5,33	Must have requirement; Front-end.
Remove a connection Node.js	5	6	8	6,17	Must have requirement; Back-end.
Register new maturity model fragment React.js	6	7	10	7,33	Must have requirement; Front-end.
Register new maturity model fragment Node.js	7	8	10	8,17	Must have requirement; Back-end.
List maturity model fragment React.js	6	7	9	7,17	Must have requirement; Front-end.
List maturity model fragment Node.js	6	7	9	7,17	Must have requirement; Back-end.
Search inside maturity model fragments list React.js	6	7	8	7,00	Could have requirement; Front-end.
Search inside maturity model fragments list Node.js	5	6	7	6,00	Could have requirement; Back-end.
View maturity model fragment details React.js	6	7	9	7,17	Must have requirement; Front-end.

Tasks	Best Case	Most Likely Case	Worst Case	Expected Case	Assumptions
View maturity model fragment details Node.js	6	8	9	7,83	Must have requirement; Back-end.
Edit maturity model fragment React.js	5	7	9	7,00	Must have requirement; Front-end.
Edit maturity model fragment Node.js	6	7	9	7,17	Must have requirement; Back-end.
Add a question to a maturity model fragment React.js	5	6	8	6,17	Must have requirement; Front-end.
Add a question to a maturity model fragment Node.js	6	7	8	7,00	Must have requirement; Back-end.
Remove question inside a maturity model fragment React.js	4	6	8	6,00	Must have requirement; Front-end.
Remove question inside a maturity model fragment Node.js	5	7	9	7,00	Must have requirement; Back-end.
Answer maturity model fragment React.js	8	9	11	9,17	Must have requirement; Front-end.
Answer maturity model fragment Node.js	9	10	11	10,00	Must have requirement; Back-end.
Access to answered maturity model fragment data React.js	5	6	8	6,17	Must have requirement; Front-end.
Access to answered maturity model fragment data Node.js	6	7	8	7,00	Must have requirement; Back-end.
Re-answer maturity model fragment React.js	7	8	10	8,17	Could have requirement; Front-end.
Re-answer maturity model fragment Node.js	6	7	9	7,17	Could have requirement; Back-end.
Remove history answered maturity model fragment React.js	5	6	8	6,17	Must have requirement; Front-end.
Remove history answered maturity model fragment Node.js	6	7	8	7,00	Must have requirement; Back-end.
Access profile data React.js	2	3	5	3,17	Must have requirement; Front-end.
Access profile data Node.js	3	4	5	4,00	Must have requirement; Back-end.
MainPage showing the BSC with MMF model	24	27	33	27,50	Main component of the project showing the BSC with the MMF

Tasks	Best Case	Most Likely Case	Worst Case	Expected Case	Assumptions
Create Node.js server	3	4	6	4,17	Application architecture
Create React.js directory and install packages	1	3	6	3,17	Application architecture
Add JWT	5	8	10	7,83	Non-functional requirement security
Stylize front-end	16	21	22	20,33	CSS and BootStrap
Connect the Node.js server to the MySQL database	2	6	8	5,67	Sequelize
Create the database MySQL database and tables	6	10	16	10,33	Back-end.
Graph in maturity model fragment answer	3	4	5	4,00	react-chartjs-2 package
Navigation bar	3	5	8	5,17	react-burger-menu package
React route	6	7	9	7,17	Deploy and architecture
Deploy on Heroku	6	8	10	8,00	

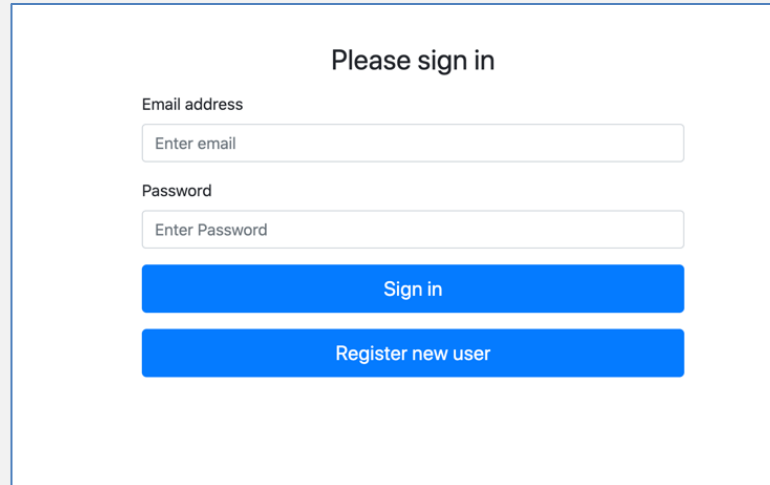
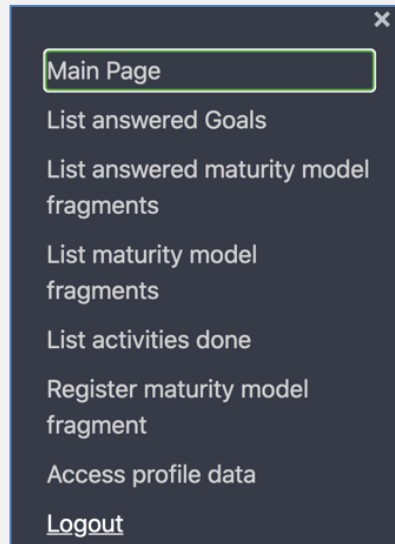
Appendix C Functional Testing

Functional testing Login.

ID:	1
Title:	Login
Main success scenario:	<ol style="list-style-type: none">1. The user inserts his credential in the appropriate fields;2. The user selects "Login";3. The system authenticates the user;4. Redirects to Main Page.
 <p>The top figure shows a login page titled "Please sign in". It features two input fields: "Email address" with the value "01@test.com" and "Password" with masked characters "....". Below the fields are two blue buttons: "Sign in" and "Register new user". The bottom figure shows the main page titled "Sparks". It has a hamburger menu icon on the left and a vertical list of four expandable menu items: "Financial +", "Customer +", "Processes +", and "Learning & growth +". A vertical card labeled "Industry 4.0 +" is positioned to the left of the menu items.</p>	
Top figure: Login page with the credentials	
Bottom figure: Main page	
Result:	Approved

Functional testing Logout.

ID:	2
Title:	Logout
Main success scenario:	<ol style="list-style-type: none">1. Press the hamburger button that will open a left navigation bar;2. Select the option "Logout";3. Redirects to Login Page.



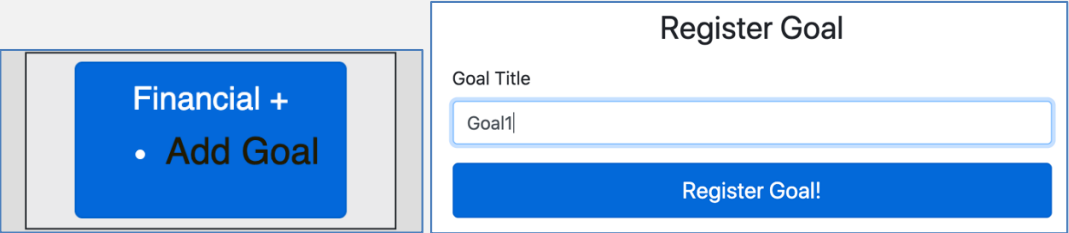
Top figure: Navigation box with Logout option

Bottom figure: Login page

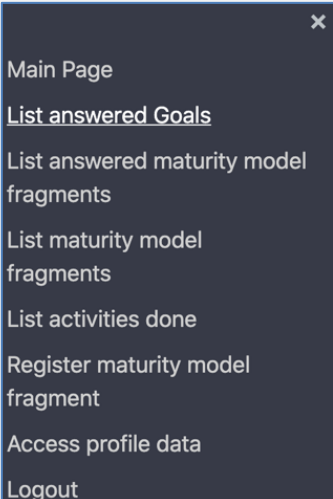
Result:

Approved

Functional Testing Add Goal.

ID:	3
Title:	Add goal
Main success scenario:	<ol style="list-style-type: none"> 1. In the perspective that pretend to add a goal the user selects the button “[perspective] +” on the left corner; 2. The user selects the option “Goal”; 3. Opens a new page on the browser where the user has to fill a form: (1) the goal title; 4. The user has to press “Register Goal” submitting the new goal. 5. The system saves the new goal. 6. The system redirects the user to the goal data page;
 <p>The image shows two screenshots. The left screenshot shows a blue button with the text 'Financial +' and a sub-menu containing 'Add Goal'. The right screenshot shows a 'Register Goal' form with a 'Goal Title' input field containing 'Goal1' and a 'Register Goal!' button.</p>	
<p>Left figure: Add Goal option Right figure: Register goal form</p>	
Result:	Approved

Functional testing List goals.

ID:	4
Title:	List goals
Main success scenario:	<ol style="list-style-type: none"> 1. Press the hamburger button that will open a left navigation bar; 2. Select the option “List all answered Goals”; 3. The system gets all registered goals and lists them;
 <p>The image shows a dark navigation menu with a close button (X) at the top right. The menu items are: Main Page, List answered Goals, List answered maturity model fragments, List maturity model fragments, List activities done, Register maturity model fragment, Access profile data, and Logout.</p>	

Goal: Goal1 Perspective: financial	2020-06-10 01:39:27
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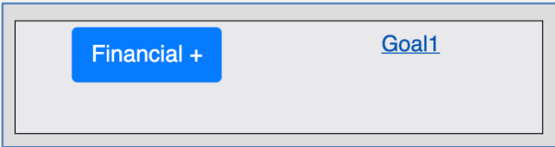
Top figure: Navigation box with List answered Goals option

Bottom figure: List answered goals page

Result: Approved

Functional testing View goal details.

ID:	5
Title:	View goal details
Main success scenario:	<ol style="list-style-type: none"> 1. The user selects a goal pressing his title; 2. The system redirects to the Goal Page; 3 The system gets all data of the goal and lists it;



Title: Goal1
Perspective: financial

Edit Remove

Metrics

Metric

Description

Actual value

Target value

Register Metric

Activities

Select...

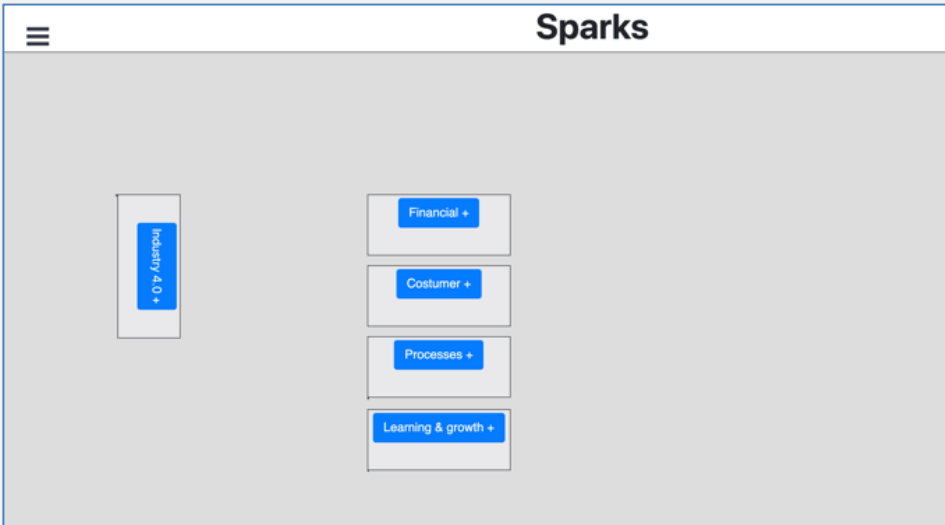
Register Activities

Top figure: Selects goal pressing his title

Bottom figure: Goal page

Result: Approved

Functional testing Remove goal.

ID:	6
Title:	Login
Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in "Remove" on the bottom of the goal data; 2. The system removes the goal; 3. Redirects to Main Page.
<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;"> <p>Title: Goal1</p> <p>Perspective: financial</p> <div style="display: flex; gap: 10px;"> Edit Remove </div> </div> 	
<p>Left figure: Remove goal button</p> <p>Right figure: Main page</p>	
Result:	Approved

Functional testing Edit goal data.

ID:	7
Title:	Edit goal data
Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in "Edit"; 2. The system creates a form with an input box and a select box under each of the details with the actual data; 3. The user makes the changes in the form; 4. The user selects "SubmitEdit"; 5. The system saves the edited goal; 6. The data refresh and the user sees new data in the goal.

Left figure: Edit goal button
 Middle figure: Editing goal
 Right figure: Goal data after editing

Result: Approved

Functional testing Add metric to goal.

ID:	8
Title:	Add metric to a goal
Main success scenario:	<ol style="list-style-type: none"> The user fills the form inside the goal with the title "Metrics": (1) Metric title; (2) Description; (3) Actual Value; (4) Target Value. The user clicks "Register Metric" submitting the new metric; The system saves the new metric.

Metrics

Metric

Description

Actual value

Target value

Register Metric

Metrics

Title:Metric1

Actual value:5%

Target Value:10%

Edit
Remove

Metric

Description

Actual value

Target value

Register Metric

Top figure: Add metric form

Bottom figure: After add metric submit

Result:	Approved
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Functional testing Edit metric inside a goal.

ID:	9
Title:	Edit metric inside a goal
Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in "Edit" on the bottom of the metric; 2. The system creates a form with input boxes under each of the details with the actual data; 3. The user makes the changes in the form; 4. The user selects "SubmitEdit"; 5. The system saves the edited metric; 6. The data refresh and the user sees new data in the metric.

Title:Metric1

Actual value:5%

Target Value:10%

Edit
Remove

Title:Metric1

Actual value:5%

Target Value:10%

SubmitEdit
Remove

Title:MetricEdit1

Actual value:5%

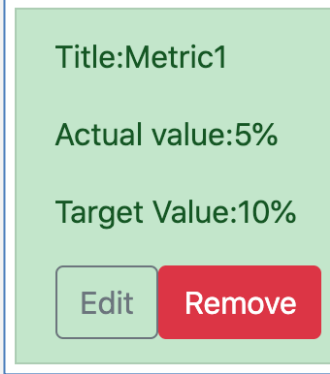
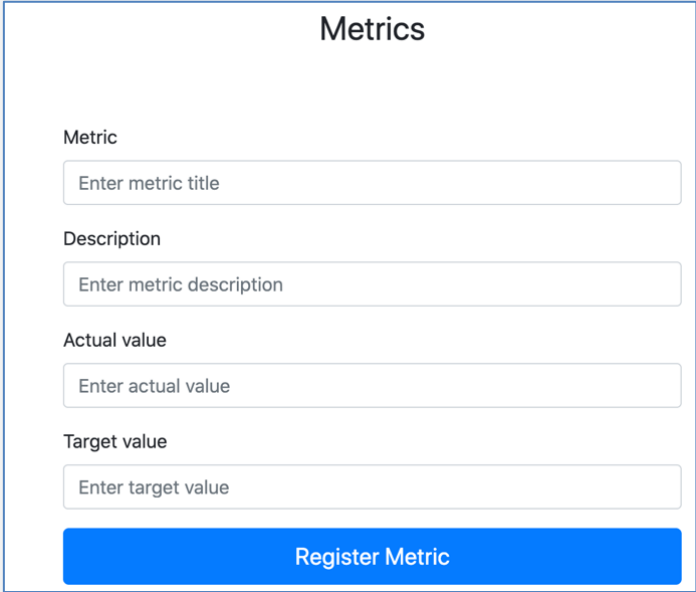
Target Value:10%

Edit
Remove

Left figure: Edit metric button
 Middle figure: Editing metric
 Right figure: Metric data after editing

Result: **Approved**

Functional testing Remove metric inside a goal.

ID:	10
Title:	Remove metric inside a goal
Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in "Remove" on the bottom of the metric; 2. The system removes the metric; 3. The metric list refresh without the metric.
 <p>The screenshot shows a green metric card with the following text: 'Title:Metric1', 'Actual value:5%', and 'Target Value:10%'. At the bottom, there are two buttons: 'Edit' (grey) and 'Remove' (red).</p>	 <p>The screenshot shows a form titled 'Metrics' with the following fields: 'Metric' (input: 'Enter metric title'), 'Description' (input: 'Enter metric description'), 'Actual value' (input: 'Enter actual value'), and 'Target value' (input: 'Enter target value'). A blue 'Register Metric' button is at the bottom.</p>
Left figure: Remove metric button Right figure: Metric removed	
Result:	Approved

Functional testing Add a new activity to a goal.

ID:	11
Title:	Add a new activity to a goal
Main success scenario:	<ol style="list-style-type: none"> 1. The user selects the select-box inside the goal with the title "Activities"; 2. Inserts the title of new activity; 3. The user selects "Create [title of the activity]" 4. The user clicks "Register Activities" submitting the new activity; 5. The system saves the new activity.

Top figure: Create new activity

Bottom figure: Register new activity

Result: **Approved**

Functional testing Add an existing activity to goal.

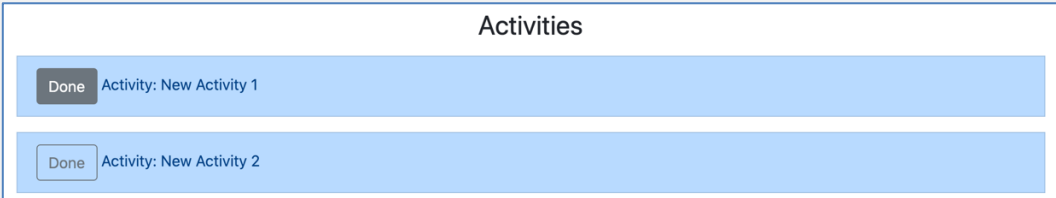
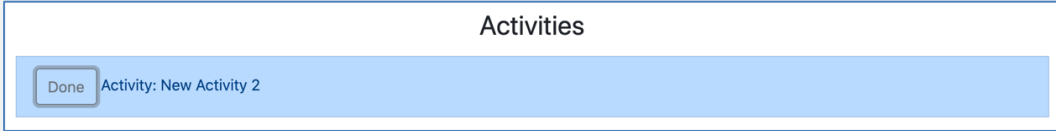
ID:	12
Title:	Add an existing activity to goal
Main success scenario:	<ol style="list-style-type: none"> 1. The user selects the select-box inside the goal with the title "Activities"; 2. Inserts the title of the activity; 3. The user selects the existing option; 4. The user clicks "Register Activities" submitting the new activity; 5. The system saves the new activity.

Top figure: Add an existing activity

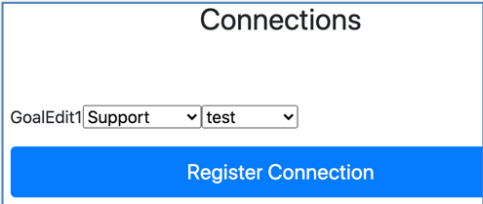
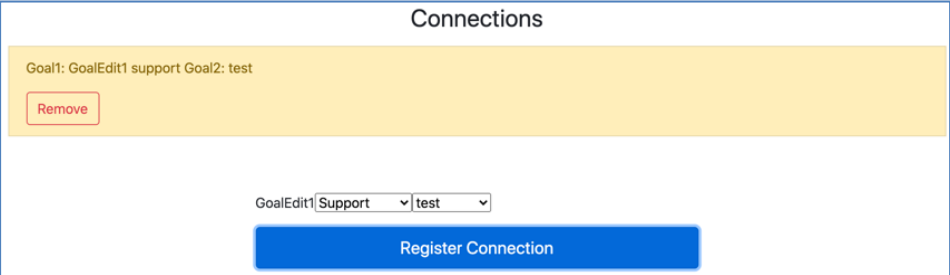
Bottom figure: Register new activity

Result: **Approved**

Functional testing Set activity as done.

ID:	13
Title:	Set activity as done
Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in "Done" on the bottom of the activity; 2. The system updates the activity to "done"; 3. The activity list refreshes without the metric.
 	
<p>Top figure: Done activity button Bottom figure: Activity set as done</p>	
Result:	Approved

Functional testing Add a connection between goals.

ID:	14
Title:	Add a connection between goals
Main success scenario:	<ol style="list-style-type: none"> 1. The user fills the form inside the goal with the title "Connections": (1 select-box) Goal; (2 select-box) Type; 2. The user clicks "Register Connection" submitting the new connection; 3. The system saves the new connection.
 	

Top figure: Register connection button	
Bottom figure: New connection	
Result:	Approved

Functional testing Remove a connection.

ID:	15
Title:	Remove a connection
Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in "Remove" on the bottom of the connection; 2. The system removes the connection; 3. The connection list refreshes without the connection.
<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid #ccc; padding: 10px; background-color: #fff9c4;"> <p>Goal1: GoalEdit1 support Goal2: test</p> <p style="text-align: center; color: white; background-color: #f44336; padding: 5px; display: inline-block;">Remove</p> </div> <div style="border: 1px solid #ccc; padding: 10px; background-color: #fff;"> <p style="text-align: center; margin: 0;">Connections</p> <p>GoalEdit1 Support test</p> <p style="text-align: center; background-color: #2196f3; color: white; padding: 5px; display: inline-block;">Register Connection</p> </div> </div> <p>Left figure: Remove connection button Right figure: Connection removed</p>	
Result:	Approved

Functional testing Register new maturity model fragment.

ID:	16
Title:	Register new maturity model fragment
Main success scenario:	<ol style="list-style-type: none"> 1. Press the hamburger button that will open a left navigation bar; 2. Select the option "Register new Maturity Model Fragment"; 3. Opens a new page on the browser where the user has to fill a form: (1) Maturity model fragment title; (2) Description; (3) Minimum value for ser; (4) Maximum value for set; (5 check-box) Public; (6 select-box) Perspective; 4. The user has to press "Register Maturity Model Fragment" submitting the new maturity model fragment. 5. The system saves the new maturity model fragment. 6. The system redirects the user to the main page;

Register Maturity Fragment

Maturity Model Fragment Title

Maturity Model Fragment Description

Minimum value for set

Maximum value for set

Public

Register Maturity Fragment

Title: MMF1
 Perspective: I4
 Public: 1
 Description: MMF Description
 Set: [0,5]

Add new Question

Maturity Question

Register Maturity Question

Top figure: Register new maturity model fragment form

Bottom figure: Maturity model fragment data page

Result: Approved

Functional testing List maturity model fragments.

ID:	17
Title:	List maturity model fragments
Main success scenario:	<ol style="list-style-type: none"> 1. Press the hamburger button that will open a left navigation bar; 2. Select the option "List all Maturity Model Fragments"; 3. The system gets all user private maturity model fragments or all public ones; 4. Appears a list with all the get maturity model fragments

- Main Page
- List answered Goals
- List answered maturity model fragments
- List maturity model fragments
- List activities done
- Register maturity model fragment
- Access profile data
- Logout

Search:

Processes
 Learning & Growth
 I4.0

Product and services	2020-04-21 15:31:01
Description: Reduce maintenance costs; Use laser equipment; Reduce the growth periods of eucalyptus.	
Perspective: I4	
Product and services	2020-04-21 15:31:30
Description: Ensure that the origin of the wood is known.	
Perspective: Processes	
Manufacturing and operations	2020-04-21 15:32:19
Description: Reduce maintenance costs.	
Perspective: I4	
Manufacturing and operations	2020-04-21 15:32:08
Description: Ensure that the origin of the wood is known.	
Perspective: Processes	
Business model	2020-04-21 15:32:38
Description: Reduce maintenance costs.	
Perspective: I4	

Left figure: Navigation box with List maturity model fragments option
 Right figure: List maturity model fragments page
 Result: Approved

Functional testing Search inside list maturity model fragments.

ID:	18
Title:	Search inside list maturity model fragments
Main success scenario:	<ol style="list-style-type: none"> 1. User has to fill the form on top of the page choosing the search that pretends to do: (1) search by keyword; (2) check-box) perspective; 2. The user has to press "Search Maturity Model Fragment" submitting the search; 3.1 The search with keyword gets all maturity model fragments that have the keyword in the title or description and are user private or public ones; 3.2 The search with perspective gets all maturity model fragments that are from the search perspective and are user private or public ones; 4. Appears a list with all the get maturity model fragments

Search:

Enter fragment search element

Processes

Learning & Growth

4.0

Search Maturity Model

Product and services
Description: Reduce maintenance costs; Use laser equipment; Reduce the growth periods of eucalyptus.
Perspective: I4

Product and services
Description: Ensure that the origin of the wood is known.
Perspective: Processes

Manufacturing and operations
Description: Reduce maintenance costs.
Perspective: I4

Manufacturing and operations
Description: Ensure that the origin of the wood is known.
Perspective: Processes

Business model
Description: Reduce maintenance costs.
Perspective: I4

Search:

Wood

Processes

Learning & Growth

4.0

Search Maturity Model

Product and services
Description: Ensure that the origin of the wood is known.
Perspective: Processes

Manufacturing and operations
Description: Ensure that the origin of the wood is known.
Perspective: Processes

Organization
Description: Ensure that the origin of the wood is known; Reduce the waiting time for wooden trucks.
Perspective: Processes

Technology
Description: Ensure that the origin of the wood is known.
Perspective: Processes

Business Models, Product & Service Portfolio
Description: Decrease the waiting time for wooden trucks.
Perspective: Processes

Top figure: List maturity model fragments page with no search

Bottom figure: List maturity model fragments page with search

Result:

Approved

Functional testing View maturity model fragment details.

ID:	19
Title:	View maturity model fragment details
Main success scenario:	<ol style="list-style-type: none"> 1. The user selects a maturity model fragment pressing his title; 2. The system redirects to the maturity model fragment page;

3 The system gets all data of the maturity model fragment and lists it;

The screenshot shows a list of maturity model fragments on the left and a detailed view of a fragment on the right. The list includes three items: 'Artificial intelligence' (Description: Digital Maturity, Perspective: I4), another 'Artificial intelligence' (Description: Digital Maturity, Perspective: I4), and 'MMF1' (Description: MMF Description, Perspective: I4). The detailed view for 'MMF1' shows fields for Title (MMF1), Perspective (I4), Public (1), Description (MMF Description), and Set ([0,5]). There are 'Edit' and 'Remove' buttons. Below this is an 'Add new Question' form with a text input field labeled 'Enter question' and a blue 'Register Maturity Question' button.

Left figure: Pressing maturity model fragment in the list

Right figure: Maturity model fragment data page

Result:

Approved

Functional testing Edit maturity model fragment.

ID:	20
Title:	Edit maturity model fragment
Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in "Edit"; 2. The system creates a form with an input box and a select box under each of the details with the actual data; 3. The user makes the changes in the form; 4. The user selects "SubmitEdit"; 5. The system saves the edited maturity model fragment; 6. The data refresh and the user sees new data.

The screenshot shows the 'Edit maturity model fragment' form. On the left is a preview of the current data: Title: MMF1, Perspective: I4, Public: 1, Description: MMF Description, Set: [0,5], and 'Edit' and 'Remove' buttons. On the right is the edit form with the same fields: Title (MMF1), Perspective (I4), Public (1), Description (MMF Description), and Set ([0,5]). The 'Public' field has a checked checkbox. There are 'Submit Edit' and 'Remove' buttons.

Top figure: Edit maturity model fragment button

Bottom figure: Editing maturity model fragment

Result: Approved

Functional testing Add a question to a maturity model fragment.

ID:	21
Title:	Add a question to a maturity model fragment
Main success scenario:	<ol style="list-style-type: none">1. The user fills the form inside the goal with the title "Add new Question": (1) Maturity Model Fragment Question.2. The user clicks "Register Question" submitting the new question;3. The system saves the new question.

The top figure shows a form titled "Add new Question" with a "Maturity Question" label and a text input field containing "Question 1". Below the input field is a blue button labeled "Register Maturity Question".

The bottom figure shows the same form after submission. A green bar at the top contains "Question 1" and a red "Remove" button. Below this bar, the form fields are visible again, including the "Maturity Question" label, the "Question 1" input field, and the "Register Maturity Question" button.

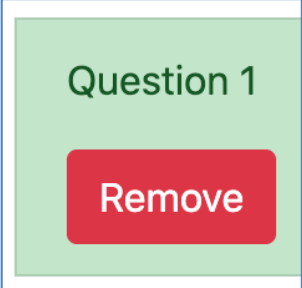
Top figure: Add a maturity model fragment question form

Bottom figure: Question registered

Result: Approved

Functional testing Remove a question inside a maturity model fragment.

ID:	22
Title:	Remove question inside a maturity model fragment
Main success scenario:	<ol style="list-style-type: none">1. The user clicks in "Remove" on the bottom of the question;2. The system removes the question;3. The questions list refresh without the removed question.

	<p>Title: MMF1 Perspective: I4 Public: 1 Description: MMF Description Set: [0,5]</p> <p>Edit Remove</p> <p style="text-align: right;">Add new Question</p> <p>Maturity Question</p> <input type="text" value="Enter question"/> <input type="button" value="Register Maturity Question"/>
Left figure: Remove question button	Right figure: Question removed
Result:	Approved

Functional testing Answer maturity model fragment.

ID:	23
Title:	Answer maturity model fragment
Main success scenario:	<ol style="list-style-type: none"> 1. In the perspective that pretends to add a goal the user selects the button “[perspective] +” on the left corner; 2. The user selects the option “Fragment”; 3. The system gets all user private maturity model fragments or all public ones from the selected perspective; 4. Appears a list with all the get maturity model fragments with a button on the bottom “Fill”; 5. The user clicks on the button “Fill”; 6. Opens a new page on the browser where the user has to fill a form with the maturity model fragment questions: (1) Actual Value; (2) Target Value; 7. The user has to press “Submit Answers” submitting the new goal. 8. The system saves the answer. 9. The system redirects the user to the main page;



Title: MMFEEdit1

Question 0: Question 1

2	4
---	---

Submit answers

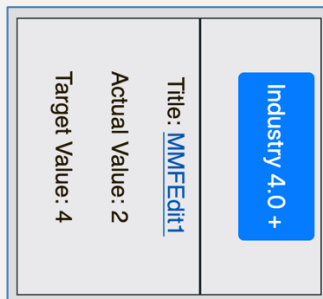
Left figure: Answer maturity model fragment option

Right figure: Register maturity model fragment answer form

Result: Approved

Functional testing Access to answered maturity model fragment data.

ID:	24
Title:	Access to answered maturity model fragment data
Main success scenario:	<ol style="list-style-type: none"> 1. The user selects a maturity model fragment answer pressing his title; 2. The system redirects to the maturity model fragment answer page; 3 The system gets all data of the maturity model fragment answer and lists it;



Title: MMFEdit1
 Perspective: I4
 Public: 1
 Description: MMF Description
 Set: [0,5]
 Remove
 ----- Re-Submit -----

Questions
Question 0 - Question 1

Actual Value Target Value

submit new answers

Historic:

Top figure: Access to maturity model fragment answer
 Bottom figure: Maturity model fragment answer data page

Result: Approved

Functional testing Re-answer maturity model fragment data.

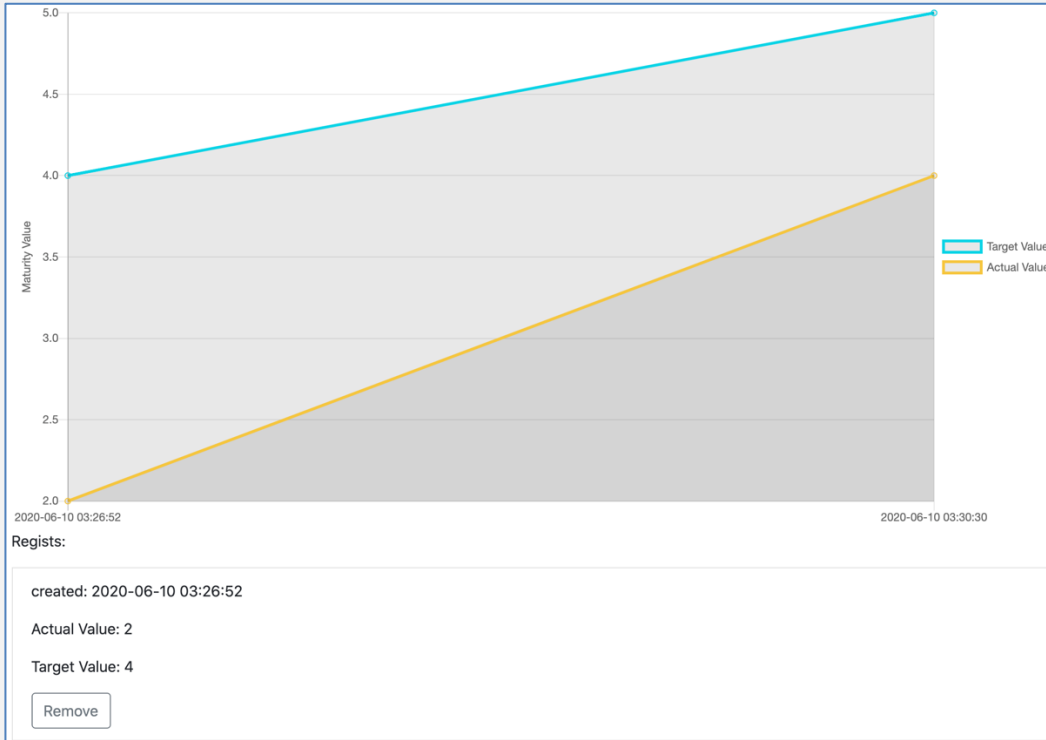
ID:	25
Title:	Re-answer maturity model fragment data
Main success scenario:	<ol style="list-style-type: none"> 1. The user selects a maturity model fragment answer pressing his title; 2. The system redirects to the maturity model fragment answer page; 3. In maturity model fragment answer page user fills a form with the maturity model fragment questions: (1) Actual Value; (2) Target Value; 7. The user has to press "Submit new Answers" submitting the new answers. 8. The system saves the new answers. 9. The system saves the old answers in historic maturity model fragment.

10. The system refreshes the maturity model fragment page;

Questions
Question 0 - Question 1

4 5

[submit new answers](#)



Top figure: Re-answer maturity model fragment

Bottom figure: maturity model fragment answers historic

Result:

Approved

Functional testing Remove history maturity model fragment.

ID:	26
Title:	Remove history answered maturity model fragment
Main success scenario:	<ol style="list-style-type: none"> 1. The user clicks in "Remove" on the bottom of the maturity model fragment answer data; 2. The system removes the maturity model fragment answer historic; 3. The system removes the maturity model fragment answer; 4. Redirects to Main Page.

created: 2020-06-10 03:26:52

Actual Value: 2

Target Value: 4

Remove

Title: MMFEdit1

Perspective: I4

Public: 1

Description: MMF Description

Set: [0,5]

Remove

----- Re-Submit -----

Questions

Question 0 - Question 1

Actual Value Target Value

submit new answers

Historic:

Left image: Remove maturity fragment model answer in historic

Right image: Maturity fragment model answer in historic removed

Result:	Approved
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Functional testing Access profile information

ID:	27
Title:	Access profile information
Main success scenario:	<ol style="list-style-type: none"> 1. Press the hamburger button that will open a left navigation bar; 2. Select the option "User profile"; 3. Opens a new page on the browser where the user has his personal data (id; first name; last name; email; password);
Figure:	Navigation box with access profile data option
Result:	Approved

Appendix D Usability Testing Reports

Teste de Usabilidade – Questionário – ID TU01

No âmbito da dissertação de mestrado em Engenharia Informática da Faculdade de Ciências e Tecnologia da Universidade de Coimbra, intitulada *An Information System for Accessing and Guiding Industry 4.0*, realizada por Pedro Nolasco, solicita-se o preenchimento deste teste de usabilidade. Pretende-se verificar a usabilidade da aplicação web perante diferentes perfis de utilizadores. As suas respostas destinam apenas a fins académicos, e estão protegidas pelos preceitos éticos que presidem à investigação científica.

Desde já se agradece pela sua colaboração!

I – Caracterização

1. Idade: 24;
2. Habilitações académicas: Mestrado;
3. Profissão: Estudante;
4. Área de trabalho: Marketing/Gestão

II – Competências

Responda às seguintes questões, assinalando numa escala de um a cinco, o valor que considera mais adequado, em que 1 é o valor mais baixo e 5 o mais elevado para cada item.

1. Tem conhecimentos na área dos *Sistemas de Informação*?

1 2 3 4 5

2. Tem conhecimentos na área da indústria?

1 2 3 4 5

3. Tem conhecimentos na área da quarta revolução industrial?

1 2 3 4 5

4. Está familiarizado com o conceito de *Balanced Scorecard*?

1 2 3 4 5

5. Está familiarizado com o conceito de Modelo de maturidade?

1 2 3 4 5


6. Encontra-se familiarizado com a utilização de aplicações web?

1 2 3 4 5

7. Encontra-se familiarizado com a utilização de ferramentas de apoio à gestão?

1 2 3 4 5

III – Tarefas

Solicita-se que a partir do browser Google Chrome  aceda à aplicação web através do link <https://industry-sparks.herokuapp.com/> . Depois de aceder ao link, comece a cronometrar o tempo e vá realizando passo a passo os pontos apresentados na tabela em baixo. Estes apresentam detalhadamente as atividades a realizar. Para cada tarefa há quatro colunas a preencher: a primeira é para assinalar o tempo que demorou a executar esse passo; a segunda será para inserir o numero de cliques que realizou; a terceira é para referir o sucesso na execução da tarefa (✓) ou se ocorreu algum erro (nº erros); a quarta e ultima coluna é referente à avaliação do grau de dificuldade/facilidade na realização da tarefa (responda de 1 a 10, em que 1 é muito difícil e 10 muito fácil).

		Tempo de Execução	Nº de cliques	Sucesso (✓) ou erro	Dificuldade e / Facilidade
T1	Introduzir as credencias login: Email: "01@test.com" Password: "test" Pressionar o botão "Sign in"	10s	3	Sucesso	10
T2	Selecionar o botão "Financial +" Selecionar a opção "Add Goal" Introduzir na caixa de texto Goal title: "Diminuir custos operacionais" Pressionar o botão "Register Goal"	12	3	Sucesso	9
T3	Preencher o formulário para adicionar uma nova métrica: Metric: "Custo atual" Description: "Valores em percentagem" Actual value: "75" Target value: "80" Pressionar o botão "Register Metric"	16	1	Sucesso	9
T4	Introduzir na caixa de texto em Activities Select...: "Mudar software de gestão" Selecionar a opção "Create Mudar software de gestão" Pressionar o botão "Register Activities"	20	1	Sucesso	9
T5	Selecionar o ícone no canto superior esquerdo Aparece uma barra lateral e selecionar a opção "Main Page"	18	4	Sucesso	9

	<p>Selecionar o botão "Industry 4.0 +"</p> <p>Selecionar a opção "Goal"</p> <p>Introduzir na caixa de texto:</p> <p>Goal title: "Otimizar utilização de inteligência artificial"</p> <p>Pressionar o botão "Register Goal"</p>				
T6	<p>No espaço inferior da página em Connections após "Otimizar utilização de inteligência artificial" onde diz "Dependent" selecionar a opção "Support"</p> <p>Pressionar o botão "Register Connection"</p>	10	2	Sucesso	9
T7	<p>Selecionar o ícone no canto superior esquerdo</p> <p>Aparece uma barra lateral e selecionar a opção "Register Maturity Model Fragment"</p> <p>Preencher o formulário para registrar um novo maturity model fragment:</p> <p>Maturity Model Fragment: "IA MMF"</p> <p>Description: "Maturidade Digital"</p> <p>Minimum value for set: "0"</p> <p>Maximum value for set: "5"</p> <p>No caixa que diz Learning and growth mudar para Industry 4.0</p> <p>Pressionar o botão "Register Metric"</p>	24	4	Sucesso	9
T8	<p>Preencher o formulário para adicionar uma nova pergunta ao maturity model fragment:</p> <p>Maturity question: Nível de tratamento dos dados recolhidos tendo por base sistemas inteligentes.</p> <p>Pressionar o botão "Register Maturity Question"</p>	8	2	Sucesso	9
T9	<p>Pressionar o botão "Edit" ao lado do botão "Remove"</p> <p>Alterar o valor:</p> <p>Description: "Inteligência Artificial"</p> <p>Pressionar o botão "Edit" ao lado do botão "Submit"</p>	20	2	Sucesso	7
T10	<p>Selecionar o ícone no canto superior esquerdo</p>	16	5	Sucesso	9

	<p>Aparece uma barra lateral e selecionar a opção "Main Page"</p> <p>Selecionar o botão "Industry 4.0 +"</p> <p>Selecionar a opção "Fragment"</p> <p>Descer na lista de maturity model fragments e selecionar o modelo com o título "IA MMF"</p> <p>Preencher o formulário para submeter uma resposta ao maturity model fragment</p> <p>Actual: "2"</p> <p>Target: "4"</p> <p>Pressionar o botão "submit"</p>				
T11	<p>Preencher o formulário para adicionar novos valores ao maturity model fragment</p> <p>Actual value: "3"</p> <p>Target value: "4"</p> <p>Pressionar o botão "Register Metric"</p>	10	2	Sucesso	9

IV – Questões

1. Realizou facilmente e intuitivamente as tarefas propostas?
Sim Não
2. O sistema apresenta a informação necessária para a execução das tarefas?
Sim Não
3. A experiência de utilização evoluiu positivamente ao longo da utilização da aplicação?
Sim Não
4. O sistema informa o utilizador das ações que este se encontra a realizar?
Sim Não
5. O sistema apresenta uma estrutura confusa?
Sim Não
6. Como descreve a sua experiência de utilização da aplicação?

Fácil, Prática e Intuitiva

-
7. Se pudesse mudar algo na aplicação o que seria?

Apenas o design, para melhor compreensão de todos.

Muito obrigado pela colaboração!

Teste de Usabilidade – Questionário – ID TU02

No âmbito da dissertação de mestrado em Engenharia Informática da Faculdade de Ciências e Tecnologia da Universidade de Coimbra, intitulada *An Information System for Accessing and Guiding Industry 4.0*, realizada por Pedro Nolasco, solicita-se o preenchimento deste teste de usabilidade. Pretende-se verificar a usabilidade da aplicação web perante diferentes perfis de utilizadores. As suas respostas destinam apenas a fins académicos, e estão protegidas pelos preceitos éticos que presidem à investigação científica.

Desde já se agradece pela sua colaboração!

I – Caracterização

1. Idade: 27;
2. Habilitações académicas: Mestrado;
3. Profissão: UI/UX Designer;
4. Área de trabalho: Desenvolvimento de aplicações nativas;

II – Competências

Responda às seguintes questões, assinalando numa escala de um a cinco, o valor que considera mais adequado, em que 1 é o valor mais baixo e 5 o mais elevado para cada item.

1. Tem conhecimentos na área dos *Sistemas de Informação*?

1 2 3 4 5

2. Tem conhecimentos na área da indústria?

1 2 3 4 5

3. Tem conhecimentos na área da quarta revolução industrial?

1 2 3 4 5

4. Está familiarizado com o conceito de *Balanced Scorecard*?

1 2 3 4 5

5. Está familiarizado com o conceito de Modelo de maturidade?

1 2 3 4 5


6. Encontra-se familiarizado com a utilização de aplicações web?

1 2 3 4 5

7. Encontra-se familiarizado com a utilização de ferramentas de apoio à gestão?


1 2 3 4 5

III – Tarefas

Solicita-se que a partir do browser Google Chrome  aceda à aplicação web através do link <https://industry-sparks.herokuapp.com/> . Depois de aceder ao link, comece a cronometrar o tempo e vá realizando passo a passo os pontos apresentados na tabela em baixo. Estes apresentam detalhadamente as atividades a realizar. Para cada tarefa há quatro colunas a preencher: a primeira é para assinalar o tempo que demorou a executar esse passo; a segunda será para inserir o numero de cliques que realizou; a terceira é para referir o sucesso na execução da tarefa (✓) ou se ocorreu algum erro (nº erros); a quarta e ultima coluna é referente à avaliação do grau de dificuldade/facilidade na realização da tarefa (responda de 1 a 10, em que 1 é muito difícil e 10 muito fácil).

		Tempo de Execução	Nº de cliques	Sucesso (✓) ou erro	Dificuldade e / Facilidade
T1	Introduzir as credencias login: Email: "01@test.com" Password: "test" Pressionar o botão "Sign in"	00:13	3	✓	1
T2	Selecionar o botão "Financial +" Selecionar a opção "Add Goal" Introduzir na caixa de texto Goal title: "Diminuir custos operacionais" Pressionar o botão "Register Goal"	00:23	4	✓	2
T3	Preencher o formulário para adicionar uma nova métrica: Metric: "Custo atual" Description: "Valores em percentagem" Actual value: "75" Target value: "80" Pressionar o botão "Register Metric"	00:27	6	✓	3
T4	Introduzir na caixa de texto em Activities Select...: "Mudar software de gestão" Selecionar a opção "Create Mudar software de gestão" Pressionar o botão "Register Activities"	00:40	8	✓	4
T5	Selecionar o ícone no canto superior esquerdo Aparece uma barra lateral e selecionar a opção "Main Page"	00:45	10	✓	4

	<p>Selecionar o botão “Industry 4.0 +”</p> <p>Selecionar a opção “Goal”</p> <p>Introduzir na caixa de texto:</p> <p>Goal title: “Otimizar utilização de inteligência artificial”</p> <p>Pressionar o botão “Register Goal”</p>				
T6	<p>No espaço inferior da página em Connections após “Otimizar utilização de inteligência artificial” onde diz “Dependent” selecionar a opção “Support”</p> <p>Pressionar o botão “Register Connection”</p>	00:19	4	✓	2
T7	<p>Selecionar o ícone no canto superior esquerdo</p> <p>Aparece uma barra lateral e selecionar a opção “Register Maturity Model Fragment”</p> <p>Preencher o formulário para registrar um novo maturity model fragment:</p> <p>Maturity Model Fragment: “IA MMF”</p> <p>Description: “Maturidade Digital”</p> <p>Minimum value for set: “0”</p> <p>Maximum value for set: “5”</p> <p>No caixa que diz Learning and growth mudar para Industry 4.0</p> <p>Pressionar o botão “Register Metric”</p>	00:59	10	✓	6
T8	<p>Preencher o formulário para adicionar uma nova pergunta ao maturity model fragment:</p> <p>Maturity question: Nível de tratamento dos dados recolhidos tendo por base sistemas inteligentes.</p> <p>Pressionar o botão “Register Maturity Question”</p>	00:14	2	✓	1
T9	<p>Pressionar o botão “Edit” ao lado do botão “Remove”</p> <p>Alterar o valor:</p> <p>Description: “Inteligência Artificial”</p> <p>Pressionar o botão “Edit” ao lado do botão “Submit”</p>	00:55	5	✓	7
T10	<p>Selecionar o ícone no canto superior esquerdo</p>	00:38	10	✓	4

	<p>Aparece uma barra lateral e selecionar a opção "Main Page"</p> <p>Selecionar o botão "Industry 4.0 +"</p> <p>Selecionar a opção "Fragment"</p> <p>Descer na lista de maturity model fragments e selecionar o modelo com o título "IA MMF"</p> <p>Preencher o formulário para submeter uma resposta ao maturity model fragment</p> <p>Actual: "2"</p> <p>Target: "4"</p> <p>Pressionar o botão "submit"</p>				
T11	<p>Preencher o formulário para adicionar novos valores ao maturity model fragment</p> <p>Actual value: "3"</p> <p>Target value: "4"</p> <p>Pressionar o botão "Register Metric"</p>	00:10	3		3

IV – Questões

1. Realizou facilmente e intuitivamente as tarefas propostas?

Sim Não

2. O sistema apresenta a informação necessária para a execução das tarefas?

Sim Não

3. A experiência de utilização evoluiu positivamente ao longo da utilização da aplicação?

Sim Não

1. O sistema informa o utilizador das ações que este se encontra a realizar?

Sim Não

1. O sistema apresenta uma estrutura confusa?

Sim Não

2. Como descreve a sua experiência de utilização da aplicação?

Realizei as tarefas solicitadas por teste de forma fácil, no entanto sinto que apenas o consegui fazer por haver indicações, pois a navegação do sistema pareceu-me um pouco confusa e nalguns casos a experiência não foi a melhor (texto na vertical), pouca hierarquia de navegação (tanto visual como de informação) e alguns cliques extra desnecessários.

3. Se pudesse mudar algo na aplicação o que seria?

- Navegação – organizar o sistema por grupos, tarefas, ou ações (zona apenas de criação, outra zona apenas para mostrar dados,etc)
- Usar apenas o hamburger menu em mobile e evitar acordeons para revelar ações, pois executei o teste em desktop e há espaço suficiente para mostrar toda a informação que estava escondida de uma só vez, poderá evitar muitos cliques.

Muito obrigado pela colaboração!

Teste de Usabilidade – Questionário – ID TU03

No âmbito da dissertação de mestrado em Engenharia Informática da Faculdade de Ciências e Tecnologia da Universidade de Coimbra, intitulada *An Information System for Accessing and Guiding Industry 4.0*, realizada por Pedro Nolasco, solicita-se o preenchimento deste teste de usabilidade. Pretende-se verificar a usabilidade da aplicação web perante diferentes perfis de utilizadores. As suas respostas destinam apenas a fins académicos, e estão protegidas pelos preceitos éticos que presidem à investigação científica.

Desde já se agradece pela sua colaboração!

I – Caracterização

1. Idade: 23
2. Habilitações académicas: Licenciado
3. Profissão: Estudante
4. Área de trabalho: Inteligência Artificial

II – Competências

Responda às seguintes questões, assinalando numa escala de um a cinco, o valor que considera mais adequado, em que 1 é o valor mais baixo e 5 o mais elevado para cada item.

1. Tem conhecimentos na área dos *Sistemas de Informação*?

1 2 3 4 5

2. Tem conhecimentos na área da indústria?

1 2 3 4 5

3. Tem conhecimentos na área da quarta revolução industrial?

1 2 3 4 5

4. Está familiarizado com o conceito de *Balanced Scorecard*?

1 2 3 4 5

5. Está familiarizado com o conceito de Modelo de maturidade?

1 2 3 4 5


6. Encontra-se familiarizado com a utilização de aplicações web?

1 2 3 4 5

7. Encontra-se familiarizado com a utilização de ferramentas de apoio à gestão?

1 2 3 4 5

III – Tarefas

Solicita-se que a partir do browser Google Chrome  aceda à aplicação web através do link <https://industry-sparks.herokuapp.com/> . Depois de aceder ao link, comece a cronometrar o tempo e vá realizando passo a passo os pontos apresentados na tabela em baixo. Estes apresentam detalhadamente as atividades a realizar. Para cada tarefa há quatro colunas a preencher: a primeira é para assinalar o tempo que demorou a executar esse passo; a segunda será para inserir o numero de cliques que realizou; a terceira é para referir o sucesso na execução da tarefa (✓) ou se ocorreu algum erro (nº erros); a quarta e ultima coluna é referente à avaliação do grau de dificuldade/facilidade na realização da tarefa (responda de 1 a 10, em que 1 é muito difícil e 10 muito fácil).

		Tempo de Execução	Nº de cliques	Sucesso (✓) ou erro	Dificuldade e / Facilidade
T1	Introduzir as credencias login: Email: "01@test.com" Password: "test" Pressionar o botão "Sign in"	10s	3	✓	10
T2	Selecionar o botão "Financial +" Selecionar a opção "Add Goal" Introduzir na caixa de texto Goal title: "Diminuir custos operacionais" Pressionar o botão "Register Goal"	35s	3	✓	10
T3	Preencher o formulário para adicionar uma nova métrica: Metric: "Custo atual" Description: "Valores em percentagem" Actual value: "75" Target value: "80" Pressionar o botão "Register Metric"	30s	5	✓	10
T4	Introduzir na caixa de texto em Activities Select...: "Mudar software de gestão" Selecionar a opção "Create Mudar software de gestão" Pressionar o botão "Register Activities"	45s	5	✓	5
T5	Selecionar o ícone no canto superior esquerdo Aparece uma barra lateral e selecionar a opção "Main Page"	40s	5	✓	10

	<p>Selecionar o botão "Industry 4.0 +"</p> <p>Selecionar a opção "Goal"</p> <p>Introduzir na caixa de texto:</p> <p>Goal title: "Otimizar utilização de inteligência artificial"</p> <p>Pressionar o botão "Register Goal"</p>				
T6	<p>No espaço inferior da página em Connections após "Otimizar utilização de inteligência artificial" onde diz "Dependent" selecionar a opção "Support"</p> <p>Pressionar o botão "Register Connection"</p>	45	6	✓	5
T7	<p>Selecionar o ícone no canto superior esquerdo</p> <p>Aparece uma barra lateral e selecionar a opção "Register Maturity Model Fragment"</p> <p>Preencher o formulário para registrar um novo maturity model fragment:</p> <p>Maturity Model Fragment: "IA MMF"</p> <p>Description: "Maturidade Digital"</p> <p>Minimum value for set: "0"</p> <p>Maximum value for set: "5"</p> <p>No caixa que diz Learning and growth mudar para Industry 4.0</p> <p>Pressionar o botão "Register Metric"</p>	1m5s	9	✓	10
T8	<p>Preencher o formulário para adicionar uma nova pergunta ao maturity model fragment:</p> <p>Maturity question: Nível de tratamento dos dados recolhidos tendo por base sistemas inteligentes.</p> <p>Pressionar o botão "Register Maturity Question"</p>	30s	2	✓	10
T9	<p>Pressionar o botão "Edit" ao lado do botão "Remove"</p> <p>Alterar o valor:</p> <p>Description: "Inteligência Artificial"</p> <p>Pressionar o botão "Edit" ao lado do botão "Submit"</p>	20s	3	✓	10
T10	<p>Selecionar o ícone no canto superior esquerdo</p>	40s	9	✓	9

	<p>Aparece uma barra lateral e selecionar a opção "Main Page"</p> <p>Selecionar o botão "Industry 4.0 +"</p> <p>Selecionar a opção "Fragment"</p> <p>Descer na lista de maturity model fragments e selecionar o modelo com o título "IA MMF"</p> <p>Preencher o formulário para submeter uma resposta ao maturity model fragment</p> <p>Actual: "2"</p> <p>Target: "4"</p> <p>Pressionar o botão "submit"</p>				
T11	<p>Preencher o formulário para adicionar novos valores ao maturity model fragment</p> <p>Actual value: "3"</p> <p>Target value: "4"</p> <p>Pressionar o botão "Register Metric"</p>	10s	3	✓	10

IV – Questões

1. Realizou facilmente e intuitivamente as tarefas propostas?
Sim Não
 2. O sistema apresenta a informação necessária para a execução das tarefas?
Sim Não
 3. A experiência de utilização evoluiu positivamente ao longo da utilização da aplicação?
Sim Não
 4. O sistema informa o utilizador das ações que este se encontra a realizar?
Sim Não
 5. O sistema apresenta uma estrutura confusa?
Sim Não
 6. Como descreve a sua experiência de utilização da aplicação? Parece relevante!
-
7. Se pudesse mudar algo na aplicação o que seria? Fornecer tips nos campos de preenchimento e tomada de ação
-

Muito obrigado pela colaboração!

Teste de Usabilidade – Questionário – ID TU04

No âmbito da dissertação de mestrado em Engenharia Informática da Faculdade de Ciências e Tecnologia da Universidade de Coimbra, intitulada *An Information System for Accessing and Guiding Industry 4.0*, realizada por Pedro Nolasco, solicita-se o preenchimento deste teste de usabilidade. Pretende-se verificar a usabilidade da aplicação web perante diferentes perfis de utilizadores. As suas respostas destinam apenas a fins académicos, e estão protegidas pelos preceitos éticos que presidem à investigação científica.

Desde já se agradece pela sua colaboração!

I – Caracterização

1. Idade: 47;
2. Habilitações académicas: 5º Ano do Curso de Gestão e Desenvolvimento Social da Universidade Católica;
3. Profissão: Bancário;
4. Área de trabalho: Acompanhamento de empresas;

II – Competências

Responda às seguintes questões, assinalando numa escala de um a cinco, o valor que considera mais adequado, em que 1 é o valor mais baixo e 5 o mais elevado para cada item.

1. Tem conhecimentos na área dos *Sistemas de Informação*?

1 2 3 4 5

2. Tem conhecimentos na área da indústria?

1 2 3 4 5

3. Tem conhecimentos na área da quarta revolução industrial?

1 2 3 4 5

4. Está familiarizado com o conceito de *Balanced Scorecard*?

1 2 3 4 5

5. Está familiarizado com o conceito de Modelo de maturidade?

1 2 3 4 5


6. Encontra-se familiarizado com a utilização de aplicações web?

1 2 3 4 5

7. Encontra-se familiarizado com a utilização de ferramentas de apoio à gestão?

1 2 3 4 5

III – Tarefas

Solicita-se que a partir do browser Google Chrome  aceda à aplicação web através do link <https://industry-sparks.herokuapp.com/> . Depois de aceder ao link, comece a cronometrar o tempo e vá realizando passo a passo os pontos apresentados na tabela em baixo. Estes apresentam detalhadamente as atividades a realizar. Para cada tarefa há quatro colunas a preencher: a primeira é para assinalar o tempo que demorou a executar esse passo; a segunda será para inserir o numero de cliques que realizou; a terceira é para referir o sucesso na execução da tarefa (✓) ou se ocorreu algum erro (nº erros); a quarta e ultima coluna é referente à avaliação do grau de dificuldade/facilidade na realização da tarefa (responda de 1 a 10, em que 1 é muito difícil e 10 muito fácil).

		Tempo de Execução	Nº de cliques	Sucesso (✓) ou erro	Dificuldade e / Facilidade
T1	Introduzir as credencias login: Email: "01@test.com" Password: "test" Pressionar o botão "Sign in"	10s	3	✓	10
T2	Selecionar o botão "Financial +" Selecionar a opção "Add Goal" Introduzir na caixa de texto Goal title: "Diminuir custos operacionais" Pressionar o botão "Register Goal"	35s	3	✓	10
T3	Preencher o formulário para adicionar uma nova métrica: Metric: "Custo atual" Description: "Valores em percentagem" Actual value: "75" Target value: "80" Pressionar o botão "Register Metric"	30s	5	✓	10
T4	Introduzir na caixa de texto em Activities Select...: "Mudar software de gestão" Selecionar a opção "Create Mudar software de gestão" Pressionar o botão "Register Activities"	45s	5	✓	5
T5	Selecionar o ícone no canto superior esquerdo Aparece uma barra lateral e selecionar a opção "Main Page"	40s	5	✓	10

	<p>Selecionar o botão “Industry 4.0 +”</p> <p>Selecionar a opção “Goal”</p> <p>Introduzir na caixa de texto:</p> <p>Goal title: “Otimizar utilização de inteligência artificial”</p> <p>Pressionar o botão “Register Goal”</p>				
T6	<p>No espaço inferior da página em Connections após “Otimizar utilização de inteligência artificial” onde diz “Dependent” selecionar a opção “Support”</p> <p>Pressionar o botão “Register Connection”</p>	45	6	✓	5
T7	<p>Selecionar o ícone no canto superior esquerdo</p> <p>Aparece uma barra lateral e selecionar a opção “Register Maturity Model Fragment”</p> <p>Preencher o formulário para registrar um novo maturity model fragment:</p> <p>Maturity Model Fragment: “IA MMF”</p> <p>Description: “Maturidade Digital”</p> <p>Minimum value for set: “0”</p> <p>Maximum value for set: “5”</p> <p>No caixa que diz Learning and growth mudar para Industry 4.0</p> <p>Pressionar o botão “Register Metric”</p>	1m5s	9	✓	10
T8	<p>Preencher o formulário para adicionar uma nova pergunta ao maturity model fragment:</p> <p>Maturity question: Nível de tratamento dos dados recolhidos tendo por base sistemas inteligentes.</p> <p>Pressionar o botão “Register Maturity Question”</p>	30s	2	✓	10
T9	<p>Pressionar o botão “Edit” ao lado do botão “Remove”</p> <p>Alterar o valor:</p> <p>Description: “Inteligência Artificial”</p> <p>Pressionar o botão “Edit” ao lado do botão “Submit”</p>	20s	3	✓	10
T10	<p>Selecionar o ícone no canto superior esquerdo</p>	40s	9	✓	9

	<p>Aparece uma barra lateral e selecionar a opção "Main Page"</p> <p>Selecionar o botão "Industry 4.0 +"</p> <p>Selecionar a opção "Fragment"</p> <p>Descer na lista de maturity model fragments e selecionar o modelo com o título "IA MMF"</p> <p>Preencher o formulário para submeter uma resposta ao maturity model fragment</p> <p>Actual: "2"</p> <p>Target: "4"</p> <p>Pressionar o botão "submit"</p>				
T11	<p>Preencher o formulário para adicionar novos valores ao maturity model fragment</p> <p>Actual value: "3"</p> <p>Target value: "4"</p> <p>Pressionar o botão "Register Metric"</p>	10s	3	✓	10

IV – Questões

1. Realizou facilmente e intuitivamente as tarefas propostas?
Sim Não
 2. O sistema apresenta a informação necessária para a execução das tarefas?
Sim Não
 3. A experiência de utilização evoluiu positivamente ao longo da utilização da aplicação?
Sim Não
 4. O sistema informa o utilizador das ações que este se encontra a realizar?
Sim Não
 5. O sistema apresenta uma estrutura confusa?
Sim Não
 6. Como descreve a sua experiência de utilização da aplicação?
- Aplicação Intuitiva e fácil utilização
-
7. Se pudesse mudar algo na aplicação o que seria?
- Eventual apoio online
-

Muito obrigado pela colaboração!

Teste de Usabilidade – Questionário – ID TU05

No âmbito da dissertação de mestrado em Engenharia Informática da Faculdade de Ciências e Tecnologia da Universidade de Coimbra, intitulada *An Information System for Accessing and Guiding Industry 4.0*, realizada por Pedro Nolasco, solicita-se o preenchimento deste teste de usabilidade. Pretende-se verificar a usabilidade da aplicação web perante diferentes perfis de utilizadores. As suas respostas destinam apenas a fins académicos, e estão protegidas pelos preceitos éticos que presidem à investigação científica.

Desde já se agradece pela sua colaboração!

I – Caracterização

5. Idade: _62_____;
6. Habilitações académicas: _11º_____;
7. Profissão: ___Empresário_____;
8. Área de trabalho: _Transportes por conta de outro_____;

II – Competências

Responda às seguintes questões, assinalando numa escala de um a cinco, o valor que considera mais adequado, em que 1 é o valor mais baixo e 5 o mais elevado para cada item.

8. Tem conhecimentos na área dos *Sistemas de Informação*?

1 2 3 4 5

9. Tem conhecimentos na área da indústria?

1 2 3 4 5

10. Tem conhecimentos na área da quarta revolução industrial?

1 2 3 4 5

11. Está familiarizado com o conceito de *Balanced Scorecard*?

1 2 3 4 5

12. Está familiarizado com o conceito de Modelo de maturidade?

1 2 3 4 5

13. Encontra-se familiarizado com a utilização de aplicações web?

1 2 3 4 5

14. Encontra-se familiarizado com a utilização de ferramentas de apoio à gestão?

1 2 3 4 5

Solicita-se que a partir do browser Google Chrome  aceda à aplicação web através do link <https://industry-sparks.herokuapp.com/> . Depois de aceder ao link, comece a

cronometrar o tempo e vá realizando passo a passo os pontos apresentados na tabela em baixo. Estes apresentam detalhadamente as atividades a realizar. Para cada tarefa há quatro colunas a preencher: a primeira é para assinalar o tempo que demorou a executar esse passo; a segunda será para inserir o numero de cliques que realizou; a terceira é para referir o sucesso na execução da tarefa (✓) ou se ocorreu algum erro (nº erros); a quarta e ultima coluna é referente à avaliação do grau de dificuldade/facilidade na realização da tarefa (responda de 1 a 10, em que 1 é muito difícil e 10 muito fácil).

		Tempo de Execução	Nº de cliques	Sucesso (✓) ou erro	Dificuldade e/ Facilidade
T1	Introduzir as credencias login: Email: "01@test.com" Password: "test" Pressionar o botão "Sign in"	10s	3	x	10
T2	Selecionar o botão "Financial +" Selecionar a opção "Add Goal" Introduzir na caixa de texto Goal title: "Diminuir custos operacionais" Pressionar o botão "Register Goal"	15s	3	x	9
T3	Preencher o formulário para adicionar uma nova métrica: Metric: "Custo atual" Description: "Valores em percentagem" Actual value: "75" Target value: "80" Pressionar o botão "Register Metric"	15s	6	x	9
T4	Introduzir na caixa de texto em Activities Select...: "Mudar software de gestão" Selecionar a opção "Create Mudar software de gestão" Pressionar o botão "Register Activities"	32s	5	x	8
T5	Selecionar o ícone no canto superior esquerdo Aparece uma barra lateral e selecionar a opção "Main Page" Selecionar o botão "Industry 4.0 +" Selecionar a opção "Goal" Introduzir na caixa de texto:	22s	5	x	8

	Goal title: "Otimizar utilização de inteligência artificial" Pressionar o botão "Register Goal"				
T6	No espaço inferior da página em Connections após "Otimizar utilização de inteligência artificial" onde diz "Dependent" selecionar a opção "Support" Pressionar o botão "Register Connection"	17s	3	x	8
T7	Selecionar o ícone no canto superior esquerdo Aparece uma barra lateral e selecionar a opção "Register Maturity Model Fragment" Preencher o formulário para registrar um novo maturity model fragment: Maturity Model Fragment: "IA MMF" Description: "Maturidade Digital" Minimum value for set: "0" Maximum value for set: "5" No caixa que diz Learning and growth mudar para Industry 4.0 Pressionar o botão "Register Metric"	1min9s	8	x	8
T8	Preencher o formulário para adicionar uma nova pergunta ao maturity model fragment: Maturity question: Nível de tratamento dos dados recolhidos tendo por base sistemas inteligentes. Pressionar o botão "Register Maturity Question"	12s	2	x	8
T9	Pressionar o botão "Edit" ao lado do botão "Remove" Alterar o valor: Description: "Inteligência Artificial" Pressionar o botão "Edit" ao lado do botão "Submit"	23s	2	x	8
T10	Selecionar o ícone no canto superior esquerdo Aparece uma barra lateral e selecionar a opção "Main Page" Selecionar o botão "Industry 4.0 +" Selecionar a opção "Fragment"	45s	5	x	8

	<p>Descer na lista de maturity model fragments e seleccionar o modelo com o título "IA MMF"</p> <p>Preencher o formulário para submeter uma resposta ao maturity model fragment</p> <p>Actual: "2"</p> <p>Target: "4"</p> <p>Pressionar o botão "submit"</p>				
T11	<p>Preencher o formulário para adicionar novos valores ao maturity model fragment</p> <p>Actual value: "3"</p> <p>Target value: "4"</p> <p>Pressionar o botão "Register Metric"</p>	13s	3	x	9

1. Realizou facilmente e intuitivamente as tarefas propostas?
Sim Não
 2. O sistema apresenta a informação necessária para a execução das tarefas?
Sim Não
 3. A experiência de utilização evoluiu positivamente ao longo da utilização da aplicação?
Sim Não
 4. O sistema informa o utilizador das ações que este se encontra a realizar?
Sim Não
 5. O sistema apresenta uma estrutura confusa?
Sim Não
 6. Como descreve a sua experiência de utilização da aplicação? Foi maioritariamente fácil trabalhar na plataforma.
 7. Se pudesse mudar algo na aplicação o que seria?
Quando é submetido um passo a caixa com a confirmação ter uma cor condizente com a ação (ficar verde e não vermelha) porque dá ideia que cometemos um erro.
-

Muito obrigado pela colaboração!