School of Industrial Engineering

POLITECNICO MILANO 1863

Master of Science in Management Engineering

SKILLS DEVELOPMENT MODEL TOWARDS MARITIME INDUSTRY DIGITALIZATION

Supervisor: Monica Rossi

Co-Supervisor: Lucia Ramundo

Authors:

Andrea Napolitano Matr. 893532

Alessio Pedrazzoli Matr. 905794

Academic year 2018/2019

Abstract

Nowadays, the issue of skills development is becoming increasingly relevant considering the industrial domain. New digital technologies envisaged by the advent of Industry 4.0 are constantly impacting the status quo of manufacturing companies, redesigning the production systems and with them a new associated skillset. Without an adequate skills development plan, the implementation of digital technologies will never be fully realized. Maritime sector is certainly no exception. On the contrary, it is currently embracing digitalization with a slower pace than the one of other comparable industrial sectors. After a precise definition of the research boundaries, this thesis aims to investigate the above-mentioned digital "delay" of the sector under analysis, finally developing a plan for the development of digital technologies tailored to the realities of the maritime industry. Initially, a systematic literature search is conducted in the three research fields: digital technologies, skills development and the maritime sector itself. In addition to the literary component, an empirical research is carried out through semi-structured interviews with experts in the field, who have provided complementary knowledge necessary for the development of an intuitive and consistent general model. This thesis proposes, in particular, three models to facilitate synergistically the implementation of digital technologies in the maritime sector through an adequate development of the necessary skills. Finally, these models are subjected to validation by meeting the consent of experts in the field.

The objective of this research thesis is to contribute, through skills development, to the construction of solid foundations for a digitalization plan of the maritime sector that will be increasingly enriched over time.

Keywords: Digital Skills Development; Maritime 4.0; Maritime Skills Development; Digital Technologies; Maritime Sector; Skills Development.

Abstract – Versione in lingua italiana

Oggigiorno, la tematica dello sviluppo delle competenze sta diventando sempre più rilevante considerando il dominio industriale. Le nuove tecnologie digitali contemplate dall' avvento dell'Industria 4.0 impattano costantemente lo status quo aziendale manifatturiero, ridisegnando nuovi sistemi produttivi e con essi nuove competenze associate. Senza un congruo piano di sviluppo delle competenze, l'implementazione delle tecnologie digitali non potrà mai concretizzarsi pienamente. Il settore marittimo certamente non costituisce un'eccezione. Esso anzi, sta subendo un processo di digitalizzazione più procrastinante rispetto ad altri settori industriali comparabili. Dopo aver definito con precisione i confini della ricerca, questa tesi ha lo scopo di investigare riguardo il sopracitato "ritardo" digitale del settore in analisi, sviluppando infine un piano di sviluppo delle tecnologie digitali adattato alle realtà dell'industria marittima. Inizialmente una ricerca letteraria sistematica è condotta sui tre ambiti di ricerca analizzati: tecnologie digitali, sviluppo delle competenze e settore marittimo. Alla componente letteraria, si aggiunge poi una ricerca empirica svoltasi per mezzo di interviste semi-strutturate con esperti del settore, che hanno fornito conoscenze complementari necessarie per lo sviluppo di un modello generale intuitivo e consistente. Questa tesi propone, nello specifico, tre modelli atti a facilitare sinergicamente l'implementazione delle tecnologie digitali nel settore marittimo attraverso un adeguato sviluppo delle competenze necessarie. Infine, questi modelli sono sottoposti a validazione riscontrando il consenso di esperti del settore.

L' obiettivo di questa tesi di ricerca è quello di contribuire alla costruzione di solide basi per un piano di digitalizzazione del settore marittimo che andrà sempre più arricchendosi nel tempo.

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List of Abbreviations and Acronyms

WMF	World Manufacturing Forum
SMEs	Small and Medium Enterprises
PESTE	Political Economic Social Technological Environmental
IoT	Internet of Things
AR	Augmented Reality
AM	Additive Manufacturing
ML	Machine Learning
VR	Virtual Reality
AI	Artificial Intelligence
DBMS	Data Base Management System
IOS	Information Operative Systems
EU	European Union
IT	Information Technologies
IS	Information Systems
RFID	Radio Frequency Identification
IAR	Industrial Augmented Reality
ETO	Engineering To Order
ME	Maritime Education
IMO	International Maritime Organization
MET	Maritime Education and Training
RQ	Research Question

UNIDO	United Nations Industrial Development Organizations
CEO	Chief Executive Officer
DG	Directorate General
SBCE	Set-Based Concurrent Engineering
LINCOLN	Lean Innovative Connected Vessels
CFD	Computational Fluid Dynamics
HPC	High Performance Computing
LCPA	Life Cycle Performance Assessment
ROI	Return On Investment
IaaS	Infrastructure as a service
PaaS	Platform as a service
SaaS	Software as a service
CAD	Computer Aided Design

Executive Summary

Nowadays, the overall industrial landscape is experiencing a pervasive revolution called "Industry 4.0". New digital technologies are reshaping the way to make business, and together with it the necessary skillset of the workforce. Skills development is a process that cannot be neglected to embrace the Industry 4.0 technologies, otherwise, the advantages brought by them would be lost or not fully exploited. The maritime sector is surely no exception.

Before discussing the content of the thesis, its logical flow is presented to the reader (*Figure 1*), considering all the chapters composing it.

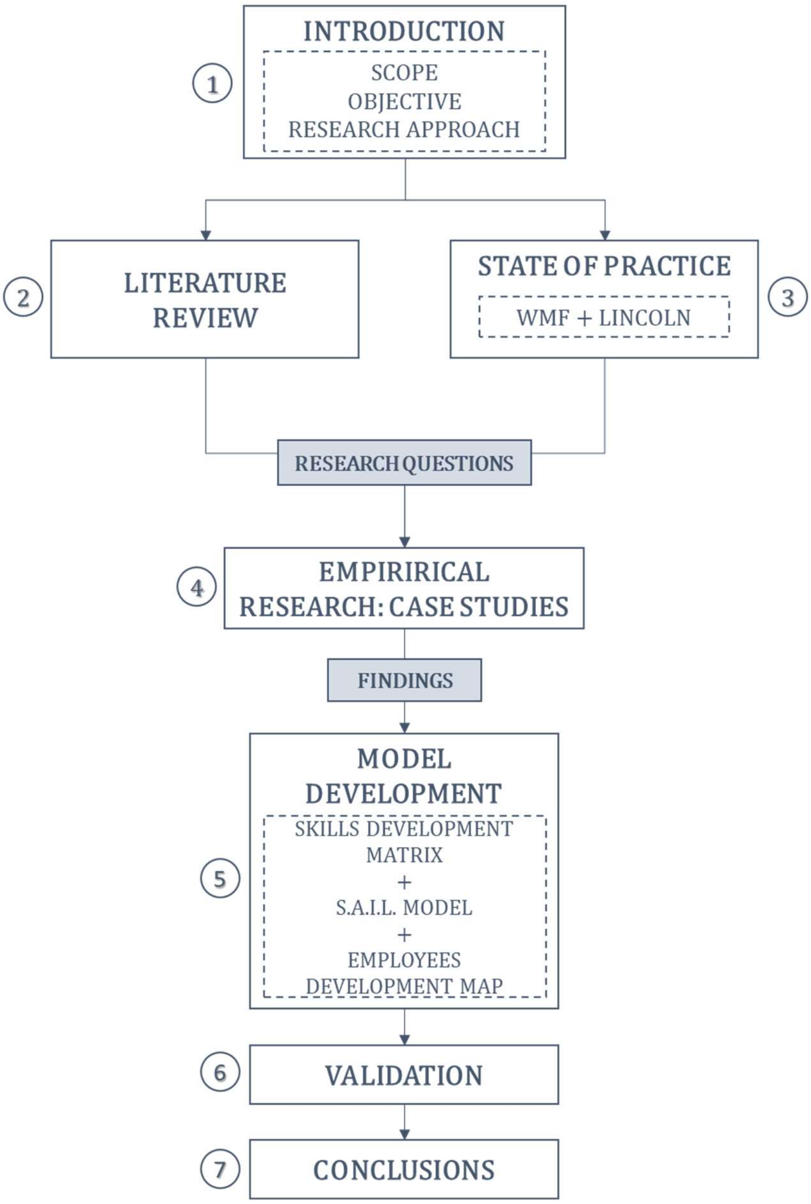


Figure 1. Thesis structure, reflecting the research approach

① INTRODUCTION

The maritime sector is a wide and complex industrial domain in which several different players are involved. it is not merely related to Ports, Shipping and Logistics (which characterizes the 90% of the world trade's volume) but it envisages also the Shipyards together with all the connected services (Design Studios and external providers) and the Academic world behind it. These announced players are the ones that will the research scope considering the maritime sector.

What is perceived from an introductory analysis, is that the maritime sector is lacking in terms of digitalization, and the embedded skillset of maritime companies is currently acting more as a barrier rather than an enabler.

Thus, the objective of this research is the one to investigate about the current digital skills gap of the maritime sector and to provide maritime companies with reliable guidelines to facilitate the adoption of the most suitable digital skills development plan with the aim to reduce this gap. The means to perform this work are the literature review, the analysis of the state of practice and the case studies.

② LITERATURE REVIEW

Before starting to collect the academic articles to build the knowledge base to go forward in the analysis, the authors wanted to practically define the direction of the research. The research is developed considering three relevant research fields: the maritime field, the digital technologies field and the skills development's one. The literature review has been conducted with the aim to inspect these fields and their intersections, in order to have a simultaneously broad and specific overview on the concept of digital skills development in the maritime industry. *Figure 2* summarizes all the research areas taken into considerations to collect the necessary information through the literature review, together with the logical flow followed by the authors.

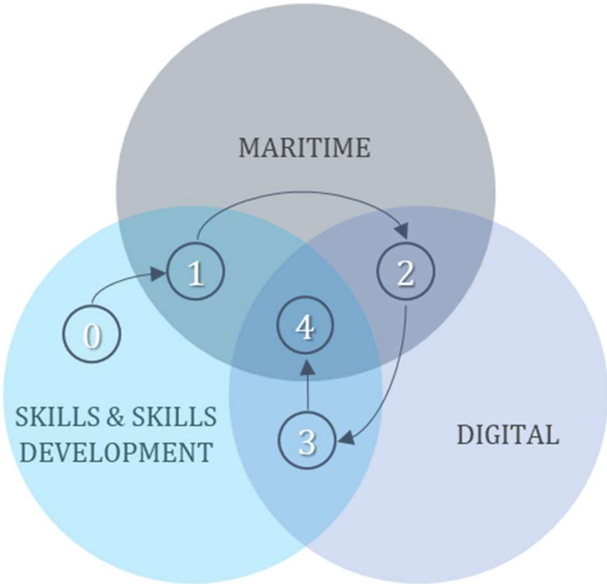


Figure 2. The five areas of research

First, it is necessary to understand the most common practices of skills development (*Area 0*) to concentrate then on the ones adopted in the maritime sector (*Area 1*). Secondly, the state-of-the-art of digital technologies within the maritime sector has to be assessed, understanding all the possible advantages and criticalities that these technologies have brought or could bring to the maritime cluster (*Area 2*). Lastly, an analysis on the possible options to perform digital skills development in general had to be inferred (*Area 3*) in order to finally focus the analysis on the research area of this thesis: the digital skills development of maritime industry (*Area 4*). This is the overall research logic.

The methodology applied within the literature review can be described as a systematic literature search using inclusion and exclusion criteria defined *a priori.* The first step consisted in the identification of "search words", for each of the three research fields. By combining the search words of the three research fields it was possible to infer the combinations related to each of the five areas, in order to conduct the articles research area by area. By starting the research on the browsers with the obtained combinations, it was possible to generate the first academic articles' sample from which extract the relevant papers. From this first sample, a systematic filtering approach (both quantitative and qualitative) has been adopted until the identification of 51 papers. These papers, together with others found in their references and others suggested by the research team, were used to enable the development of a trustable knowledge base necessary to approach the case studies.

What comes out from this literature review is a feeling of unpreparedness of the maritime sector to digital innovation especially considering the needed skills that, at the moment, are not proper to allow digitalization. From the literature review, a list of skills development methods to cope with this problem has been identified:

- Classic Training;
- E-learning;
- Mixed solutions, Flipped classes;
- Communities of Practice;
- One-To-One Training;
- Collaboration;
- Recruitment of new talents;
- Outsourcing.

Despite the effectiveness of the literature review, it was necessary to collect more insights both on the digital skills development and on the Maritime 4.0 environment.

3 STATE OF PRACTICE

To develop a more complete knowledge base before facing the case studies, other activities have been conducted with the aim to collect further insights not found during the literature review.

The authors attended the World Manufacturing Forum (WMF) 2019 conference, that was mainly centred on the topic of Skills Development in the digital era. Thanks to this event it was possible to collect relevant opinions of industrial and political leaders on the role played by companies, governments and society in the new emerging industrial scenario in which digital skills will constitute a paramount enabler. During the event, digital skills have been deeply analysed, allowing the authors to understand which are the real needs of companies in terms of workforce preparation, and new possible roles emerged, like the one of the "digital mentors", employees dedicated to the enrichment of the digital skillset of their peers. Finally, the contraposition between E-learning and Classic Training has been widely discussed, allowing the authors to better understand the benefits and criticalities of different skills development methods.

During the WMF, a session has been fully dedicated to the LINCOLN project. This project consisted in the experimentation of new digital technologies (e.g. Internet of Things platforms, Simulation software) among some maritime partners which were principally Shipyards and Design Studio. Thanks to this project, these companies have understood the potentiality of Industry 4.0, developing an increased willingness to invest to digitalize their businesses. The witnesses during the conference and the practical examples provided by the project allowed the readers to collect relevant opinions on digital technologies by maritime experts and to have a more physical perception of the new technologies' implementation in the maritime industry.

Finally, thanks to the knowledge developed through chapter 2 and chapter 3 it was possible to elaborate some Research Questions with the aim to find reliable responses from the case studies and from the authors' propositions. The Research Questions were as follows:

- RQ1) Are there effectively digital gaps in the maritime sectors?

- RQ2) Are the current skills embedded in maritime companies congruent with the development of digital solutions?

- RQ3) Which methods of skills development are more proper to foster the implementation of technologies in the maritime sector?

- RQ4) How can maritime companies successfully implement a skills development plan for industry 4.0 technologies through the years?

4 EMPIRICAL RESEARCH: CASE STUDIES

After a theoretical analysis, the thesis needs a more practical and empirical application. The case studies consisted in semi-structured interviews conducted with six subjects that took part to the LINCOLN project. The semi-structured interview format has been chosen after a specific literature review conducted on the possible interviews methodologies, because of its good trade-off between the structured definition of the interview and the flexibility degree conceded to the interviewee. The latter, thanks to the semi-structured interview's characteristics, is subjected to a well-defined scheme of questions keeping the possibility to add personal considerations and insights about his or her company.

The structure of the interview was settled by the authors with the aim to collect as much information as possible in the limited time lapse of the interviews. The structure of the interview consisted in four distinct phases:

- Q1) *General information:* collection of the information about the company and the subject in general;

- Q2) *Technologies investigation:* understanding the awareness and implementation of all the technologies obtained during the literature review;

- Q3) *Skills development investigation:* investigation about the usual skills development methods adopted by the interviewee's company and the reasons behind his or her choices;

- Q4) *Maritime sector and LINCOLN project considerations:* collection of the opinions and considerations of the subject about the maritime sector in general and the benefits provided by the LINCOLN project.

The companies under investigation are the ones depicted in *Table 1*. They are Shipyards, Design Studios and Research centres (which provide and suggest technological solutions to maritime companies).

COMPANY	INDUSTRY	NR OF EMPLOYEES
Company A	Shipyard	≅25
Company B	Design Studio	≅100
Company C	Shipyard	≅5
Company D	Research centre	≅2.000
Company E	Design Studio	≅10
Company F	Research centre	≅20

Table 1. Summary of the belonging Companies of the interviewees

The companies are mostly SMEs in which it is furtherly witnessed a lack in terms of digitalization. Despite this, the LINCOLN project helped them to develop a certain awareness about the benefits provided by Industry 4.0 technologies, but today there are barriers about their full implementations (*Figure 3* addresses this gap between the awareness and the effective implementation of technologies from these companies). These barriers are both objective constraints (e.g. reduced financial availability) and subjective constraints (e.g. low risk-taking tendency).

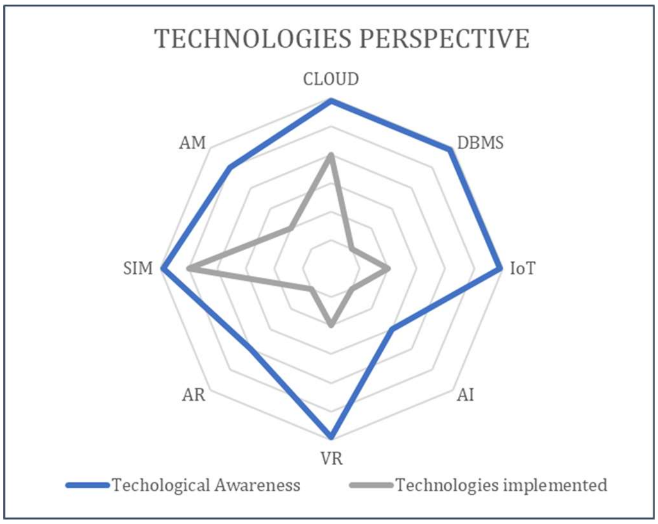


Figure 3. Radar chart from a technological perspective; awareness vs implementation

About the skills development field, these companies rely on the entire skills development methods portfolio derived from the literature review. To these practices, **Self-learning** has been added, being a typical activity of small firms, which consists in an individual skills development process in which the single highly motivated employee is able to nurture his or her personal skills through an open-source research. What came out during the interviews was that these companies usually select the skills development process depending on the characteristics of the company and on the digital skills to enhance.

5 MODEL DEVELOPMENT

After the conclusion of the interviews, it was possible to draw up some findings with the aim to respond to the previous research questions. The digital skills gap has been confirmed to be present by the interviewees, and maritime companies seem to be lost about the skills development process, without knowing which method is more proper for them. The aim of the model to be proposed is the one to guide these realities towards a successful elaboration of a detailed skills development plan. To manage this complexity, the authors developed three models which synergistically cooperate giving both a broad and a specific understanding of the company context.

The first model is the **Skills Development Matrix** (*Figure 4*).

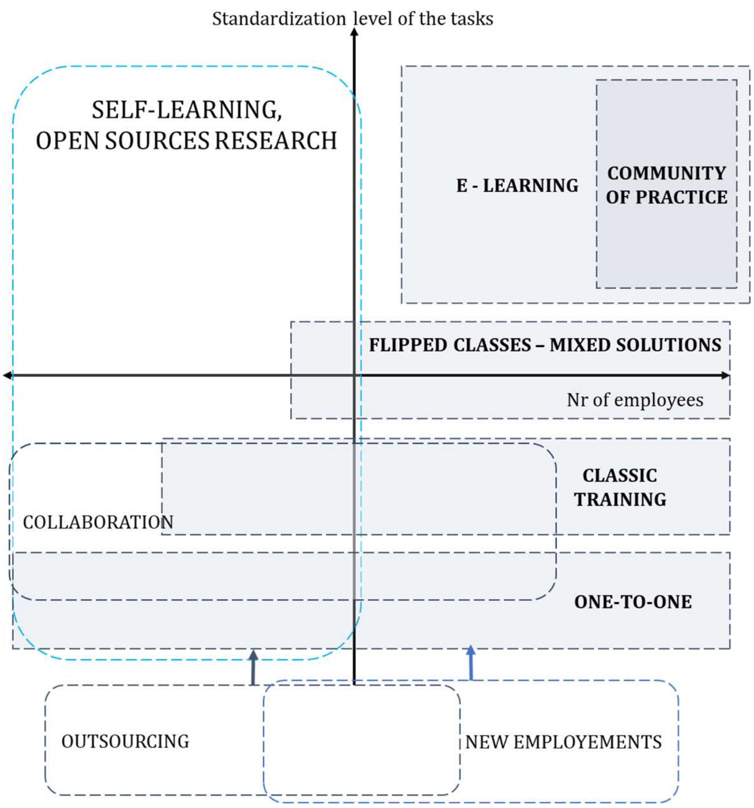


Figure 4. The Skills Development Matrix Model

This model started from the assumption, come out from both the literature review and the case studies, that most impacting factors for the selection of the skills development method of a generic company are the specificity of the tasks to execute and the number of employees. By matching these factors with the skills development methods characteristics, it was possible to fulfil a 2x2 matrix.

The second model instead is the **S.A.I.L. Model** (*Figure 5*), which considers even the technologies on which developing the skills and the company strategy about their full implementation. This model describe the evolving approaches of a company with a specific technology, identifying four stages of confidence: Skeptical, Aware, Illuminated and Leader. The objective is the one to suggest to companies the most proper skills development methods to adopt depending on the stage of confidence on which the company is relatively to a specific technology to enhance.

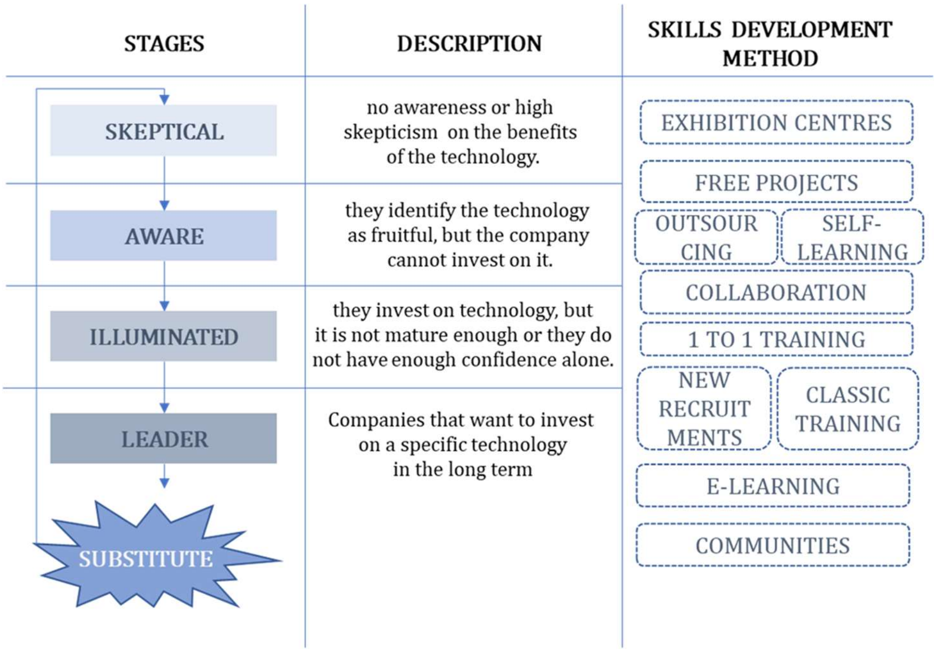


Figure 5. S.A.I.L. Model

Finally, the last model is the one that considers even the maritime sphere; the **Employee Development Map** (*Figure 6*). This last model is a detailed process considering the different possible profiles of the employees to be trained in terms of digital confidence and maritime expertise. The objective of this model is the one to provide clear directions to develop a skills development plan which would align the competences of the workforce before the effective training on the Industry 4.0

technologies. Once this alignment has been performed, thanks to the aid of the other two models the company will conclude the process through a suitable skills development method to be adopted on the specific employee.

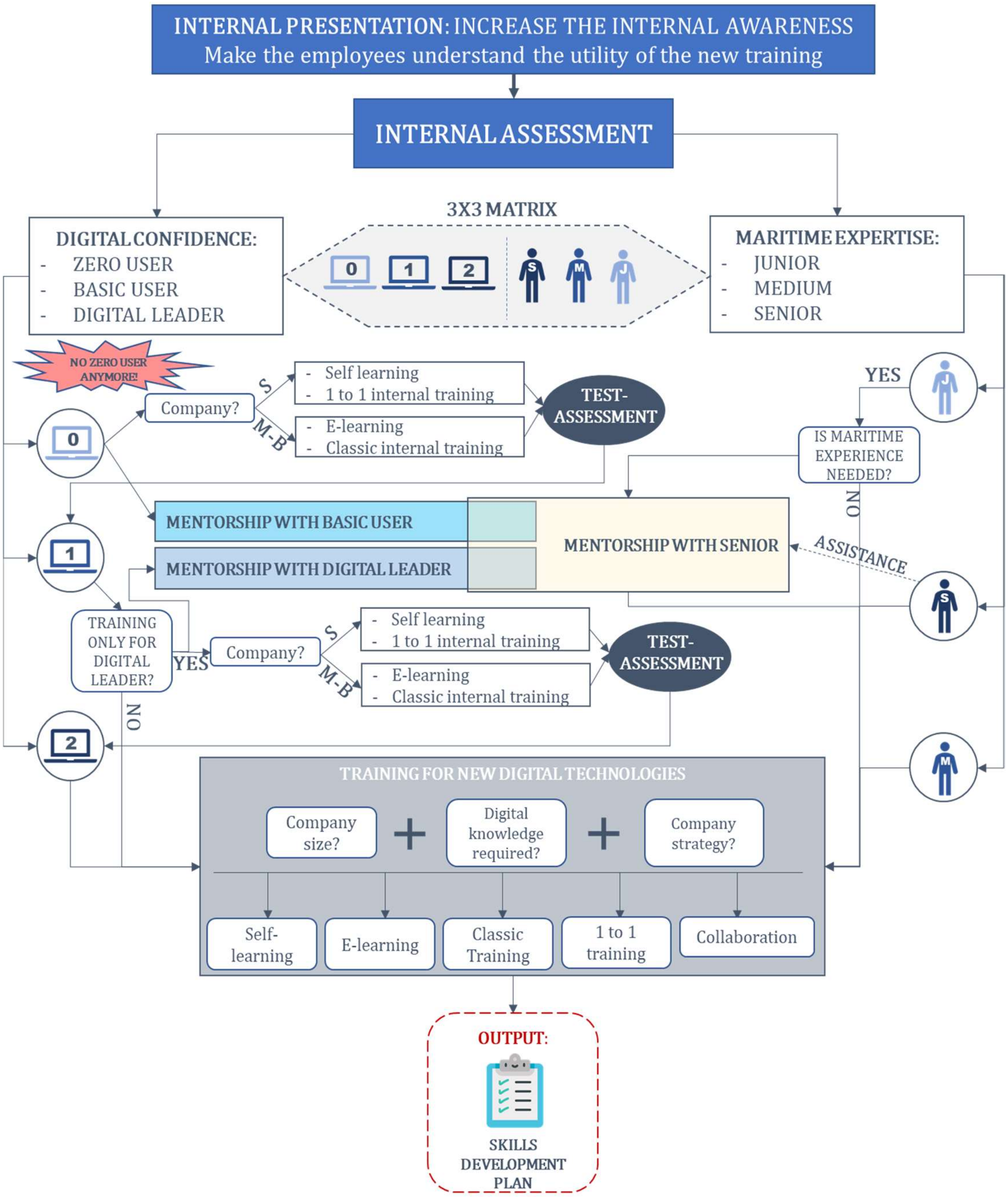


Figure 6. The Employees Development Map

These models combined help maritime companies to firstly assess the most suitable skills development method for them and their company strategy on digital technologies, secondly to generate a skills development plan tailored on the employees' characteristics.

The way in which these models cooperate is summarized in *Figure 7.*

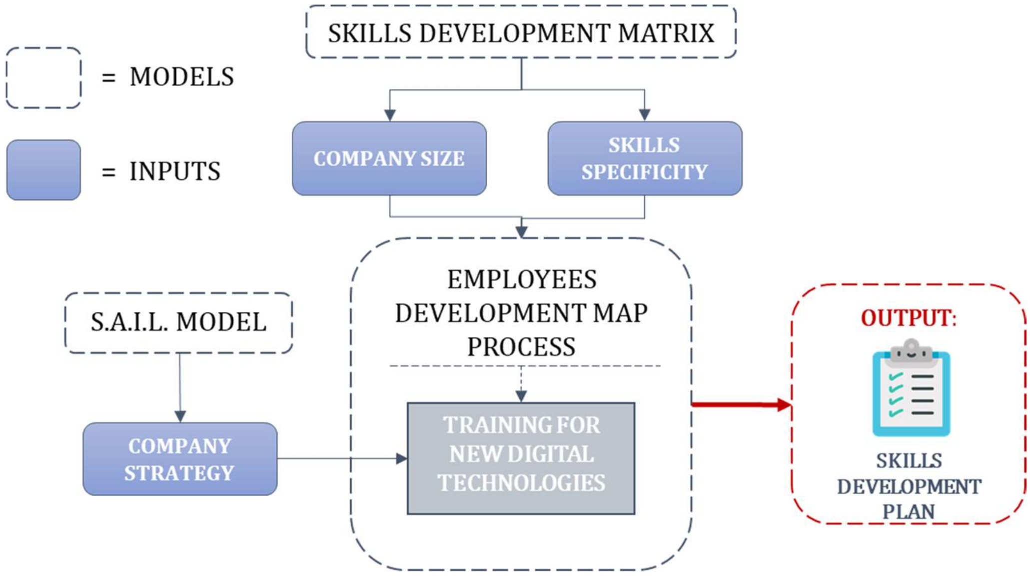


Figure 7. Synergies of the models

6 VALIDATION

Once the models are developed, it is necessary to validate them. The validation process consisted in other semi-structured interviews with two of the previously interviewed subjects, to understand their opinions and possible interest on the proposed models. The interviews have been conducted with the aim to extrapolate from the interviewees some notions which would have confirmed the propositions of the authors, without directly show them the finished models.

The models met the enthusiasm of the interviewed maritime experts, who agreed in almost all the concepts, providing then furtherly hints to make slight adjustments to the models themselves without compromise or changing their overall sense.

To furtherly confirm this validation, a skills development plan has been delivered after the interview by one of the interviewees. This plan, accordingly to the Employee Development Map, divided the skills to intensify in maritime and digital competences. This was the central assumption on which the last model is based.

7 CONCLUSION

Thanks to the work performed, it is possible to draw up some conclusions about the propositions of the authors. Through an effective implementation of the explained three models, maritime companies will reach organizational time savings and will increase the effectiveness of their skills development process as a starting point to exploit the Industry 4.0 advantages.

From an academic point of view, the objective of the authors was the one to enrich the "core" area of analysis: *Area 4*. By drawing from the information collected in the other research areas and from the case studies, it was possible to build a trustable knowledge base to generate a detailed model divided in three parts to enrich the field of digital skills development in the maritime sector. The logic of authors' contribution is schematized by *Figure 8.*

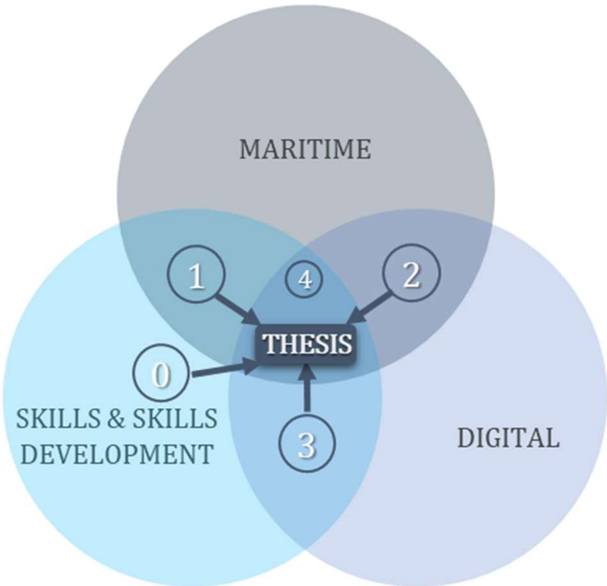


Figure 8. Authors' contributions area

Despite the contributions of the authors, further research is needed in this field, together with a more practical validation of the proposed models.

1. INTRODUCTION

This thesis is the result of a research conducted within three different fields: the maritime sector, the digital innovation and skills development process associated with the implementation of new technologies. The authors studied these fields both individually and collectively, in order to identify the touching points, with the aim of producing an overall final picture that could facilitate the implementation of new technologies in the maritime sector.

The research was carried out chronologically firstly through an extensive literature review covering each of the three fields and their intersections, secondly through the participation to the World Manufacturing Forum (WMF) 2019 and the involvement of the LINCOLN project and finally through semi-structured interviews with some maritime sector experts. All these steps, which will be widely explained, have supported the development of an intuitive model with the aim of guiding maritime companies towards industry 4.0 technologies by suggesting them the most appropriate way to develop the necessary skills. As last step, further interviews have been conducted to validate the authors' outcomes.

This thesis was born from the emerging need to intensify the digitalization of the maritime sector and to optimally exploit the augmented performances of industry 4.0. New technologies imply the development of a new skills set, as discussed during the WMF 2019. From this perspective, skills development, that has always been marked as a non-core and marginal process in businesses, is going to be crucial for companies embracing the digital disruption, and with it the identification of the smartest possible way to manage and to enhance the necessary knowledge.

To conclude, the three research fields (i.e. maritime, digitalization and skills development) and the consequent scope of research are going to be introduced, leaving room to further analysis in the next chapters; finally, the objective and the general research methodology are going to be presented.

1.1 MARITIME SECTOR OVERVIEW

The term "maritime" can be perceived as extremely general. In fact, the maritime sector itself comprehends several different kinds of domains, in terms of companies, authorities and people involved. Due to this, it became necessary to set the right boundaries and to attempt to roughly define the different modules composing the maritime sector (e.g. Ports, Shipbuilders, etc.).

A first attempt to approach the maritime sector could be done through a "cluster analysis", which considers not only the protagonist entities of the maritime sector, but even the actors both influenced and influencing such sector within the same geographical area. The traditional maritime cluster configuration proposed by the University of Aegen in 2014 [1] identifies all these internal and external stakeholders (*Figure 9*):

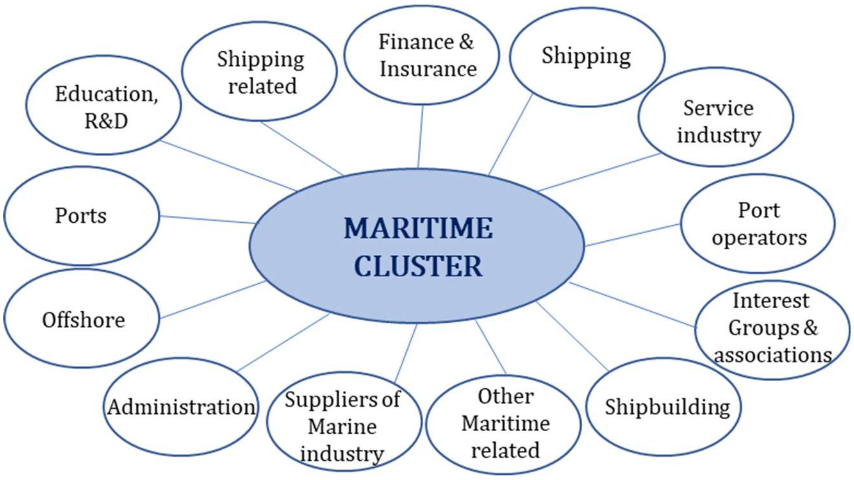


Figure 9. The maritime cluster

From this macro perspective of the maritime cluster, the authors focused the analysis on just some of these actors, considering the characteristics of the companies inspected through the literature review and the case studies:

- *Shipbuilding companies*, which should be furtherly differentiated depending on the size of the produced vessels;
- *Ports* and *Port operators*, considering the authorities and entities managing the ports;

- *Shipping & Logistics*, considering the huge logistic function covered by the maritime transports and the actors embedded (e.g. seafarers);
- *Service industry*, with a particular focus on the *Design studios*, which provide the necessary service of designing, exploiting a wide and peculiar set of technical skills, and the more general *External providers*, that through several supporting activities sustain the companies' business in the case of lacking tools or skills;

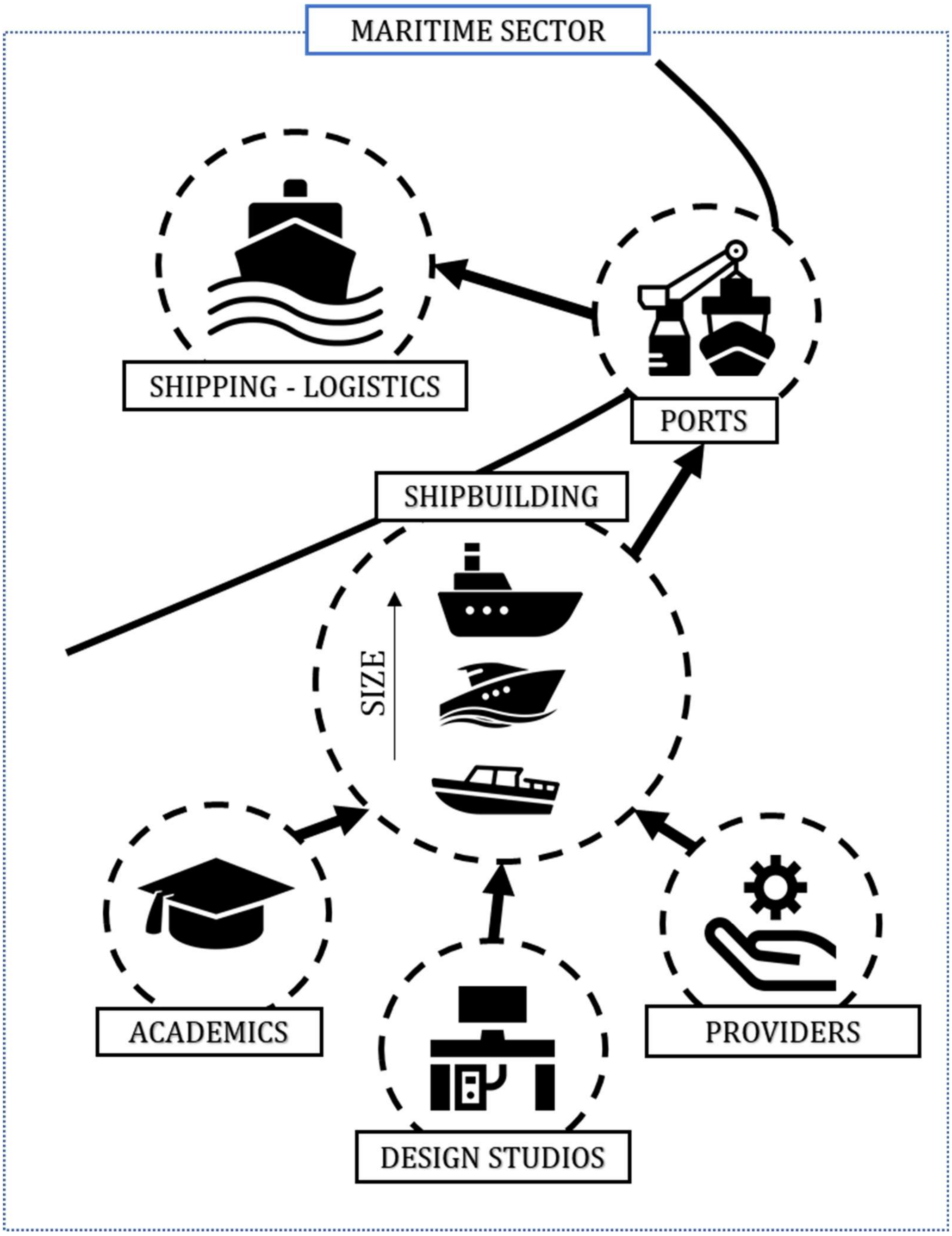


Figure 10. Maritime sector considered

- *Education, R&D*, which refers to the collaboration of companies with universities in order to preemptively identify the right skills to embed in the system.

This set of entities define the scope of the research on which the thesis will focus that is illustrated in *Figure 10*.

Despite the economic relevance of other branches (e.g. offshore platforms), they were not covered by the thesis in order to increase the specificity of the examination. By the way, further specifications need to be presented, especially referring to the Shipbuilding and Shipping Modules because of their different shapes.

Shipbuilding can be differentiated between the big size vessels building (e.g. cruise ships) and the boat building sector.

The first one is producing big size vessels such as: Liquid bulk carriers, Dry bulk carriers, Container ships, Specialized vessels, Cruise ships & ferries and Mega-yacths [2]. It is generally constituted by multinational players (e.g. Fincantieri, with an annual turnover over the 5 Billions € and more than 19.000 employees), with an estimated global industry revenues of 258,21 Billion USD in 2014, 60,2% of which coming from the three sector-giant countries: Japan, South Korea and China [3]. These data are useful to give the reader a clear perception of the dimension of this sector, and with it a perception on the overall amount of investments performed by the major players through the years. This is the reason why, from a technological perspective, it should be necessary to distinguish entities operating in this sector from the companies operating in more specific ones. To witness this assumption, it is possible to refer to what stated by the Chairman of Fincantieri in the past: "*The most effective defence strategy is to distance itself from competitors from a technology standpoint by engaging in increasingly intense and effective research and development activities*" [4].

On the other hand, the boating industry, taking as reference the recreational boats sector, is mainly made up of small and medium-sized enterprises (97% of businesses are SMEs) and a small number of large companies (over 1.000 employees).

Considering the European domain, the boat building sector consists of 3.600 companies employing over 82.000 people [5]. For these reasons, the production is extremely diversified, but the possible investments on technological innovation are limited, as will be shown by the technological delay resulting from the case studies and the literature review in the next chapters. Nevertheless, in the last 5 years the boating market is registering a slight increase in the overall retail value, to witness a good overall potentiality that can be furtherly exploited [6]. *Figure 11* shows also the Compounded Average Growth Rate (CAGR) of the sector in the last years, with the final Year over Year value (YoY).

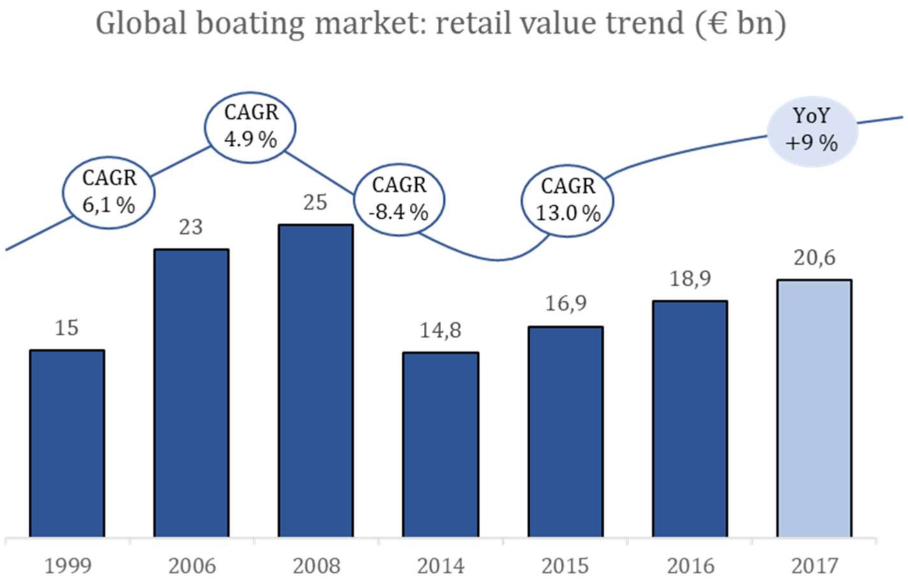


Figure 11. Data on the overall retail value of the boating sector. Source: Boating market monitor, Deloitte 2018

Despite this differentiation within the shipbuilding sector itself, the research considered the actors working in this industry as a whole bundle, by calling the overall industry "Shipbuilding".

Shipping is another macro-sector that could be deeply discussed through an extensive literature review. Maritime transportation is well known to be, by far, the most cost-effective and at the same time the most time-consuming method to transport goods and raw materials. This assumption is furtherly consolidated by the difference between the world merchandise trade volume (90%) and value (60%)

performed by sea every year [7]. Despite these values, the sector is lagging in terms of digitalization [8], thus one of the main goals of the future will be to optimize the navigation systems exploiting new technologies (e.g. autonomous ships).

To conclude, the reader is left with a final overlook on the issues that are going to affect the global maritime industry in the next future. The scatterplot below resumes the general perceptions, extrapolated by a survey involving 52 experts, in terms of preparedness of the companies, impact and likelihood of the events (*Figure 12*).

Exploiting the data collected by the Global Maritime Issues Monitor of 2018 [9], the authors bundled the issues depending on their nature, to compose a rough PESTE analysis. As it can be noticed, the cyber-attacks are perceived as the most urgent issue in which there is the least preparedness, as a clue of the digitalization need of the sector. At the same time the workforce skills shortage is a present relevant issue.

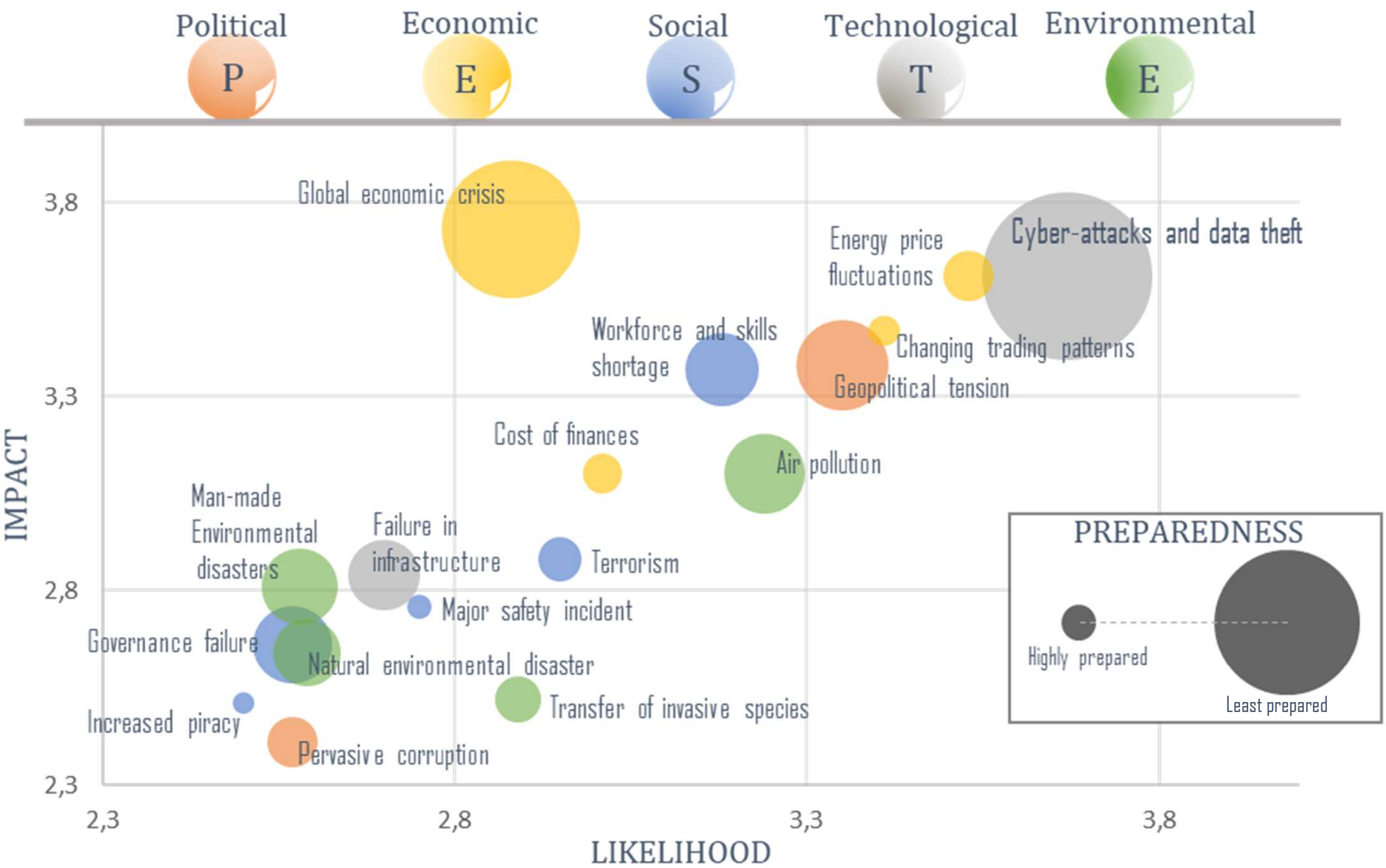


Figure 12. Global Maritime Issues Monitor, 2018. Data collected by Marsch and IUMI through questionnaires with grades from 1 to 4. The scatterplot results from the arithmetic means.

1.2 DIGITAL TECHNOLOGIES AND INDUSTRY 4.0 OVERVIEW

Industry 4.0 is going to reshape the overall industrial environment in the next years, exploiting digital technologies to "virtualize" the reality. The terminology "Industry 4.0" was coined in 2011 by a German initiative of federal government with universities and private companies with the aim of increasing productivity and efficiency at a national level [10]. The concept behind this revolution represents a new industrial stage of the manufacturing systems achieved by integrating a set of emerging and convergent technologies that add value to the whole product lifecycle [11]. There are several technologies enabling industry 4.0. These are the ones generally listed by the academic papers that the authors identified during the literature review:

- Internet of Things (IoT) platforms and Smart Sensors;
- Additive Manufacturing (AM);
- Augmented Reality (AR) and Wearable Devices;
- Virtual Reality (VR);
- Fog, Edge and Cloud computing;
- Simulations and digital twins;
- Big data analytics;
- Machine learning (ML) and Artificial Intelligence (AI).

These listed technologies shaped the technological scope of this research in terms of literature review and case studies (*Figure 13*).

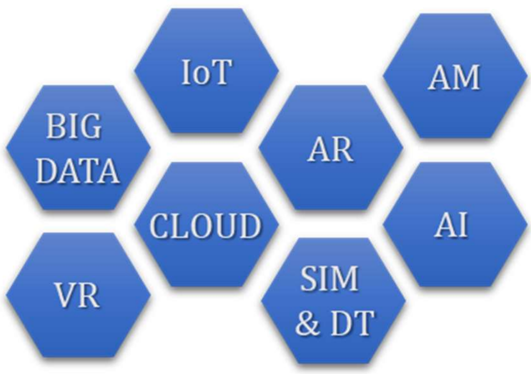


Figure 13. Industry 4.0 bundle; technological scope

Despite these technologies, the real peculiarity of this revolution does not concern the technological disruption, but the integration of all these pieces. While the other industrial revolutions were implied by disruptive technologies that totally upset the mankind (e.g. the electrification in the second industrial revolution), the technologies exploited by Industry 4.0 do not entail the same disruption degree, as stated by a research expert during the WMF 2019: "*are, in your opinion, sensors disruptive nowadays? I don't think so*" [12].

Industry 4.0 is associated with many opportunities and benefits like high flexibility in mass production, reduction of complexity costs and real time coordination and optimization of value chains [13]. A more detailed analysis will be conducted in ***Section 2: Literature review*** to have a detailed description of the proposed technologies, inspecting the overall set of benefits and criticalities that can be met embracing industry 4.0.

1.3 SKILLS DEVELOPMENT OVERVIEW

In order to define what skills development is, it is firstly needed to define the skills themselves. A skill is "*an ability or capacity acquired through deliberate, systematic and sustained effort to smoothly and adaptively carry out complex activities or job functions involving ideas (cognitive skills), things (technical skills), and/or people (interpersonal skills)*" [14]. Competences can be considered as synonymous, even if they have a slight tendency to comprehend the concept of "knowledge". In fact, a competence is "*a cluster of related abilities, knowledge and skills that enable a person to act effectively in a job or in a situation*" [14]. After these considerations, it is possible to finally describe skills development as the "*process of identifying skills gap and developing and honing these skills*" [15]. It is dutiful to distinguish this process from the more general one of training because many times, people confuse these two concepts. Training indeed is "*a process that provides conditions in which individuals gain knowledge skills or ability" (King, 1964)* [16], so it is one of the possible means to achieve the skills development itself. Other methods are identified in the report of WMF 2019 in the Outsourcing Activities, the Upgrade of the Internal Workplace and the Recruitment of New Talents (*Figure 14*).

Figure 14. Ways to enable skills development. Source: WMF 2019 report

Each of these ways entails different strategies of internal development which can be pursued either individually or complementarily. Training, which is oriented on the enrichment of current employees, can be perceived as a more long-term investment in comparison with Outsourcing, being the latter a fast way to exploit new skills. Thus, a method can be more effective depending on the endogenous and exogenous conditions in which a company operates. If a job-market presents a high turnover of workers among companies, it can have more sense to recruit new talents or to rely on external stakeholders to acquire new skills (as witnessed by Subject B of the case studies).

The skills development process become critical in the adoption of a new set of technologies, thus leading this field of research, that is still considered marginal by several companies, to become more strategic in the years of industry 4.0.

1.4 OVERALL SCENARIO

After having introduced all the 3 fields of research (*Figure 15*) it became necessary to make an integrated reasoning before extrapolating a thesis' objective and the consequent research methodology.

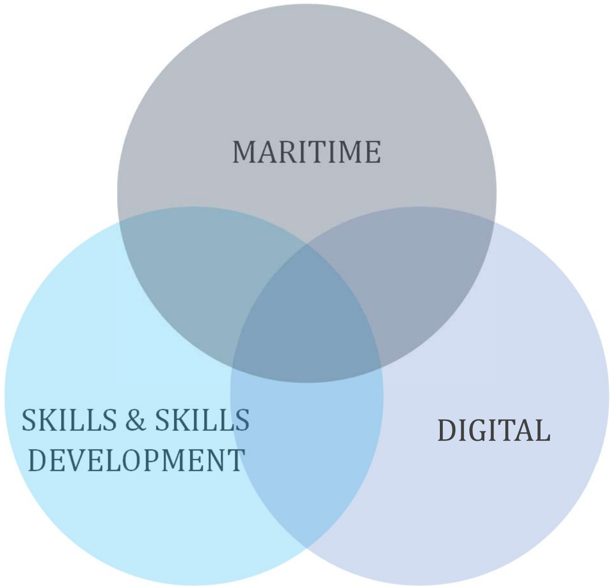
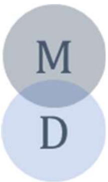


Figure 15. the three research fields and their intersections



The perception behind the technologies of industry 4.0 is that there is a current delay in their implementation in the maritime sector. Even though maritime industry is looking for ways to implement digital technologies, the industry feels itself as not prepared to face the era of digitalization [9], as shown by this second scatterplot built up through surveys (*Figure 16*).

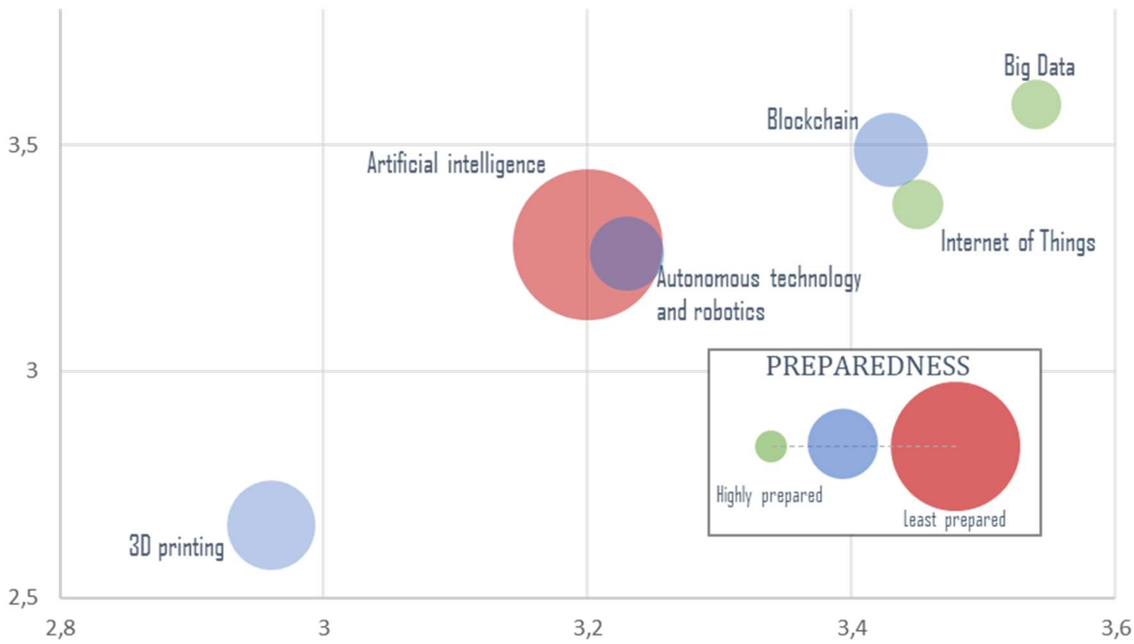


Figure 16. Likelihood, impact and preparedness to the technology within the maritime sector. Data collected by the global maritime issues monitor through 52 surveys, similarly to Figure 12

The literature review and the case studies in the next chapters will corroborate the feeling of delay generally perceived within the maritime domain, especially regarding the SMEs producing boats and the shipping sector.

Of course, technological advancement could provide companies with new ways to foster value creation, but the real benefits of the digital era can be achieved only when organisations also embed the right skills and knowledge to allow an effective use of new technologies. Therefore, expert skilling is necessary to go in depth and capitalise on these specific technologies [17]. Thus, the thesis will inspect how companies can achieve technical skills in the most effective way, through the right tailored method of skills development. Technologies cannot stand alone in a company, but they need to be carried out together with a compliant strategy of skills enrichment.

Moreover, maritime industry could be described as a traditional manufacturing sector that relies largely on a synthetic knowledge base. In other words, the workforce has a high level of experience-based and tacit knowledge especially in the field of engineering [18]. This characteristic of the sector helps to deduce that it will be furtherly necessary to adopt a clearer way to manage the skills internally. To embrace new technologies, maritime companies will not only need to introduce new skills, but, once embedded, even to successfully share them among the workforce. "*Make tacit knowledge explicit*" [19], this concept not only helps the knowledge sharing, but reinforce the current embedded skills as well. As stated by the world-renowned psychologist William Glasser [20], "*We learn:*

- *The 10% of what we read;*
- *The 20% of what we hear;*
- *The 70% of what we discussed;*
- *95% of what we teach to someone else."*

All these correlations and aggregated considerations helped the authors to identify a thesis' objective.

1.5 OBJECTIVES OF RESEARCH

Considering all the assumptions made until now, the final goals of this thesis needed to be inferred. First, the authors wanted to inspect the effective presence of a lack in the digitalization level of the maritime sector, through the literature review and the case studies. Then, collecting notions from the literature review itself and from other practices, the authors investigated how digital tools can be implemented and how the connected skills can be successfully developed. The final aim was the one to generate a framework guiding the choice of the most suitable way of skills development relatively to every different context of implementation, taking inspiration from the patterns coming from the case studies. Together with the objectives, a clear methodological approach needs to be presented to the reader.

1.6 RESEARCH APPROACH

Before going deeply in the content of the study, the general methodology of research is presented to the reader, as the key to successfully examine the overall work done. After the presentation of the scope and of the objectives through the introduction, the next steps are going to be the ones presented below in a glance, together with the specific applied methodology. The proceeding flow is even depicted in *Figure 17,* in order to give a more immediate perception of the steps that the authors followed. From the image it is possible to notice that the literature review and the state of practice steps have been conducted in parallel to develop the knowledge base before facing the case studies.

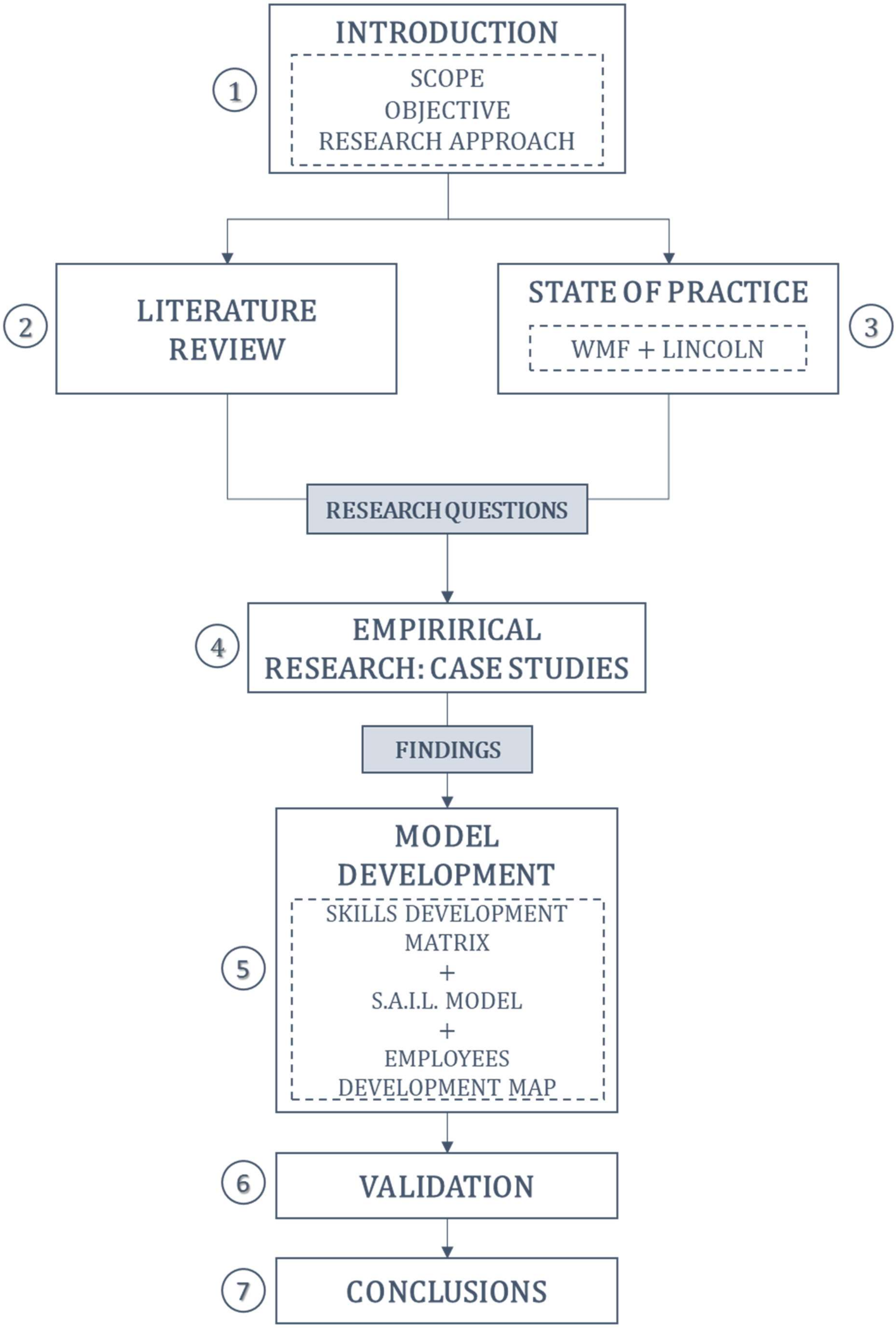


Figure 17. Thesis structure, reflecting the research approach

1.6.1 Literature Review

This step was performed through a systematic literature search [21]. The guideline of the overall research was the scheme presented in *Figure 15*, in which all the three fields are intercepted. The aim is the one to systematically identify all the possible articles connected to these areas and to their intersections. Thus, the authors identified all the possible combinations of search words which could have resulted in interesting academic articles, in order to define the current state of the maritime sector. Starting from all the possible ways to perform skills development in every kind of context, the authors shifted to all the current ways of skills development employed in the maritime industry. Then, the inspection moved on the current digital level of the maritime sector, in order to conclude at the end with the intersection of all the areas, thus identifying the methods to develop the necessary skills required by industry 4.0 within the maritime context. This research was performed by scanning four research browsers in order to collect all the possible inherent articles, and then by filtering them to develop a knowledge background before starting the analysis of the case studies.

1.6.2 State of Practice

To have a more complete knowledge about the topic, the authors have looked for inspiration even in other ways. Skills development is nowadays a popular topic extremely related to industry 4.0. During the WMF 2019 the authors had the chance to get more in touch with the incoming threats brought by digitalization to the current capabilities of the manufacturing workers all around the world. This trends of course affect also a manufacturing environment like the shipbuilding one. This is the reason why, during the 25^{th} and the 26^{th} of September, after the more central topics of the WMF, even the LINCOLN project's results were discussed together with all the involved actors. The LINCOLN project is a research project involving sixteen partners from six different EU countries and led by Politecnico di Milano. The actors work especially within the end users' maritime sectors. The project was developed with the aim to foster the implementation of new technologies within the sector in order to increase the awareness of the players relatively to the benefits proposed by industry 4.0. These two experiences helped to complete the knowledge of the authors within the research scope, giving to the thesis more concreteness. At the end of these two steps, the research questions were finally developed.

1.6.3 Empirical Research

The empirical research was based on the realization of six semi-structured interviews with the aim to confirm the ideas generated through the previous analyses, and to provide more insights within the maritime environment. The interviews were realised through a specific literature review on the development of semi-structured interviews. The adopted method enabled a higher degree of flexibility differently from the questionnaire and classic interview methods. In fact, through the semi-structured interview it was possible to leave the subject a higher freedom in terms of treated topics. The authors developed a general approach scheme in order to guide the interviewees on the research topics, but they were even free to discuss their favourite arguments regarding their companies. This aspect gave to the thesis a broader view on the maritime industry. The interviewees were maritime experts involved in the LINCOLN project working in the shipbuilding industry. At the end of the case studies it was possible to generate some final findings in order to proceed with the generation of a new framework that could contribute to the literature status of the digital skills development within the maritime cluster.

1.6.4 Model Development

Analysing the patterns between all the information collected through the previous steps, the authors generated an overall final model which provides guidelines on the most suitable skills development method depending on the different context. More in detail, the model is composed by three. A first model framework which connects the kind of company to the most proper skills development method (Skills Development Matrix). A second model which sorts all the different methods in relationship with the growth stage in which a specific company belongs inherently to a single technology (S.A.I.L Model). Finally, the last model attempts to generate a training syllabus for the maritime companies, in order to give a higher concrete feeling depending on the kind of training to be treated and to the different employees' profiles present in the company (Employees Development Map).

To summarize, the first part suggests the company how to develop the skills, the second gives the company a view not only on the present but even on the future moves to be taken, in order to aid the development of a mid-long-term strategy. Eventually, the third part gives a more practical acknowledgment on the effective implementation of the skills development strategy, depending on the specific context and trainees' characteristics.

1.6.5 Validation Phase

The last step of the research process was the validation of the proposed models. It consisted in a second interview with two experts previously interviewed, one working in a Shipbuilding company, and the other working in a Design Studio. They were asked about the relationships proposed in the previous chapter. Their answers have been combined with the outcomes of the authors in order to identify the matching and the mismatching of the proposed frameworks with the actual state of the maritime industry. Thanks to their suggestions the Models have been slightly modified in order to increase its compatibility with the reality.

1.6.6 Conclusions

At the end, the authors came to terms with the overall performed work, analysing their academic contribution together with a critical analysis on its limitations, and finally leaving room to further research in this area.

2. LITERATURE REVIEW

In this chapter, the authors are going to show in depth the results obtained through the literature review. First, the methodology applied is going to be deeply illustrated, to make the reader understand the logic behind the collection of the necessary amount of academic articles inherent to the research fields. Secondly, the quantitative results in terms of number of articles for each area of interest are going to be depicted in order to give a concrete understanding of the current academic situation of each research field. Finally, the information collected are going to be presented with a specific order, together with the area that connects all the three topics (i.e. maritime sector, digital technologies and skills development). This macro-step was essential to enable the authors to be successfully prepared before facing the case studies and to be able to subsequently draw reliable conclusions.

2.1 METHODOLOGY OF RESEARCH

The literature review was conducted through a systematic literature search using inclusion and exclusion criteria defined *a priori* [21]. More in depth, the authors firstly identified the gross overall amount of possible inherent articles, and then they filtered it exploiting the functionalities available on the research browsers. The research browsers used were Scopus, ScienceDirect, Web of Science and Emerald. Instead, Google Scholar was useful as backup browser: in the cases in which the searched article was not available in the original browser, it was likely to find it on Scholar transcribing the entire title.

2.1.1 Research Logic

Before presenting the methodology, it is necessary to refer again to the general scheme of the thesis illustrated before but with the general order followed by the authors. In fact, the literature review was the result of a research firstly conducted on more general arguments, secondly shifting the focus on the intersection between them. The research has been conducted following five principal steps reflecting five specific sub-areas represented by *Figure 18:*

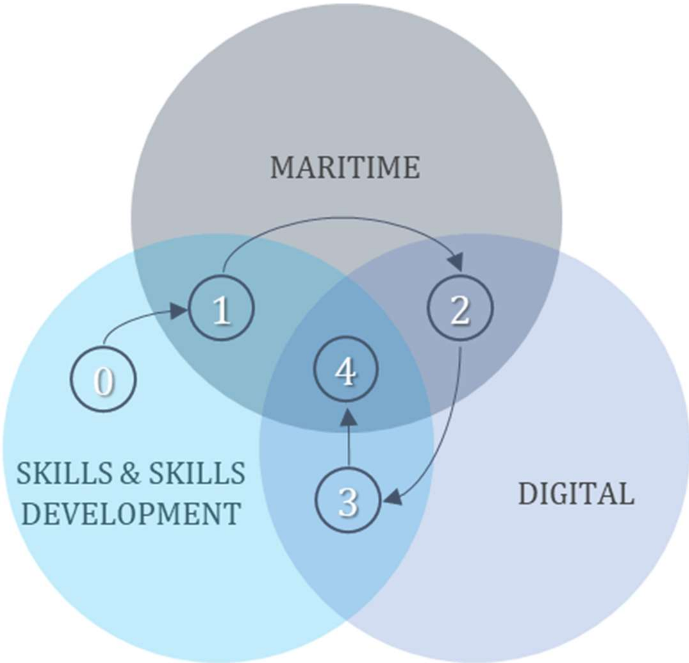


Figure 18. the five areas of the research, coming from the intersections of the principal fields

- *Area 0:* the first step was the most general one. At the beginning the authors wanted to inspect the general ways through which companies enabled skills development within the working environment until today. In this way it was possible to understand all the possible ways to enrich the skills set in a company, and at the same time understanding which are the positive and negative aspects of each method, understanding even which are the most suitable depending on the context in which a company operates.

- *Area 1*: the second stage was similar to the first one but considering only the maritime domain. The aim in this case was double; first to identify the skills development methods adopted by maritime organizations in the past and in the present, second understanding the possible presence of a current skills gap in this sector. Thus, the focus this time was not only on the skills development but even on the skills themselves. The expectations for this area were to inspect the peculiarities of the industry under examination and the reasons behind possible current gaps. In these two areas by the way, the authors were not considering the technological level of the companies.

- *Area 2*: starting from this area, the focus was completely shifted. The authors this time were completely neglecting the skills to concentrate on the digital technologies applied by maritime companies until today, especially regarding the peculiar technologies of industry 4.0 that were identified as potentially useful for the sector under examination. The goal of this step was to define the technological state-of-the-art of maritime organizations in order to inspect the presence of a possible digital gap. Considering the different realities present in the maritime cluster, the results were supposed to be quite fragmented; but this step was propaedeutic for the introduction of the competence development which could have accompanied the implementation of digital technologies themselves.

- *Area 3*: After the inspection of the digital level of maritime industry, it was essential for the authors to understand the most common practices to make skills development in the digital era. In fact, as will be furtherly demonstrated by the central topic of the WMF 2019, the skills development is going to be a crucial aspect of the embracement of new digital technologies. By the way, these considerations have been conducted without any distinction in terms of industry, just to provide a general idea on the ways to treat the new necessary skills in relationship with the workforce.

- *Area 4*: finally, the "core" section is presented. This area is the final outcome of mixing all the considerations conducted until this point. Of course, it was the most specific area considering all the peculiarities of the three research fields, so the expectations were that the area would has been relatively inconsistent in terms of number of articles. In this step, the objective was the identification of all the ways of skills development adopted in the maritime industry relatively to new digital technologies. It can even be interpreted in the other way around; the objective was, at the same time, to understand which kind of skills are becoming necessary to be developed in order to embrace the new digital technologies of industry 4.0 within the maritime domain. The ambition of the authors was the one to humbly enrich this very specific area of research through this thesis.

After the reasoning conducted on the literature research structure, it was possible to shift to the practical method adopted to identify the necessary articles.

2.1.2 Articles Research

This paragraph is going to consider the effective way through which the authors defined the overall articles sample from which it was possible to extract the articles to analyse, together with the logic behind the articles' selection.

SEARCH WORDS IDENTIFICATION

As first step, the authors, aided by the research team, made a brainstorming session in which the objective was to identify all the possible relevant words for each of the three research fields. It is needed to specify that these words are not necessarily keywords, because the first research step was considering as domain the field "Title, Abstract and Keywords".

By using all the "core" words coming from the thesis title itself, the authors tried to identify all the eligible synonymous in order to have a complete view on the topics under investigation, and to cover the entire available relevant bibliography. This methodology did not come from a specific methodology applied in other papers, but from a consultation within the research team. Moreover, it is important to highlight that during the reading of the articles, it was possible to add new search words found within the articles read, to dynamically enlarge the research sample. This aspect left to the authors the freedom to postpone the closure of the literature review, until there were other new interesting search words coming from the reading of the previous articles or from the suggestions of the research team.

Therefore, the first stage of the academic research consisted in the identification of the search words to apply in the first available filter of the browsers: the "Article, Abstract and Keywords" field. In this way the authors could find all the articles inherent to the investigation, filtering them only in the steps forward.

The search words identified for each of the three research fields in order to start the articles selection were the ones shown below in *Figure 19*:

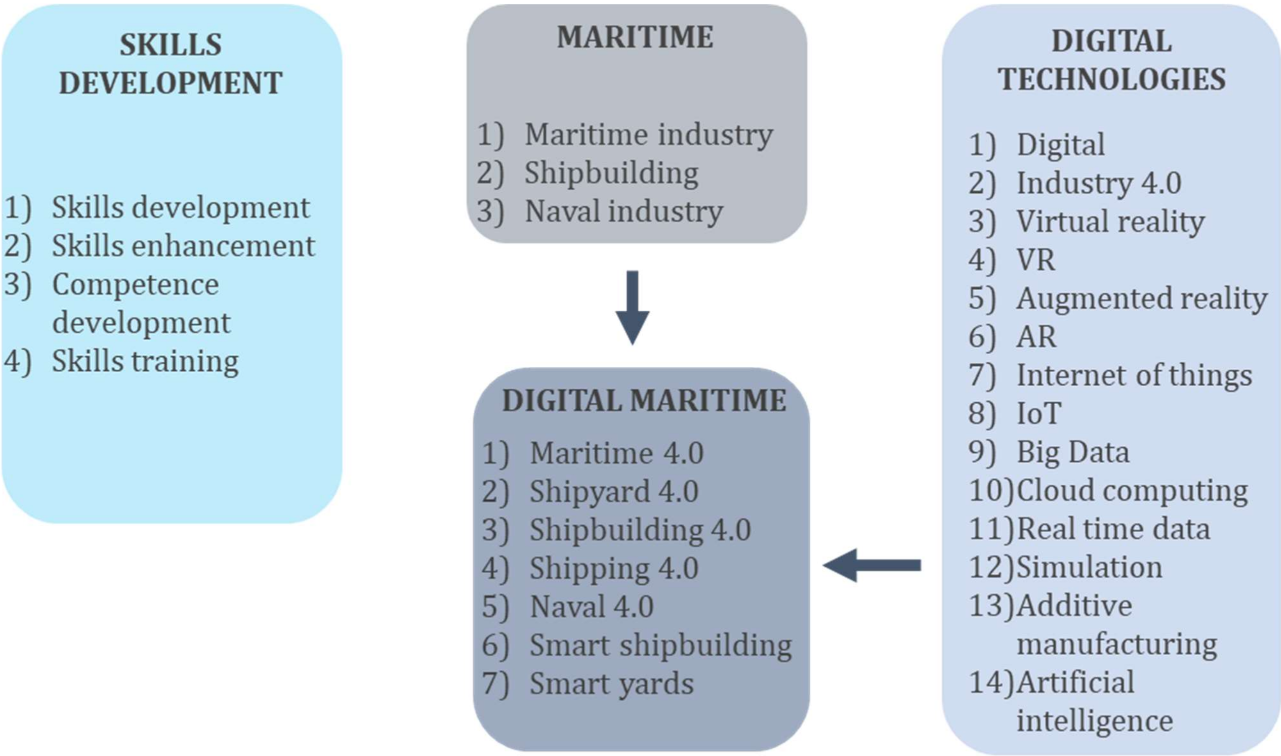


Figure 19. Reference words applied for the research, distinguished for each research field

The search words reported are the specific ones for the three fields, except for the intersection field "digital maritime" (*Area 2*) in which there were specific search words possible to be applied. For the academic research of all the other intersection fields the authors worked on mixing the previously listed words.

More in detail, concerning the intersection between just two research fields (*Area 1, Area 2, Area 3*) the procedure consisted in using a pivotal field and turning the search words of the other one. For instance, when the research was conducted on *Area 2*, the researched words were following the subsequent logic:

- Digital maritime industry;
- Digital shipbuilding;
- Digital naval industry;
- Industry 4.0 maritime industry;
- Industry 4.0 shipbuilding;
- …

In this example, the pivotal field was the digital one. This method led to the creation of several combinations. During the process, if a word was not producing satisfying results from the combination with the others, it was discarded. For example, "skills enhancement" was fruitful only in the research of *Area 0,* hence it has been discarded for the other areas of research. Furthermore, the authors attempted to use some other specific words, especially for the maritime field:

- Yachting;
- Vessels industry;
- Boating industry.

These words were soon discarded because they were extremely lacking in the research browsers.

Concerning the article research for the "core" area (i.e. *Area 4*) coming from the multiple intersection of all the three fields, the number of combinations was too high, increasing both the complexity and the unlikelihood to identify a good sample of articles (too many words in a single research could have led to a potential loss of information). Thus, for this area the authors decided to apply one single search word for the digital field (i.e. "digital") and mixing the ones of the other two, generating the following list of search words:

- Digital skills development maritime;
- Digital skills maritime;
- Digital training maritime;
- Digital competences maritime;
- Digital skills development shipbuilding;
- Digital training shipbuilding;

- Digital skills shipbuilding;
- Digital competences shipbuilding;
- Digital skills development naval;
- Digital skills naval;
- Digital training naval;
- Digital competences naval;
- Digital capabilities maritime.

The only exception of this list is "digital capabilities maritime" that was applied just to have a further synonymous only for the word that was more compliant with the thesis scope (i.e. "maritime").

For *Area 0* instead, the words applied were the ones listed in *Figure 19* within the skills development box.

The positive aspect of this approach was surely the fact to not exclude almost any possible article to build up a solid and reliable knowledge base. On the other hand, as negative aspect, this approach led to multiple overlapping articles that were not possible to be avoided in the examination of the number of articles identified. Thus, when the amount of articles was obtained at the end of the research from each of the four browsers, it was not possible to clean the numerical data obtained from the overlapping articles coming from the other research browsers.

To see all the 111 combinations applied as first step of research, see the appendix *Section 8.1: combinations tables*.

SAMPLE FILTERING

After having explained the logic behind the obtainment of the overall gross amount of articles, it becomes necessary to illustrate the filters applied by the authors to spot the articles that had to be read. As previously stated, the extent of the filtering was related to the functionalities individually offered by the databases. The steps of research, thus, were tailored for each of the four exploited browsers. The actions undertaken by the authors to univocally identify the articles are depicted in the scheme below (*Figure 20*).

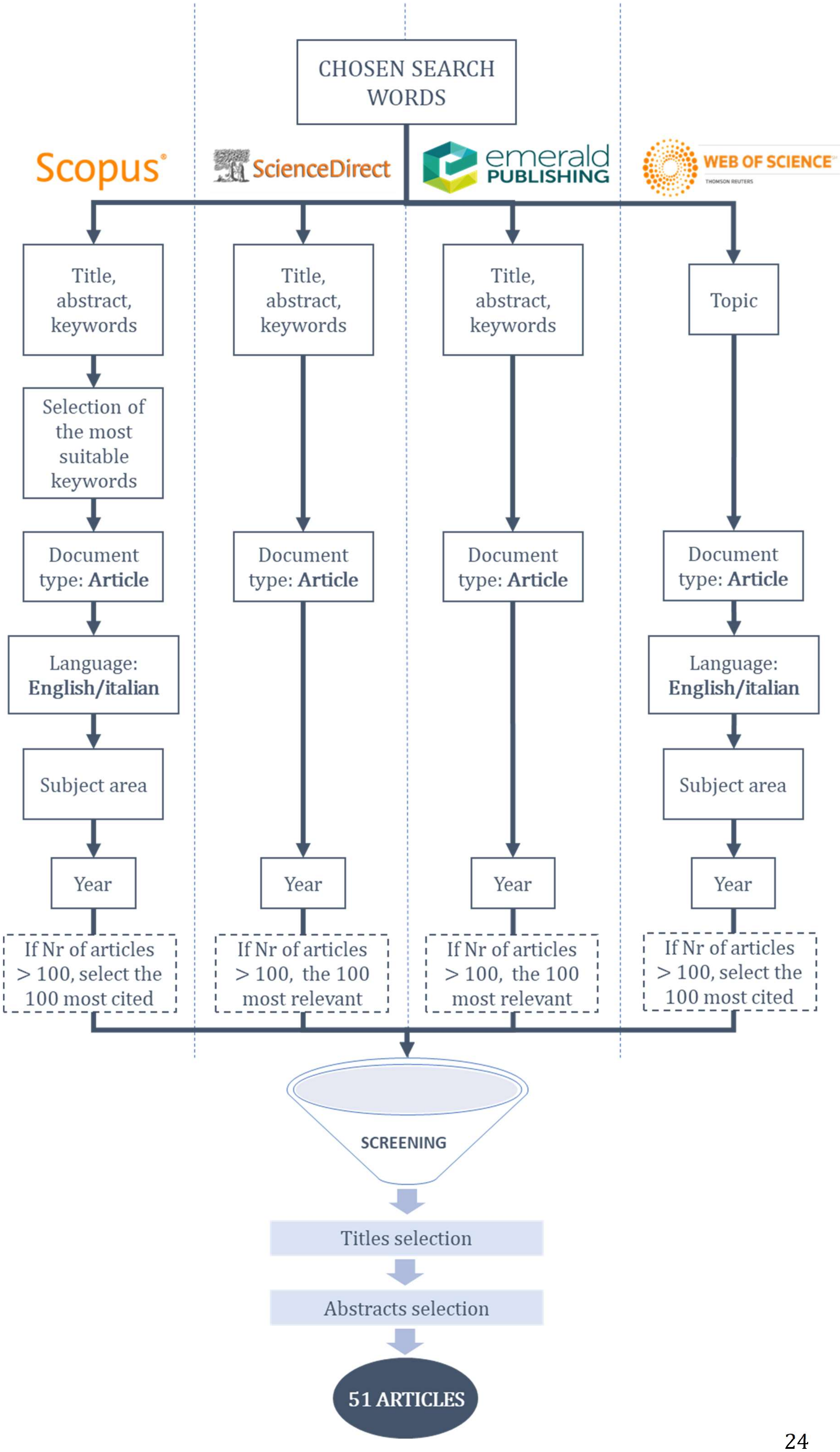


Figure 20. Research process, from the browsers until the analysed papers

By observing the scheme, it is possible to notice that the most flexible database in terms of possible available actions was Scopus. During this scanning process the authors followed these steps:

- *Title, abstract, keywords/topic (all the browsers)*: The first sample was obtained by adopting each combination generated before in this field of research;

- *Selection of keywords (Scopus)*: on Scopus, if the sample of articles identified was very large and difficult to manage (more than 100 articles), the authors filtered the keywords by selecting the more congruent ones with the topic under search. In this case, the further selection of keywords was qualitative, depending on the list presented by the databases;

- *Document type (all the browsers)*: considering the extended sample to be managed, the authors preferred to only look for academic articles, excluding the other types of document;

- *Language (Scopus and Web of Science)*: the authors selected English and Italian articles, being them in their mother-tongue language. Despite this, the articles selected were exclusively written in English;

- *Subject area (Scopus and Web of Science)*: A further specification was allowed by the selection of the subject area. This field contemplated a multitude of different disciplines, and the authors selected only the ones even slightly linked with the thesis' topic;

- *Year (all the browsers)*: the last "mandatory" filtering step was the one referred to the publication date. The authors voluntarily left this one at the end, in order to conserve a certain degree of flexibility in changing the final sample depending on the dates, always without going too much in the past. In this way, all the numbers collected in the steps before were not going to be touched when the authors wanted to enlarge or to restrict the sample by changing the time window. Furthermore, this passage allowed the plotting of the trends through the years about publications per argument. In this way, the time window was never fixed, but dynamic depending on the width of the amount found;

- *Most cited articles (Scopus and Web of Science)*: a further filter before screening all the remaining articles, was related to the number of citations. If the number of articles found at the end of the previous steps was still too large to be managed, only the first 100 articles in terms of number of citations were considered, before screening the titles. Nonetheless, this criterion generated a contradiction; the more an article is recent, the less the number of citations in comparison with an older one. A partial solution to this contradiction was given in the step before. Indeed, in the selection of the publication dates, if the available amount of articles was too high, the authors considered the most recent ones (the ones published in the last two or three years). In this way, the sample was previously already reduced and the number of citations between the articles was comparable because of the tight time window considered.
  Concerning Emerald and ScienceDirect instead, the sample was difficult to clean in this sense. The option provided by the browsers was to sort the papers depending on their relevance. Thus, in the case of a too big sample, the authors opted for this sorting, selecting the first 100 in the same way;

- *Screening*: in this last macro-phase, the objective was the one to select only the eligible articles to be read. In fact, despite the systematic filtering applied in the previous steps, many outliers were still showed by the databases. This aspect forced the authors to qualitatively identify the eligible papers basing on two sequential aspects:

  1) *Titles*; from the sample found through the specific combination of words, the most promising articles were selected to be furtherly

analysed. From the title it was already possible to distinguish the articles which were completely out of scope. The downloaded papers from this step were 97;

2) *Abstracts*; after the download of the articles, the selection was focused on the abstract and on a fast view of the article content, to understand if the paper was effectively compliant with the thesis' topics.

At the end of this process, the articles to be necessarily read were 51, that could seem few compared with the amount of combinations attempted. The reason behind this number is that it was impossible to avoid the overlapping articles. Many articles were showed multiple times for some similar combinations. Nonetheless, the authors preferred to incur in many repetitions instead of risking to lose some potential useful information.

Despite the reading of the 51 papers, many other articles were read in order to complete the information set needed. These further articles came from other sources, like the material provided by the research team or the references of the already read papers.

2.1.3 Quantitative Results

In this paragraph, the quantitative analysis of papers obtained from the research is discussed, while to have all the effective number of papers obtained from each browser and for each research step it is possible to see the detailed table provided in the appendix ***Section 8.1: Combinations Tables***. Of course, these quantities change a lot through the time, including the period of elaboration of the thesis. The research has not been conducted simultaneously for all the combinations, considering the dynamic adjustment of the possible combination through the time, but all the data have been collected between May and October 2019.

First of all, these are the results on the effectiveness of the filtering phase for all the four browsers, from the first step until the one considering only the publication years (without considering overlapping papers). The data are summarized in *Table 2* distinguishing between the four databases:

BROWSER	NR OF ARTICLES	SELECTED ARTICLES	% OF SELECTED
Scopus	476126	5117	1,07%
Science Direct	11695	3623	30,98%
Emerald	713179	53626	7,52%
Web of Science	955813	6963	0,73%

Table 2. Number of articles. From "Title, Abstract, Keywords" to "Year".

These data reflect the overall filtering scheme previously shown in *Figure 20*, that depicted Web of Science and Scopus as the browsers with the most stringent applicable filters. In fact, the percentage of the remaining articles was close to 1%. Different scenario was the one of the other two browsers where the remaining articles were reflecting a higher percentage, especially concerning ScienceDirect because of the initial sample that was the smallest one by far.

BROWSER	NR OF ARTICLES	SCREENED ARTICLES	% OF SCREENED
Scopus	476126	2052	0,43%
Science Direct	11695	2031	17,37%
Emerald	713179	6438	0,90%
Web of Science	955813	3169	0,33%

Table 3. Number of articles. From "Title, Abstract, Keywords" to the citations filter.

Table 3 instead is related to the number of articles that were selected in the step forward, in which the authors had to select the exact sample of titles to be screened. This phase consisted in a fast view of all the titles, downloading the ones that were looking more capturing and inherent to the thesis topic in a qualitative way, in order to avoid clear outliers. In this phase many overlapping articles were shown by the four different browsers for different kind of combinations. In fact, these data look difficult to be manually managed, but the overall amount of screened articles is not reflecting the ones shown multiple times by the databases. Despite this, the controlling phase was quite long to be performed. These data were not anymore reflecting a quantitative selection, but a qualitative one, because in this phase it was necessary to exploit the human reason to identify the most attractive titles. By the way, the reduction of the final sample in this step resulted linear in some extent between the browsers.

Until this point, data have been considered as a whole bundle, but let's analyse them in terms of the area to which the samples belonged. In this way, it will be possible to have a perception of the population within each research field.

As it was easy to imagine, *Area 0* (data in *Table 4*) was the most populated research field, with an average of 367.445 articles present for each browser. The screening of this area was relatively fast in comparison with the others, just to obtain any further possibility from the ones obtained in the other intersections involving skills development.

	BROWSER	NR OF ARTICLES	SELECTED ARTICLES	SCREENED ARTICLES	% OF SCREENED
AREA 0	Scopus	308423	515	271	0,09%
	Science Direct	701	157	157	22,40%
	Emerald	256000	12917	400	0,16%
	Web of Science	904657	2113	329	0,04%

Table 4. Data inherent to the Skills development area (Area 0)

The other areas coming from a single intersection, were less populated but still consistent. From these data it is possible to understand the effect of the "maritime" research field on the databases. Indeed, both *Area 1 (Table 5)* and *Area 2 (Table 6)* with respectively an average number of 3.071 and 15.225 articles found were much less plentiful than *Area 3 (Table 7)* ,the one coming from the intersection of the two other field (i.e. digital and skills) with an average of 152.710 articles. This is an initial suggestion of the academic lack regarding the maritime industry. As it is depicted in the last columns, the higher number of articles present in *Table 7* resulted obviously in a lower percentage of effectively considered documents.

	BROWSER	NR OF ARTICLES	SELECTED ARTICLES	SCREENED ARTICLES	% OF SCREENED
AREA 1	Scopus	2868	150	150	5,23%
	Science Direct	106	43	43	40,57%
	Emerald	7813	521	485	6,21%
	Web of Science	1498	277	231	15,42%

Table 5. Data of Area 1

	BROWSER	NR OF ARTICLES	SELECTED ARTICLES	SCREENED ARTICLES	% OF SCREENED
AREA 2	Scopus	14021	553	489	3,49%
	Science Direct	1185	460	396	33,42%
	Emerald	35851	4594	1876	5,23%
	Web of Science	9842	1255	1154	11,73%

Table 6. Data of Area 2

	BROWSER	NR OF ARTICLES	SELECTED ARTICLES	SCREENED ARTICLES	% OF SCREENED
AREA 3	Scopus	150603	3865	1108	0,74%
	Science Direct	9699	2960	1432	14,76%
	Emerald	410822	34998	3081	0,75%
	Web of Science	39717	3253	1390	3,50%

Table 7. Data of Area 3

Regarding *Area 4* instead the treatment was much more different. In fact, the selection has been less stringent considering a huge percentage of the articles offered by the databases proposing the combinations illustrated in the previous paragraphs. As it is possible to observe in *Table 8*, the percentage of screened articles is much higher than the previous ones. In this case, the average number of articles offered was 752, without excluding the overlapping ones. It is a first hint of the reasons behind the objective of this thesis: to intensify the knowledge of this field by matching the information coming both by the current academic databases and the case studies to be subsequently faced.

	BROWSER	NR OF ARTICLES	SELECTED ARTICLES	SCREENED ARTICLES	% OF SCREENED
AREA 4	Scopus	211	34	34	16,11%
	Science Direct	4	3	3	75,00%
	Emerald	2693	596	596	22,13%
	Web of Science	99	65	65	65,66%

Table 8. Data of Area 4

But which is the trend of this amount of articles through the time? Due to the huge amount of combinations attempted by the authors, it was too complicated to collect the time data for all of them. Thus, a reduced sample of combinations for each area has been taken into consideration. To depict the evolution of the documents, Scopus has been taken as reference browser, because of its huge amount of articles provided and because of its flexibility in the management of the resulting papers. For the next graphs the data are reported in terms of percentage of articles coming from a specific year on the entire sample.

The most populated field *Area 0*, resulted in a more frequent increase of articles in the last years, with a sort of proportional trend. This is witnessing that, even if the search words were not referred to the new technological trends, even the topic of skills development is becoming more popular year by year (*Figure 21*).

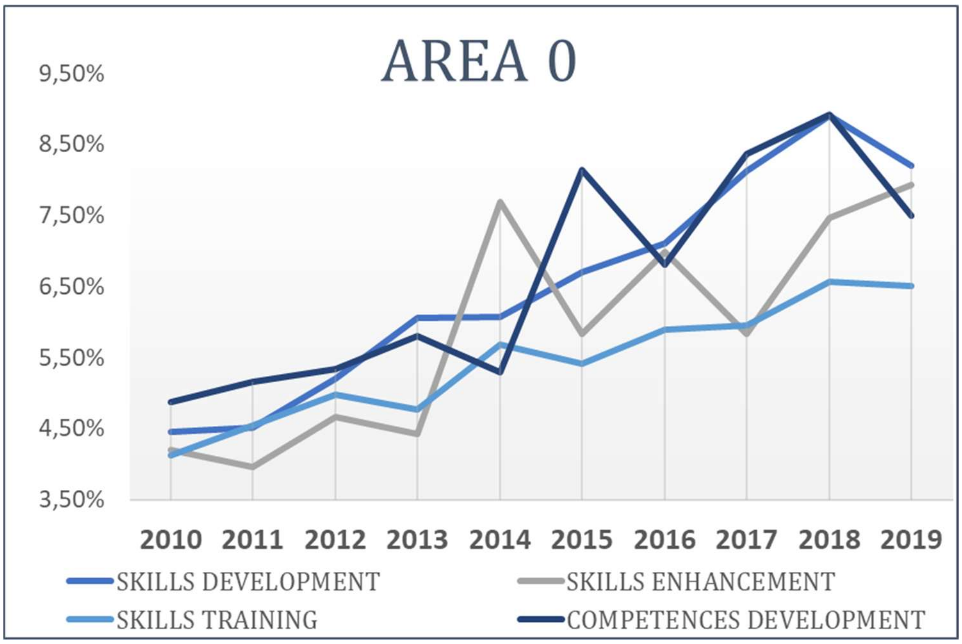


Figure 21. Evolution of the number of papers for each year in relationship with the total amount of papers for each search words on Scopus

In contraposition with what previously stated, the maritime sector does not look so much affected by this increase in the attention for the skills, at least by watching the trends through the time, the number of articles are changing in a random way, so the attention to the topic is neither significantly increasing or decreasing contextually to the maritime cluster (*Figure 22*).

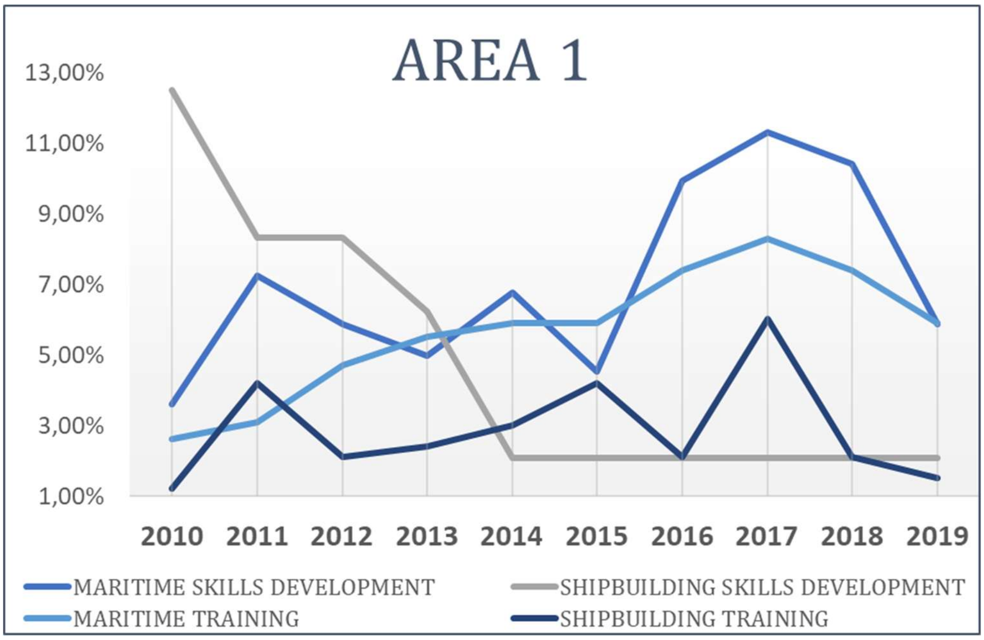


Figure 23. Evolution of the number of papers of Area 1

Concerning the area intercepting the maritime and the digital realities, there are several data possible to be depicted. The authors reported the popularity of all the technologies under investigation searched in combination with the word "maritime" (except for additive manufacturing that was much more congruent with the word "shipbuilding"), dividing them in two graphs depending on their popularity: the four combinations presenting less articles (*Figure 23*) and the ones presenting more articles (*Figure 24*).

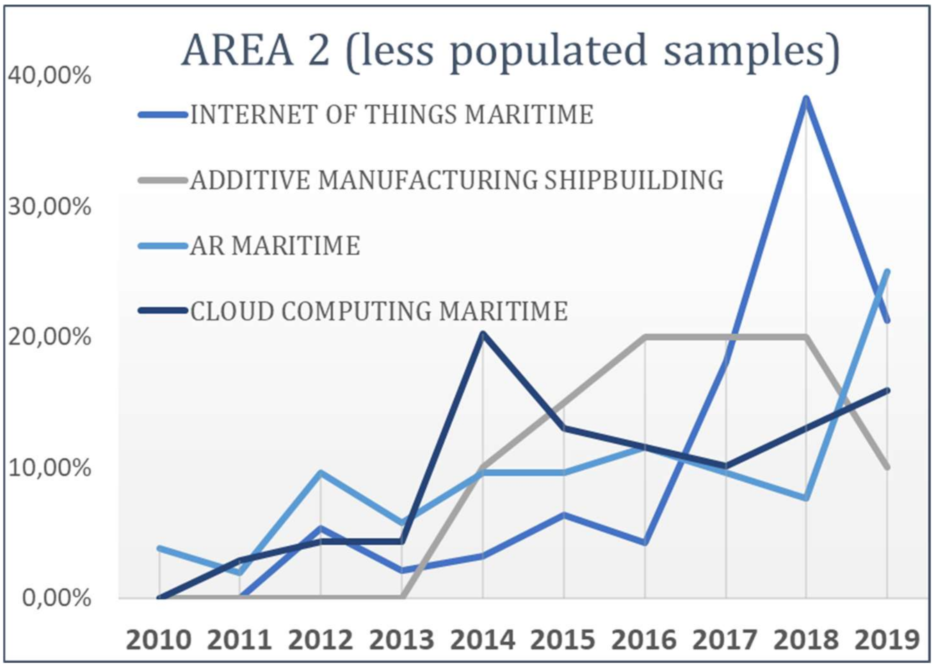


Figure 22. Evolution of the number of papers related to the least popular technologies

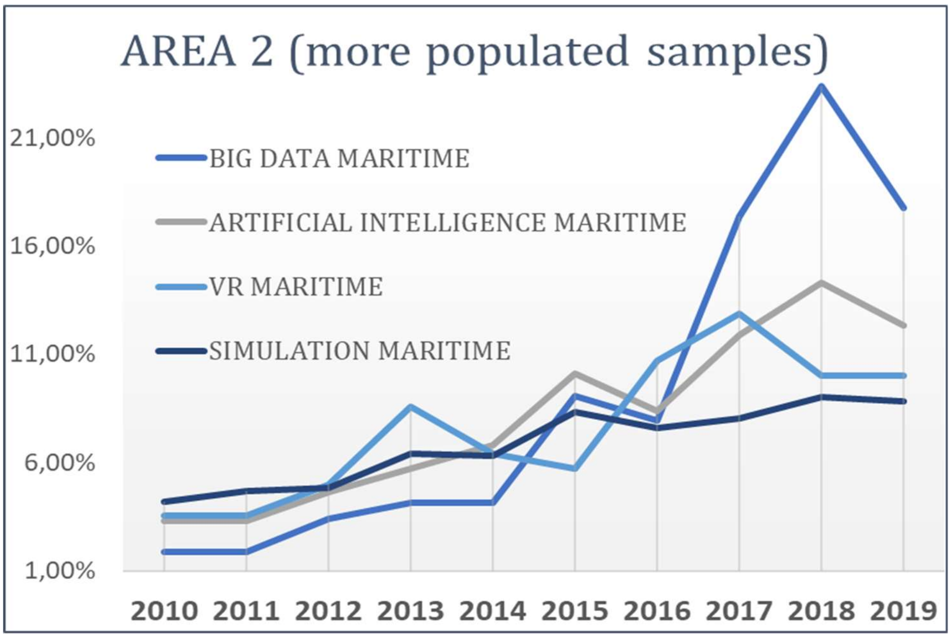


Figure 24. Evolution of the number of papers for the most common technologies

As it was possible to imagine, the trend of all these technologies is increasing even within the maritime domain. The first of these graphs resulted in a more swinging lines because of the lower number of articles.

To summarize this pattern of higher digitalization within the maritime sector, another more general graph is presented here below, in which all the articles coming from two combinations not related to a specific technology are depicted (*Figure 25*).

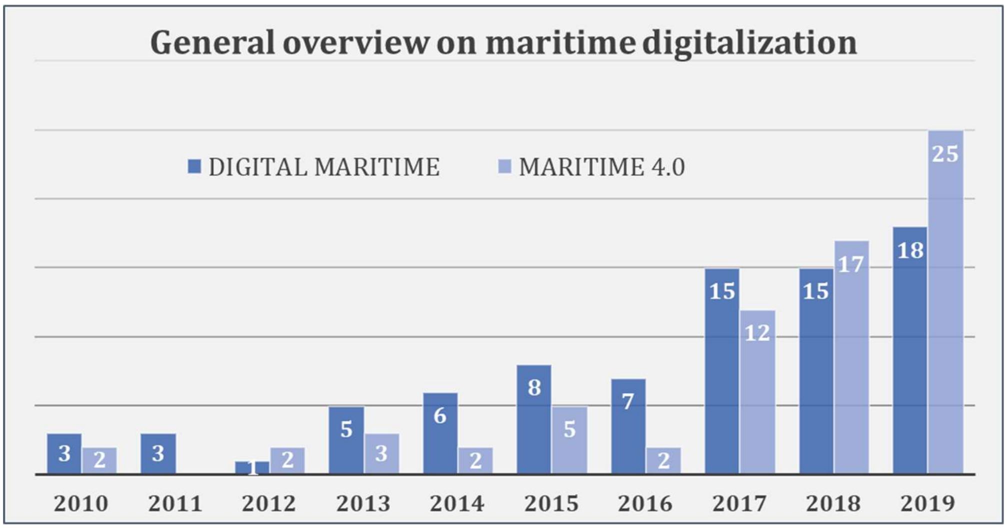


Figure 25. Evolution of the specific amount of papers for these two combinations

The “maritime 4.0” combination is increasing with a faster pace than the “digital maritime” one, because of its correlation with the industry 4.0 trend. “Digital maritime” instead is increasing at the same time, but a relevant number of articles was present even in the years before 2010.

From these data it is possible to understand that new digital technologies and industry 4.0 are more and more popular in the recent years, even inside the maritime academic environment. Despite this, the relative concentration of academic articles relative to industry 4.0 in the maritime and shipbuilding sectors is low in comparison with other industrial sectors. To demonstrate this, it is enough to compare the results coming from the patterns of this research with the ones coming from a comparable industry, such as the automotive sector. The articles coming from the research “Shipbuilding 4.0” and “Maritime 4.0” are respectively 33 and 95, while the ones coming from “Automotive 4.0” are 431.

By focusing on the digitalization combined with the skills development and training topic instead, it is possible to highlight an emerging tendency to accompany the new technologies with the necessity to enhance the current competences embedded in companies. Just observing the slopes of the lines depicted in *Figure 26*, it is possible to identify the increasing attention for industry 4.0 in the last three years (as it was possible to imagine), while the more general digital technologies’ topics are increasing in a constant way.

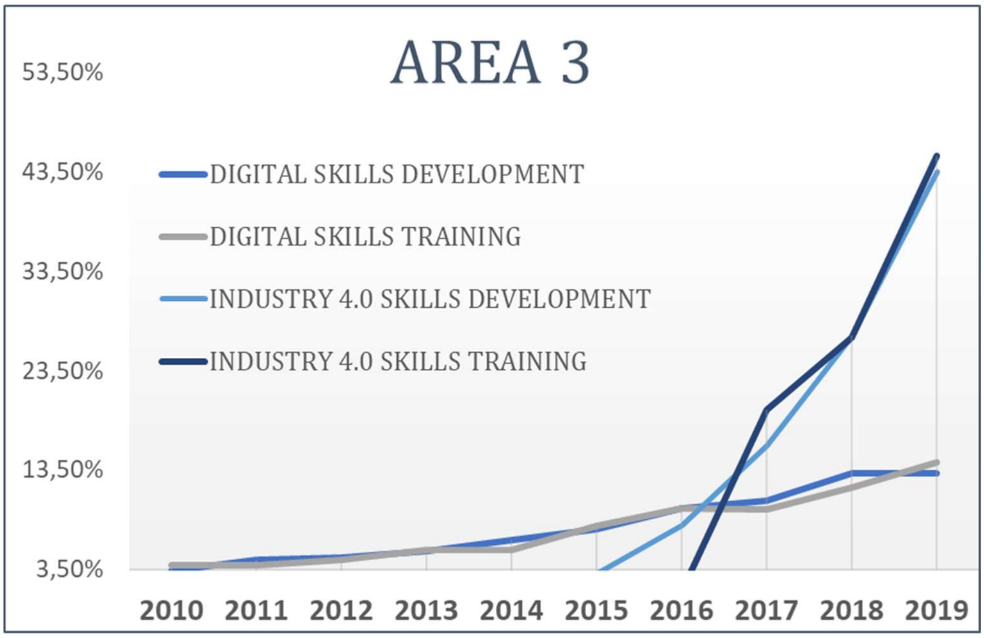


Figure 26. Evolution of the number of articles for Area 3

Nonetheless, the most important data are coming from the area that the thesis aims to corroborate, thus *Area 4,* which are represented by the most popular combination of words (i.e. "digital training maritime") in *Figure 27.*

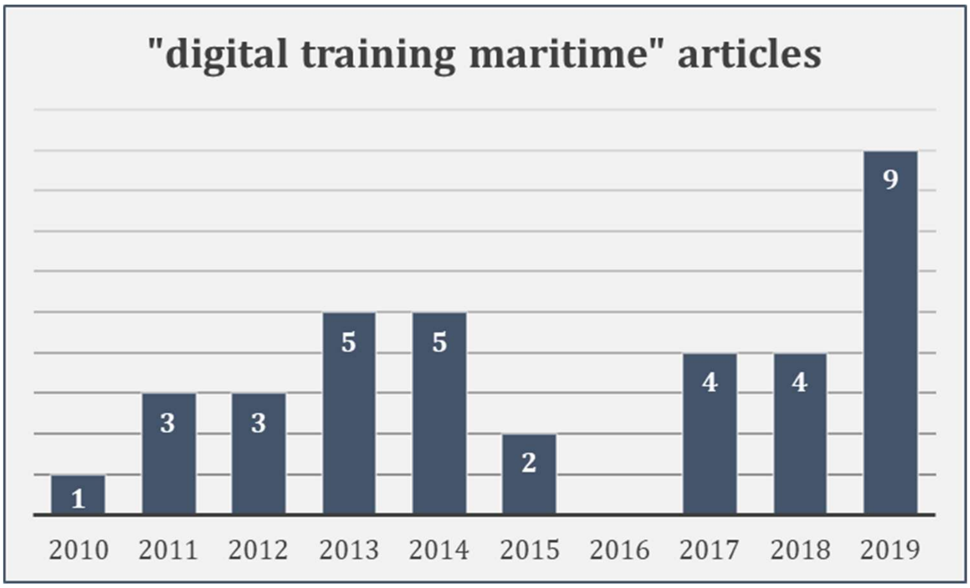


Figure 27. Evolution of the specific amount of articles for the "digital training maritime" combination

Despite the slightly increasing attention to the thesis topic in the last years (2019 was the most fruitful one), this section resulted as relatively lacking in terms of number of articles. Indeed, Scopus, that was one of the most exploited and fruitful browsers, provided just 45 articles for the most popular combination of words of this area, even considering some articles that were still considered outliers by the authors. For other attempts, the research was extremely lacking, like the combination "digital competences shipbuilding" that resulted in just one paper.

The last analysis was focused on the final selected articles, after having qualitatively filtered the sample basing on the titles and the abstracts. The final sample was composed of 51 articles, distributed in the subsequent way. During the analysis of the abstract, the authors realized that many papers found in *Area 4* were actually belonging to other less specific areas. The second column of *Table 9* shows the numbers considering this last conceptual shift.

AREA	NR OF READ ARTICLES	NR OF ARTICLES POST SHIFT
AREA 0	8	6
AREA 1	7	7
AREA 2	9	11
AREA 3	7	13
AREA 4	20	14

Table 9. Last sample, before and after the shift to the inherent area

Specifically to the maritime field, the articles related to maritime industry (thus the one coming from *Area 4, Area 2 and Area 1*) were distributed through the different maritime actors as shown in *Figure 28.* Many articles were referred to more than one actor of the maritime cluster.

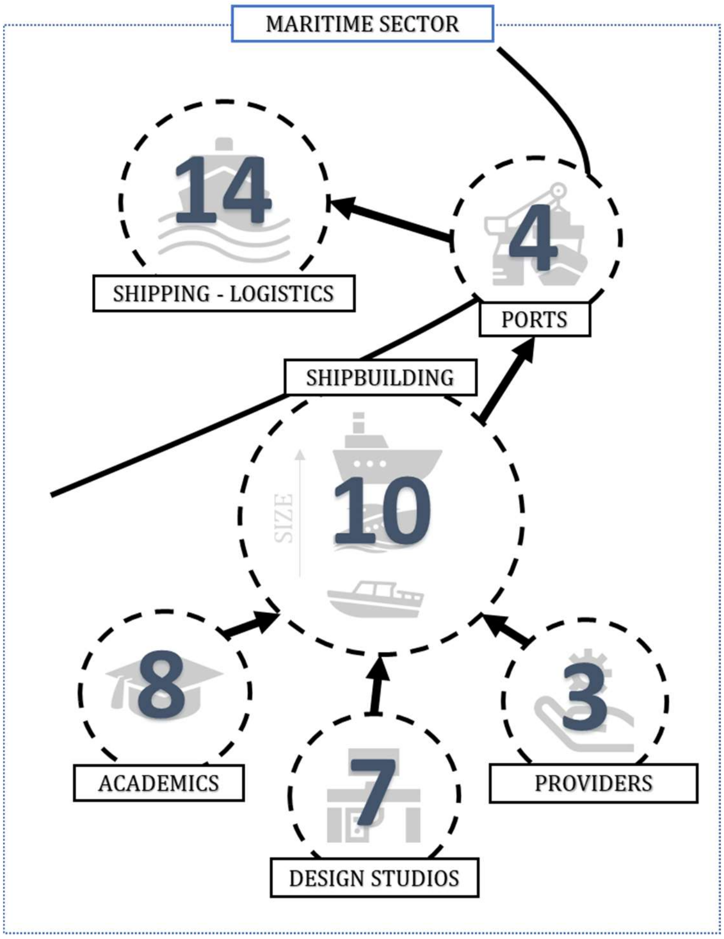


Figure 28. Maritime articles (Area 4,2,1) distributed between all the different actors

Even without reading the articles, the research suggested until this point a considerable academic lack.

2.1.4 Articles Analysis

The reading of papers was conducted considering the five areas already described. Despite this, the order of the analysis was opposite to the overall logic of research. Even if the authors' approach was structured going from the most general area (*Area 0*) until the most specific one (*Area 4*), the effective analysis of the contents was exactly the opposite. In fact, being *Area 4* the most relevant and specific one for the thesis content, the authors wanted firstly to inspect the overall available information within this. After this initial scanning it was possible to parallelly shift to the fields coming from the other single intersections (*Area 3, Area 2, Area 1*), identifying the skills development methods applied in the maritime sector, its digital level and the most common ways to develop digital skills. Only in the end, the focus went on the *Area 0*, to get other possible skills development methods that were missing in *Area 1*, but that were possibly adaptable to the maritime industry. The reason behind this procedure is coming from the authors intent to start from the most specific content. In fact, it was considered more effective to firstly assess the current knowledge inside the "core" area, in order to enlarge the research only when some gaps were identified. When the authors realized that in *Area 4* there was the potentiality to increase the content, the focus shifted on the other external areas in order to take inspiration from them, "pushing" new adaptable concepts inside the "core" area. A scheme of the effective research flow is depicted below (*Figure 29*).

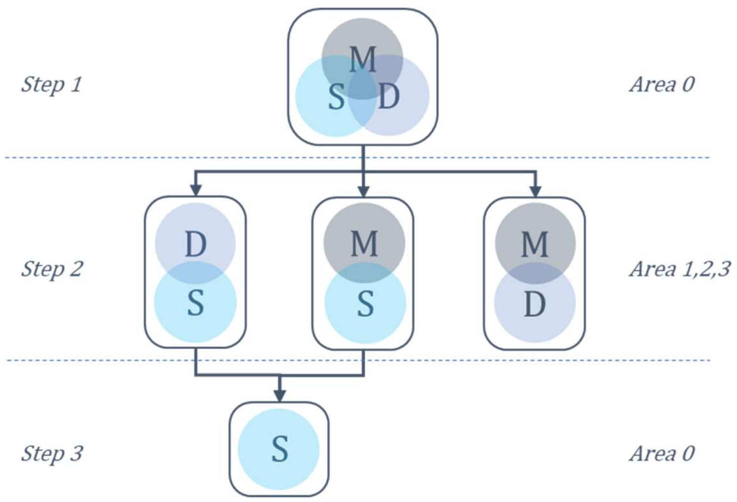


Figure 29. Analysis of the selected articles step by step process

To give a higher physical feeling of what stated before, an example can be provided: imagine that the authors identified a very successful digital skills development method within Area 3 (i.e. the intersection excluding the maritime sector). Their willingness will be the one to propose this knowledge within the *Area 4*, if the method is feasible in the maritime industry. But, before trying it, they need to be sure that this method is not currently present in the "core" area, so they need to have already assessed that research.

Furthermore, this approach (i.e. from the most specific until the most generic domain) helped the authors to stay in touch with the core area from the beginning of the work.

2.2 LITERATURE REVIEW CONTENT

The content of what discovered through the literature review will be showed following the aforementioned scheme of *Figure 29*. As previously stated, the articles coming from the repetitively explained process were 51, but the authors complemented this knowledge with other articles coming from the references of the already read articles or from other sources. Furthermore, it is necessary to specify that many articles belonging to *Area 4*, once read were showing content not inherent with all the three research fields, but with only two of them. Thus, their content was shifted to the other less specific research areas.

2.2.1 Digital Skills in The Maritime Sector – *Area 4*

First of all, it is necessary to well define the concept of the digital skill itself from the skills related to industry 4.0. Digital skills have been widely defined by Glister, that coined the term "digital literacy" as the ability to understand and use information in multiple formats from a wide range of sources when it is presented via computer. Thus, digital skills involve the knowledge and ability to determine information needs from digital technology sources, and to appropriately use digital tools and facilities t input, access, organize, integrate and assess digital resources as well as to construct new knowledge. So, they include both technical and processing skills [22].

The European commission instead defined a "digital competence" as the confident and critical use of information technology for work, leisure, learning and communication. It is underpinned by basic skills in ICT, such as the use of computers to retrieve and to manage information in order to communicate with peers into a collaborative network via the Internet [23] These definitions leave room to a wide interpretation of digital skills. To have a more practical view on it, Huynh et al. [24] tried to formulate a framework in order to distinguish three kinds of skills:

- Baseline digital skills: skills needed by everyone to participate in an increasingly digital economy. This entails confidence to interact with technology and computers;

- Workforce digital skills: the occupation-specific skills needed to allow the workforce to rapidly carry out its tasks. These skills can include performing specific task using specific software and tools;

- Professional digital skills: The skills needed to develop new digital technologies, products and service. It can include skills needed by software developers, machine learning engineers and data scientist.

A similar distinction has been performed by the Australian Qualification Framework [25], depicted in *Figure 30*, in which three level of ICT skills, in relationship with the companies' behaviour, have been identified:

- Foundation ICT: or entry level tied to the foundation of a digital literacy (equipping individuals with the essential ICT skills for life and work);

- Extension ICT: existing ICT skills are extended to occupational skills by enhancing the digital literacy;

- Strategic ICT: where a user is able to adopt and to deploy high-end e-skills creating a real added value for an organization.

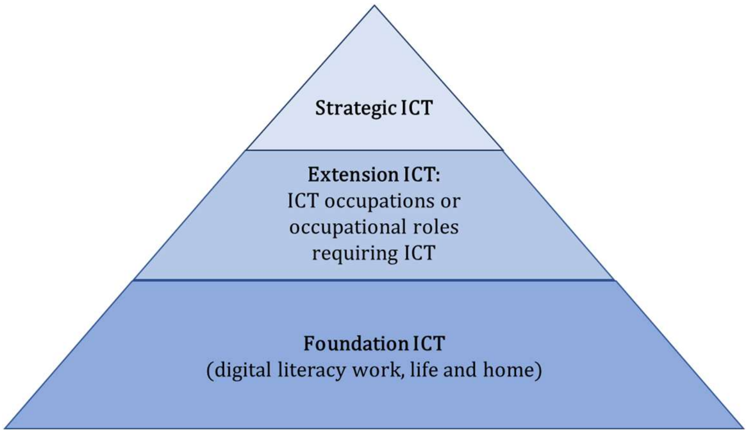


Figure 30. AQF framework to identify three levels of ICT skills. Source: Bowles (2013)

From this optic, it is possible to practically distinguish different layers of digital confidence, in which the skills needed to implement industry 4.0 solutions are the third ones, while the digital skills themselves can be identified in the first two types. In this way, digital skills become the real enablers of industry 4.0, as it is furtherly stated by the WMF 2019 report that defines digital literacy as a fundamental overall skill to allow the implementation of industry 4.0 technologies [17].

Which is the current level of these skills and technologies in the maritime cluster? And which ways to develop them have been implemented until today? These are the questions to which this paragraph needs to answer.

Generally speaking, in the maritime industry there is the perception of unpreparedness relatively to the technologies of industry 4.0, but the digital disruption is affecting even the maritime world, and it is unavoidable. For some of them there is the feeling of a higher readiness (i.e. Big Data), while for others the sector is still far from the implementation (i.e. Additive Manufacturing), as witnessed by the survey conducted by the Global Maritime Issues Monitor [9]. Another Publication corroborating the current digital skills gap in the maritime cluster is the Inmarsat report specifically referring to the IoT technology: from a survey conducted with 750 subjects of the maritime industry, the sector is perceived itself as laggard in the adoption of the IoT, especially referring to the skills the companies currently have in order to embrace this technology. The subjects identified a widening gap between the advancing technologies and the skillsets available to handle them, even in terms of security and data management skills [26]. This topic is even furtherly proposed referring to the area of e-navigation (so narrowly to the shipping industry) in which it is identified a huge gap between ICT capacities and the degree of their exploitation that inhibits the intelligent use of ICT [8].

Referring to the manufacturing environment, in the industry 4.0 era, the shipyards need to have skilled engineers, specialists in technical science, but also in IT science and all data management [27].

Another typical aspect of maritime industry is related to the weight given to the expertise of workers. In the design environment for instance, the ship designers usually rely on their personal experience to assist the design work. But to exclusively rely on traditional experience could lead to a degradation of the overall design quality, decreasing the robustness of the projects [28].

This current skills gap is a real constraint for the maritime industry, that in this way cannot fully exploit the advantages coming from the new technologies, that will be furtherly specified in the next paragraphs.

Despite the need of digital skills, the current industrial revolution asks even for other complementary skills. The future educated maritime workers need to be characterized by diversity, personal achievements, social values and preparedness for future challenges [29].

The steps to follow now in order to maintain a good logical order are: to investigate the level of the industry 4.0 technologies in the maritime cluster (*Area 2*), to identify the methods to enhance the skills related to these technologies (*Area* 3) and finally the methods adopted by maritime entities to acquire or internally generate skills and competences (*Area 1*).

2.2.2 Maritime 4.0: assessing digital technologies – *Area 2*

The word “maritime 4.0” is a word merging the maritime cluster with the industry 4.0 itself. Another way to express this concept is “digitalization of the maritime industry", where the term digitalization itself refers to the "use of digital technologies to change a business model and provide new value producing opportunities; it is the process of moving to a digital business" [30].

But which is the evolution of technology in the maritime world? Differently from what showed in the previous paragraph, here the reference is to digital technologies alone, without considering the skills. Basically, lagging in the preparation to technologies in terms of skills, the maritime industry lags even in their effective implementation, as stated by these citations:

- A typical analysis of basic features of digitalization, is the use of interorganizational Information Operative Systems (IOS). The organizations involved in the hinterland transport have a share of IOS higher than 70%, while the ones involved in maritime transport have a share lower than 25% [31];
- The European Union (EU) does not have a clear strategy of digitalization in the maritime industry [32];
- Ports are lagging behind the utilization of Information Technologies and Information Systems (IT/IS) [33].

The maritime transport industry has experienced a great increase in operations in the recent period, with a 40% growth between 2005 and 2015 [34]. Therefore, it can't not to be positively affected by digital technologies; it is an industry that will be key for digitalization at a global scale. Moreover, the industry creates daily an enormous quantity of data that should be used to optimize the processes and operations, improving the economic results of the various participating actors [35].

After Maritime 4.0, if the reference is to a smaller domain, some other combinations can come to mind, such as Naval 4.0 and Shipbuilding 4.0. The latter refers to the new ways to build vessels, developing smart production systems that are characterized by adaptability, resource efficiency and ergonomic but also tight cooperation between the shipbuilder and the shipowner. The latter nowadays is asking for reduced delivery times and so Shipbuilders have to design and to build ships faster than ever before [36]. Several are the ways to meet this requirement;

for instance, real-time collaboration opportunities with the different actors of the Supply Chain (i.e. suppliers) can consistently improve the ship performances, accelerating its construction and even reducing costs [37].

Thus, as it is possible to understand, new type of shipbuilding supports design and manufacturing trends are moving toward lower cost and better respond to customers' needs, while preparing the on-demand production of optimal and intelligent solutions [38].

Shipyard 4.0 instead is the actual concretization of the merging of shipbuilding processes and the enabling technologies [27], which are the ones introduced at the beginning of the thesis. In fact, the authors performed the research on a selected range of digital technologies to develop the literature review. Now it is necessary to separately sum up all the information found about all of them in relationship with the maritime environment.

IoT *INTERNET OF THINGS (IoT)*

The term IoT ("Internet of Things") was first used by Kevin Ashton, a researcher at MIT, Massachusetts Institute of Technology, where the standard for RFID (Radio Frequency Identification) and other sensors was discovered. For example, IoT is a fridge that orders milk when it "notices" that it is finished. IoT is a house that turns on the heat as soon as it hears you arrive. These are examples of IoT, i.e. objects that, connected to the network, allow to combine the real and virtual world. More generally, IoT is a set of technologies that allow any type of device to be connected to the Internet by using sensors [39].

From a maritime perspective, IoT can lead to strong advantages in terms of visibility and traceability thanks to the RFIDs, not only strictly into a shipyard, but even through the extended supply chain. The localization and the conditions of the fleets will increase the prediction in terms of maintenance basing on the data provided by sensors [40].

More in depth, relatively to the Shipbuilding sphere, IoT can help to produce more energy-efficient vessels by monitoring the effective current consumption [41].

Considering the Ports, using RFIDs leads to a better management of the port warehouses, with the main issues of scalability, fault tolerance and privacy [42]. Concerning the Shipping Industry the investments on this technology are going to be huge in the next three years, because of the potential benefits in terms of safety of the crew, generation of cost savings (more than added revenues), route optimization greater productivity and finally improved decision-making [26].

The issues in this case are relative to the cyber security. In fact, increasing the IoT tools exploitation, the degree of automation will increase, together with a collected and shared amount of data. This will generate higher vulnerability from the cyber-attacks for the e-navigation sector especially. This is the real reason why the current state is still stuck in a monitoring stage, at least in the Shipping Industry [43].

BIG DATA & DATABASE MANAGEMENT SYSTEMS (DBMS)

IoT, through sensors, works as the mean to collect huge amount of data, but once collected they need to be properly exploited. These are Big Data, a data set that is inappropriate to be treated by traditional data process methods because of their extremely wide range, size and complex structure [44].

Big Data analytics tools are efficient in storing the data and processing them in real time, monitoring the traffic and making predictions that improve both the service quality and the companies' revenues [45]. To have a higher physical feeling of the advantage of this technology, the sensors can provide big data in real time to control the road traffic in the cities, virtually informing the drivers to save time [46]. In Los Angeles, the use of Big Data has reduced traffic congestion by an estimated 16% [47]. Moreover, safety can also be improved with sensors that monitor the vehicles speed and the drivers' behaviour [48]. All these aspects have a direct influence even on the maritime environment, especially regarding the navigation.

The main areas of the maritime companies in which Big Data can provide good results are: technical operation and maintenance, energy efficiency, safety performance, management and monitoring of accidents and environmental risks from shipping traffic and logistics optimization [49]. Going into concrete terms, the internalization of all the data processing and analysis capabilities, maritime organization can embed new skills, increasing their independence from external stakeholders and eroding their margins. These capabilities would consist in different steps of data treatment: Data staging, Data warehousing, Data analysis and finally the KPI assessment in order to facilitate the decision-making process at a managerial level (*Figure 31*). The increased performances would be the cost-control, transparency and the service quality that would allow the realization of the so called Product-Service-Systems even in the shipbuilding industry [50].

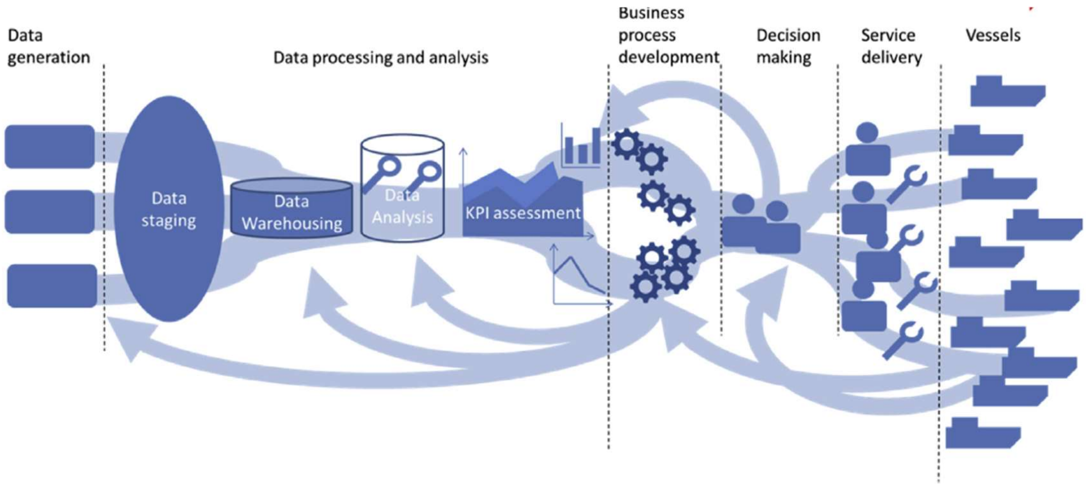


Figure 31. Data management in Shipyards . Source: Pagoropoulos et al. (2017)

The challenges to be faced are related to data quality and quantity. Ship performance and navigation data collected by sensors can have quality and quantity issues. Data can be erroneous due to sensors faults or accidental mistakes during the manual entry. To avoid the latter problem, one possible solution is the full automated data entry, which may be very costly [51]. To improve the quality of data, many cleaning strategies are present, but many times they are not suitable with the Big Data, and this aspect can lead to the rejection of very useful information [52]. The issues related to the quantity instead is relative to the data storage and integration. Koga witnessed the need of equipment with more capacity to meet the need for standardization of data in order to make data integration easier [53]. Last but not least, the shortage of specialists in data science is a very influent issue, especially in the maritime industry which is not originally information-intensive [53]. Here the circle is closed turning back to the skills shortage.

CLOUD COMPUTING

Cloud Computing could be defined as “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources, (e.g. networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction” [54]. In this field, the infrastructures, platforms and software are provided by suppliers as services to their customers following respectively the paradigms of Infrastructure as a service (IaaS), Platform as a service (PaaS) and Software as a service (SaaS). The application of Cloud Computing in traditional manufacturing can produce savings in functions that were traditionally performed internally the IT department [55]. In this case, it is possible to speak of Cloud Manufacturing

The advantage of cloud service is that the service providers can reach a greatly simplified software installation and maintenance by centralizing the control; the end-user instead can access the service “anytime, anywhere” sharing data and collaborating in a very easy way, keeping the data safely into the infrastructure [56]. By combining RFIDs with clouding, it is possible to acquire accurate information which provide updated information to engineers for an effective maintenance in ship management operations [57]. Thus, the cloud can cooperate with other technologies, acting as a real enabler. For example, Fernàndez-Caramés et al. considered Industrial Augmented Reality (IAR) helmets working through cloud, cloudlet or fog computing systems (different kind of computing systems related to the size of data to transmit) [58].

AUGMENTED REALITY (AR)

Augmented Reality (AR) is one of the key technologies pointed out by industry 4.0 as a tool for enhancing the next generation of automated and computerized factories. Usually it consists in wearable devices which provide added information to what people can physically observe. AR can be helpful for shipbuilding operators, since they usually need to interact with information that could be handled easily and more efficiently through AR devices [58].

More in depth, the shipbuilding processes can be improved in many different scenarios:

- Performing quality controls at the manufacturing stages. Usually at these stages, a supervisor needs to perform a quality control where it is necessary to compare the design model with the actual product [59];
- Assisting operators. AR can provide them with a step-by-step procedure by means of intuitive interfaces, which have proved to significantly reduce the number of human mistakes [60];
- To guide operators through the optimal route to follow within a workshop or warehouse [61];
- Visualizing hidden areas, in order to facilitate the location specific covered problems [62];
- Performing predictive maintenance, by detecting anomalies that may cause imminent or future problems [63].

The most relevant challenges of this technologies delivered by wearable devices are related to the possible violation of privacy, technological problems of the devices (e.g. battery life, processing capabilities…), policies and regulations. Another challenge is the technological skills level of the workforce [64], to conclude also this paragraph with a reminder to the skills' field.

VR

VIRTUAL REALITY (VR)

Virtual Reality is "a system which provides real-time viewer-centred head-tracking perspective with a large angle of view, interactive control, and binocular display" [65]. Usually this technology goes together with AR, but it is conceptually different, and the possible applications in the maritime industry are different as well.

In the study proposed by Kostas et al. a VR system is presented in order to orient the ship design to increase people and ship safety. This system consisted in simulating the people and ships movements in case of emergency scenarios [66].

Another application is surely the enhancement of the training of seafarers. 3D interactive simulators can be developed to narrow the training gap between classroom teaching and a bridge simulator assessment of virtual reality [67].

Last but not least, VR can work as a marketing instrument, especially in the Yachting industry, to provide to the private clients the possibility to make an immersive 360° tour on the still under construction product [68].

The cons of VR are related to the difficulties in collecting data from the devices and the possible lack of internal workers' involvement [69].

VR can even be the mean through which cope with a simulation software.

SIMULATION SOFTWARE

Simulators are technologies that aim at reproducing the reality, increasing the effectiveness of the testing phases. There are several different simulation software available for any kind of industrial environment. The selection of the most appropriate one, considering the number of the different packages, is a very difficult task within a company. The selection of the right software depends on the peculiarities of the specific industry and related problems [70].

Within the maritime cluster, simulations are especially involved in the field of manufacturing and design. Shipbuilding specific simulation software are currently lacking, even because of few characteristics of this industry. In fact, generally, shipbuilding is an Engineering to Order (ETO) industry, in which the design is made separately for each new ship. Furthermore, the whole process from contract and design to building happens concurrently. Many processes are still mainly dependent on human labour and require qualitative information that make difficult to extract detailed information at the early stages, at least concerning the SMEs [71].

Usually, most shipbuilding processes consist of job shop production, and both the modelling and simulation require professional skills and experience that are extremely specific, thus generating difficulties to adapt simulation systems [72]. Because of this aspect, the real critical phase of simulation is the modelling of the simulation itself. Being this kind of skills usually lacking in shipbuilding companies, modelling projects are usually realized by specialist based on commission. This is the reason why Back et al. [72] tried to realize an automated simulation model by redefining the shipbuilding-related data from the simulation perspective. The first challenge in this case was, of course, dealing with the difficulties to treat specificities.

Going to the maritime environment instead, the increasing complexity of maritime operations (e.g. under water maintenance) is demanding for more sophisticated algorithms which can handle the complex tasks autonomously with a high precision degree [73]. An original solution to cope with these dynamics has been proposed by Bukhari et al. [74] by exploiting fuzzy ontology on a VR simulator. The fuzzy ontology is a set of concepts deriving from the fuzzy logic, which is a computing approach based on “degrees of truth” instead on Boolean values. After having argued the simulator’s architecture, its benefits have been demonstrated to be:

- Competences embedded in the company;
- Reduced time to test;
- Higher flexibility of the software;
- User friendliness.

The more complex simulation code and the higher number of variables considered instead have led to an unavoidable increased execution time.

In the next chapters, it will be clear the high interest of the maritime players for this kind of technology, especially in relationship with the one proposed by the LINCOLN project.

AI *ARTIFICIAL INTELLIGENCE & MACHINE LEARNING*

Both Artificial intelligence and Machine learning are two buzzwords today, and usually they seem to have the same meaning, and this can lead to some confusion [75].

Artificial Intelligence (AI) is the intelligence exhibited by machines. The term "Artificial Intelligence" is used when a machine simulates the "cognitive" functions that man associates with other minds of his peers, such as "Learning" and "Problem solving" [76]. More technically, AI entails the concept that machines can be improved to assume some capabilities that have always been associated with human intelligence; thus AI can be defined as the bundle of techniques to use computers more effectively using innovative algorithms [77].

Machine learning (ML) instead is a current application of AI which consists in a class of algorithms that automates the construction of analytical models and offers computers the ability to learn without being explicitly programmed. Using algorithms that learn iteratively from data, machine learning allows to find hidden new information [76].

Within the maritime industry this technology has been applied to develop algorithms for the ships' maintenance through effective predictive models based on ML. This algorithm allows to model the degradation of the propulsion plant over time [78]. ML algorithms find application even to detect anomalies in the shipping routes by finding patterns in data that do not conform to expected behaviours. This possibility can find further application in future because at the moment the amount of data provided by vessels are not enough to identify the anomalous tracks, thus the algorithm would identify many false alarms [79].

In ports management instead, AI can be applied to manage the container stacking problem within the container yards, by increasing the retrieval operations' efficiency [80].

Another field of implementation of AI is ship design. Thanks to ML algorithms it is possible to reproduce a ship optimal design bringing to huge time and cost savings. [28].

To summarize, AI is leading to an increased level of "intelligent" automation which is translated in new autonomous vehicles and machines which are enhancing productivity and optimization of resources and better risk management [35].

The possible countereffects of this technology may impact on the society. As argued by Acemoglu et al. [81] this increasing automation degree is risking to became excessive, leading to a job displacement effect and, paradoxically, to hinder productivity. Moreover, instead of developing in tandem, the digital growth is going well beyond the simultaneous supply of skills, creating a mismatch between the requirements of new technologies and the skills of the workforce.

AM *ADDITIVE MANUFACTURING (3D PRINTING)*

Additive Manufacturing (AM), or 3D printing, is "a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies" [82]. This technology found few applications and studies in the maritime industry, as witnessed by the collected data shown in the previous paragraphs.

By the way, AM is extending its influence on various industries, especially in the ones managing steel like the shipbuilding one. AM has several advantages over its subtractive competitors such as the reduction of material wastes, the positive impact on sustainability by shortening supply chains and the improvement of part geometries. On the other hand, it suffers of limitations in controlling the properties of its final product and tolerances and in its limited building size [83].

Furthermore, from an economic perspective, 3D printing can lead in the long run to a distributed manufacturing industry rather than centralized. This effect will seriously impact the logistics-shipping industry, which consists of a large scale of physical products [84].

All the benefits and criticalities of the eight listed technologies emerged by the applications into the maritime industry are summarized in *Figure 32.*

TECHNOLOGIES	BENEFITS	CRITICALITIES
IoT	1) Visibility & tracing (Real time) 2) Preemptive maintenance 3) Cost savings 4) Increased safety 6) Route optimization 7) Productivity & decision-making	1) Cyber security: increased vulnerability 2) Huge investment
BIG DATA	1) Manage complexity 2) Decision-making 3) Time and cost savings 4) Increased safety 5) Energy efficiency 6) Cost control and transparency	1) Quality and quantity of data 2) Costly solutions 3) Data-storage 4) Data integration 5) Skills shortage
CLOUD	1) Accessibility and availability 2) Increased collaboration 3) No CAPEX 4) Integrability with other technologies	1) Security 2) Dependency on providers 3) Lower control
AR	1) Facilitated maintenance 2) Internal route optimization 3) Visualizing hidden areas 4) Preemptive maintenance through predicted anomalies	1) Low digital confidence of the users 2) Privacy issues 3) Technical problems of devices
VR	1) Enhancement of training 2) Application on simulation software 3) Simulation of emergencies 4) Selling tools	1) Workers internal involvement 2) Difficulties in collecting data
SIM	1) Time and cost savings 2) Decision-making 3) Increased safety 4) Lower time-to-test 5) Training enhancement	1) Low physical awareness 2) Current state still inadequate 3) Treating particular specificities 4) High computational time
AI	1) Anomalies detection 2) Logistic optimization 3) Time and costs savings 4) Productivity 5) Risk management 6) Autonomous vehicles	1) Social impact on workforce 2) Skills lack
AM	1) Reduced wastes 2) Shortening supply chains 3) Improvement of part geometries 4) Flexibility 5) Cost savings	1) Difficulties to manage tolerances 2) Limited building size 3) Still poor quality

Figure 32. Benefits and criticalities of digital technologies

What emerges from the deep technological literature review of *Area 2* is that skills are often identified as a real constraint to the development of technologies in the maritime industry. But if they are acting as an obstacle, as counter-effect, if enhanced, they can become the real enablers of maritime digitalization.

2.2.3 How to develop digital skills – *Area 3*

All these listed technologies entail a tailored development of the human resources. Without the right development of skills associated with these emerging technologies, both the industry and the economy risk to be weakened in terms of innovation and competitiveness [85]. Speaking in this terms, the development of the suitable set of digital skills to embrace industry 4.0 becomes a strategic choice for enterprises, that through it can build a consistent competitive advantage [86].

Basing on a survey conducted on 371 global employers, the World Economic Forum identified the top technological drivers of change for which companies need to be prepared in terms of skillset [87], as showed by *Table 10.*

TECHNOLOGY DRIVER OF CHANGE	RESPONDENTS RATING DRIVER AS TOP TREND
CLOUD TECNOLOGY	34%
BIG DATA	26%
NEW ENERGY SUPPLIES AND TECHNOLOGIES	22%
INTERNET OF THINGS	14%
SHARING ECONOMY AND CROWDSOURCING	12%
ROBOTICS, AUTONOMOUS TRANSPORT	9%
ARTIFICIAL INTELLIGENCE	7%
ADDITIVE MANUFACTURING	6%
BIOTECHNOLOGY	6%

Table 10. Technological drivers for which being prepared. Source: World Economic Forum 2016

The study conducted by Sousa et al. [88] instead, tried to rank the digital skills in terms of importance given by a pool of 127 employers, and the results are the one listed below *Table 11* (in which it was possible to give a grade between 0 and 5 for the need to develop the skill).

SKILLS FOR DIGITAL TRANSFORMATION	AVERAGE GRADE
ARTIFICIAL INTELLIGENCE	4,80
DIGITALIZATION OF OPERATIONS	4,57
NANOTECHNOLOGY	4,50
INTERNET OF THINGS	3,90
AUGMENTED REALITY	3,80
ROBOTIZATION	3,80

Table 11. Rank of needed skills for digitalization. Source: Sousa et al. (2019).

Moreover, this study tried to demonstrate in a statistical way that digital skills improvement is much more correlated with the exploitation of opportunities rather than with the number of challenges to be faced by organizations.

The topic of digital skills development will be furtherly discussed and analysed in *Section 3.2: The WMF 2019 report*, being the central topic of the WMF.

Together with digital skills, it is essential to not neglect the importance of soft skills given by employers. Employers will never hire people exclusively because of their level of digital skills but will highly evaluate candidates which are able to co-operate across teams and think strategically [89]. A way to allow the marriage between these two apparently distinct domains is through Work-Integrated learning opportunities for students and graduates, which are learning processes based on practical working experiences [90].

2.2.4 Skills development method in the maritime cluster – *Area 1*

As witnessed by the previous paragraph, regarding almost all the listed technologies the maritime sector is suffering of a current skills gap. Skills gaps lead to the necessity of a skills development plan, which until today, basing on the academic material, has been faced through the methods argued in this paragraph. It is necessary to specify, that digital skills have been treated as a whole bundle here, despite their differences.

By referring to the skills needed in the maritime sector, it should be needed a specification in terms of which kind of maritime industry are we referring to. If the focus is on the Shipping environment, the skills intended can be the ones related to the navigation, so the skilling process of the seafarers. The Shipbuilding and the Design Studios are instead related to more technical skills, such as programming simulation software.

RECRUITMENT OF NEW TALENTS

First, recruitment of new talents directly from the universities is an immediate method. Here the ME field (Maritime Education) is introduced. Education has a key role to play in meeting the challenges of the digital world, and maritime education is no exception [91]. Relatively to the shipping environment, a proper education of maritime students about various transportation technologies can directly increase the readiness, competence and knowledge of future seafarers. And together with it, a higher physical and practical experience can be enhanced through the use of sophisticated simulators to increase the readiness of students for their first working experience [92]. Indeed, maritime employers are demanding graduates that are work or industry ready, while universities are focused on student retention [93].

The advantages coming from recruitments of young engineer are related to their digital readiness, as shown by the test about technical skills such as database management and CAD knowledge conducted on 85 naval engineers. The youngest sample of engineers (27-35 years old) resulted in better results in comparison with older ones [94].

The constraint of this method is the difficulty to implement innovative technologies at universities without the direct involvement of enterprises. This is the reason why a merging and a higher collaboration of these two entities should be considered to facilitate the matching between the demand and offer of job [94].

On the other hand, the high digitalization level of young maritime engineers can result, regarding simulation skills, in a lower physical "feeling" of what is there behind an algorithm. A return to the "rules of thumb" in engineering (e.g. calculation skills) becomes a powerful tool for the digital native students, helping their programming skills by increasing the accuracy and the awareness of possible mistakes taken during the simulation stages [95]. This concept does not touch exclusively the student's education sphere, but even the training of the current workforce, as will be showed in the next point.

DIFFERENT SHAPES OF TRAINING

The introduction of new technologies in the maritime industry and the growing challenges at Port, Shipping and Logistics level increase the demand for new educational schemes, together with the demand for properly trained and skilled people. The most feasible way to generate a competitive and useful workforce with improved skills is training [96].

Training has had some various applications within the maritime cluster, in order to increase the digital confidence of the workforce.

E- learning is one of them, which is not merely distance learning, but it consists of learning activities specifically involving computer networks. Web-based training maybe has its disadvantages (such as the isolation feeling that the trainees can fell from their instructors) but it can assists the fulfilment of standard requirements of the IMO (International Maritime Organization) [97]. E-learning provides great flexibility and autonomy to the learners, increasing even their control on the learning materials [96].

Classic Training instead, can lead to long waits for training courses, and to organizational issues for companies. If the training queues can be reduced by digital learning, this will help to rectify the serious shortage of seafarers and marine engineers [98]. Furthermore, e-learning environment has a superior effect on the learning process and learning performance [99]. A very specific challenge that online courses seem to have, compared to the physical classes, is the higher number of dropouts. Moreover, the learners' adherence to attend online courses is greatly affected by their self-motivation and their IT skills related to the use of computers and the Internet [100].

Regarding physical training, Nazir et al. [101] summarized the limitations of the current training methods for seafarers in a glance, before proposing a step-by-step training syllabus. These limitations are:

- Lack of realism in training (e.g. immersive environment);
- Lack of simulated abnormalities and accident;
- Lack of team training;
- Lack of objective performance assessment;
- Lack of integration of technological tools to aid learning phenomena;
- Lack of non-technical staff training;
- Lack of generation of data from training;
- Lack of integration of results and research from other domains.

The debate between physical and digital training has been discussed even during the WMF 2019, as will be shown in the next chapter.

To solve the problems of both classic and digital training, mixed solutions have been tried which combine face-to-face classes with online courses. These solutions consist for instance in **Blended Learning** or **Flipped Classes**. These are a teaching technique where the traditional classroom is “flipped” or inverted. This approach concerns a more active trainee’s experience through moving the lecturers outside the classroom and using learning activities to move practice with concepts inside the classroom [102]. Thanks to flipped classes it is possible to practice what studied remotely together with the other trainees, and in this way more effective learners can see how they may assist in a mentoring capacity, transferring their skills to the others and corroborating their own ones [103]. Porter et al. noted that these mixed solutions facilitate the enrolment to courses and enhance students’ retention than fully online courses. An issue of this method can be found in the difficulties to arrange the most proper timetable for classrooms [104].

Digital training can even be performed through simulators, especially relatively to seafarers, and simulation software have attained a very high level of reliability and proximity to real situations, but every learner can subconsciously lose the perception of what would happen in reality that is not contemplated by the simulator [91]. Specially designed simulators that realistically reproduce articulated on-board scenarios can be used as successful method to gain experience and achieve the corresponding skills to face emergencies. Concluding, this practice can transmit a pedagogic value to MET (Maritime Education and Training) [105].

Another experimented way to develop skills is the deployment of knowledge platforms embedded in the company, which can even be called **Communities of practice.** These are "groups of people who share a concern for something they do and learn how to do it better, by interacting regularly". These platforms, even provided with online courses, are focused to manage internal knowledge of employees by learning with and from each other [106]. Communities of practice represent a strategic alternative for the development of individual skills by totally transforming business collaboration and communication [107]. A knowledge platform very close to the concept of community of practice have been proposed and tested by Coffey et al. [108] with the final result of making the tacit knowledge relative to ship maintenance browsable.

COLLABORATION

Another way, that is not much considered by the literature, is the Collaboration. Through Collaboration companies can split the efforts to develop new technologies and related skills. Some projects, such as the LINCOLN one, attempt to enhance the Collaboration of companies to foster the awareness related to current technological trends. Collaboration can be carried out both with other companies and with universities.

A successful way to face skills mismatch is the development of a shipbuilding network. This method basically consists in facing capacities issues and competence gaps through collaboration between two or more shipbuilders. In this way, companies can guarantee themselves to reach the necessary competences to face their own demand, in exchange of a lower possibility to differentiate themselves from competitors [109].

OUTSOURCING

The very last possible option to catch skills not embedded in the company, it to draw from external providers. In fact, the development of internal digital technologies (e.g. Artificial Intelligence, IoT and Big Data) and of their related digital skills, is a real strategic choice because it precludes the involvement of external stakeholders, advocating a “make” instead of a “buy” choice. Eluding outsourcing, maritime companies can increase their independency from external provider, together with cost savings, and internalize some new relevant digital skills [50].

2.2.5 Skills development in general – *Area 0*

The aim of this area of research (*Area 0*) was to provide additional information potentially useful to develop the final framework.

Skills development, or competence development, has always been considered a way to increase productivity and adaptability of workers. Thus, adopting a skills development plan is a crucial aspect of any company’s strategy, directly influencing competitiveness. The companies that usually meet more access barriers to skills development are the SMEs. These companies are looking for tailored courses to the needs of the business, thus guiding training providers to increase their flexibility in terms of delivering contents.

These barriers can be cultural, financial or related to accessibility, but the most relevant one for this study is the one connected to the awareness [110]. The consciousness of the trainee about the benefits provided by a new specific training format is a crucial aspect to evaluate a skills development plan. Learning environment success depend heavily on the trainees’ acceptance of the training itself [111]. To furtherly sustain this idea, Sundberg, referring to the SMEs environment, [112] stated that “we cannot create development of another person’s competence. Only each individual can create and develop his or her competence. What we can do is to set the scene and provide the right tools, acting like catalysts”.

Another impacting factors within a company to facilitate the skills development process is the creation of a good “educational and learning culture”. Thus, the right environment starts from the top management approach in firms. But what really impacts before it, is the overall societal background. In fact, being training never perceived as a core need within companies, the overall involvement depends a lot on the policy-related conditions for investments in education in companies, and this aspect needs to be seen in a macro-economic perspective [113].

The analysis of this area allowed the authors to identify a further skills development method, more specifically a training one, which enlarged the overall portfolio. This method is the **One-To-One** Training: it consists in a single employee training carried out by a single senior. Under this training method, the senior could firstly identify the employee's weaknesses and then fix them thanks to the practical and theoretical training [114]. To have a more academic definition One-To-One Training could be defined as "*the planned process of developing competence on units of work by having an experienced employee train a novice employee at the work setting or a location that closely resembles the work setting*" [115].

Together with the increase of the awareness and the creation of a fruitful environment, even the gamification is considered as a way to generate successful skills development plans. Vos et al. provided some guidelines to develop a simulative game to grasp knowledge [116], while Geithner et al. [117] studied the positive impacts of gaming (in this case the experiment was related to the LEGO Serious Play) on the students' readiness to cope with challenges of teamwork, risk factors and unpredictable project situations.

Concluding this area of the literature review, it is possible now to summarize all the identified skills development methods which can be divided in two clusters: the "internal" methods which aim to develop the current workforce's skills and the "external" methods that rely on external sources to grasp the necessary skills. The overall portfolio of available skills development methods to furtherly analyse through the case studies is depicted in *Figure 33*.

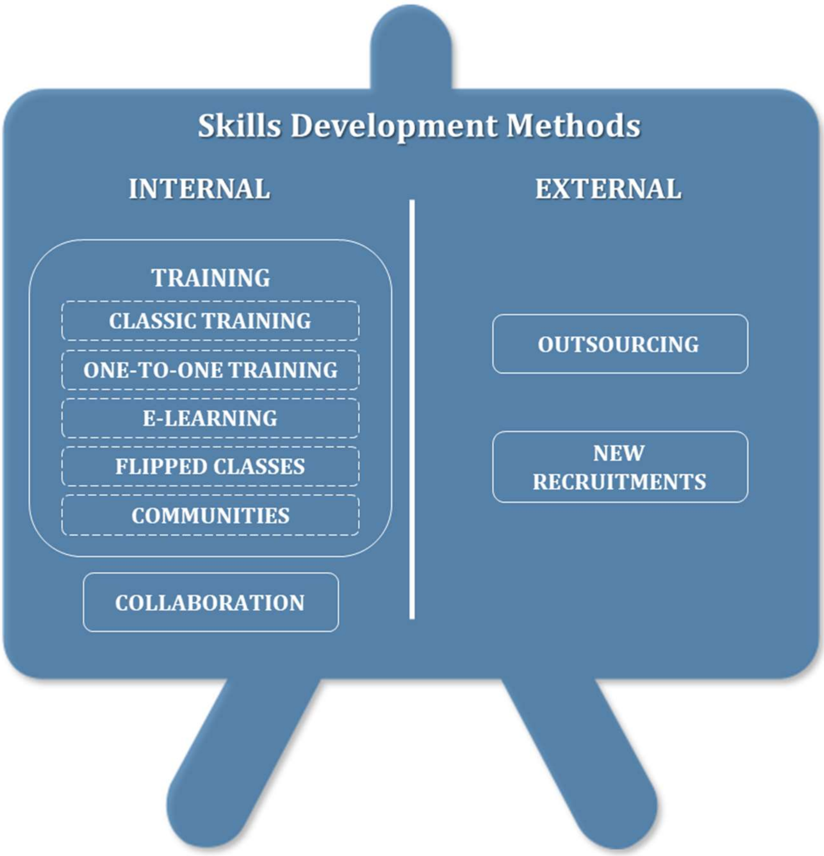


Figure 33. Skills development methods portfolio

At the end of this extensive literature review, the authors were sure to have not neglected any relevant area of research. At this point, there was the opportunity to enlarge their knowledge base through the participation to the WMF 2019. Thanks to this opportunity, the authors arrived as much prepared as possible to the interviews, getting in touch with the most recent trends and with the LINCOLN project.

3. STATE OF PRACTICE

From September 25th to September 27th, the 2019 edition of the World Manufacturing Forum was held in Cernobbio, on Lake Como.

The World Manufacturing Forum aims to enhance and spread the importance of industrial production within the global economic system: the primary aim is, in fact, to promote innovation and development in the manufacturing sector, to improve competitiveness in all countries through dialogue and cooperation between the main players in the sector.

For companies and entrepreneurs this is a networking opportunity at a global level, an opportunity to participate in the debate destined to affect the future trends of the real international economy.

The World Manufacturing Forum is organized by Confindustria Lombardia, IMS and Politecnico di Milano, in collaboration with the European Commission, Regione Lombardia and UNIDO (United Nations Industrial Development Organizations). Confindustria Emilia-Romagna is an institutional partner of the World Manufacturing Forum Foundation.

This second edition in Cernobbio - since 2018 the stable venue of the event, the most important in the sector at international level - specifically focused on the "skills" needed for the manufacturing of the future.

Among the speeches, in addition to that of the President of Confindustria Vincenzo Boccia, there were those of CEOs and managers of large groups such as Dow Chemical or personalities such as Dov Moran, the inventor of the USB stick, institutional representatives such as Max Lemke of the DG Communication and Technology of the European Commission or as Li Yong, Director General of Industrial Development at the UN, researchers and scholars such as Bruce Kramer of the National Science Foundation or Jun Ni of the University of Michigan.

Among the main activities of the World Manufacturing Forum there were publications of economic and scientific texts, starting with the annual "WMF Global Report".

The authors participated at this event and had the chance to attend all the speeches and to meet these international experts, speaking with them about the thesis and, in some occasions, interviewing them.

The focus of the event was on the industry 4.0 skills development in the manufacturing industry, it was not specifically on the maritime industry but, more in general, on the whole manufacturing industry. Despite this, the arguments and the speeches were compliant with the research and it created and added value to the thesis itself.

3.1 THE EVENT

The president of the WMF, Mr. Ribolla, presented the event speaking about the general trend in the manufacturing industry, using as an example the increased performances of the pit stops of Formula 1 through the years. In the 50s they were extremely long, it took several minutes to carry out the whole process, while right now they can last in 2.5 seconds. The curiosity of this technological evolution is that its growth is not linear, the performances increased exponentially. The general trends emerging from the president's speech for the next future are:

- Increased productivity (as stated before, more than proportionally);
- Salaries will increase;
- The necessary physical strength will decrease;
- The safety will increase;
- The skills will have to adapt to the digital evolution;
- The sustainability will increase and become crucial.

Then, to transmit a perception of what is happening, the president showed the data elaborated by McKinsey, speaking about 800 million people that will increase their income and 400 million people that will be replaced in the working environment

(24 million in Germany for instance, that is the first European actor embracing the industry 4.0).

The real challenge of nations is the one to increase people employability forging their skills, that would evolve through the time. Skills development could not play anymore a marginal role in a company because of its social impact.

During the day there were several speeches and round tables. A particular attention has been given to the speech of professor Marco Taisch, which summarized the content of the WMF 2019 report, that will be deeply analyzed in the next paragraph.

After the professor's speech, the stage was left to different industrial leaders of influential countries discussing the main topics previously presented by the professor.

What emerged from it was the necessity to foster the knowledge by incentivizing the youngest employees to generate "cognitive skills". It is not enough to acquire digital skills through the employment of digital natives, the enterprises have to generate the right environment in order empower already present workforce: "They will be more digital, but they need a clear direction". To achieve it, entrepreneurs have to ensure the creation of a feeling of open environment, in which everybody can aspirate to reach the desired status. On the other hand, the employees have to pro-actively interact with the company, without limiting their working scope. This was set as the right direction to face the incoming challenges.

Another key-factor of success is the heterogeneity within the company. The digital transformation does not imply that the industry has to accept only digital natives, but the expertise of older employees is not enough as well. Renate Hornung-Draus discussed about a German industrial company which demonstrated that the best results are achieved by mixed-age working teams.

The necessity to identify a mixed solution of physical and virtual training emerged, and as a conclusion of the discussion, a Mexican startup was introduced: Mex4industry.

This startup organizes bootcamps of intensive physical courses on several different skills such as Python programming and project management. At the end of this intensive courses, a customized E-learning platform is delivered to the clients depending on their specifications and needs.

The event subsequently shifted on macro-economic topics, such as the primary necessity to create structures able to facilitate the enhancement of suitable skills for the industry 4.0 revolution. In fact, today, the current educational level in the overall manufacturing industry is not proper, especially concerning the low-wage countries.

The speakers proposed the implementation of new training centers to fasten and concentrate the efforts for the skills development process.

In particular, emerging countries have difficulties to face this skills adaptation for the incoming technologies. Until now, the competitive advantage of emerging countries has been the low-wage workforce, but today they are facing the challenge to of a low innovation degree in the manufacturing sector. This problem may lead to the loss of the usual competitive advantage of emerging countries, and as last effect, to the stop of multinational companies' investments in these countries. This scenario is threatening the political leaders, as witnessed by this citation during the event:

"*In Pakistan, despite the cheap labor, private entities will not invest anymore because the skills set is too low between the workers. Without the right projects of skills development, the low-wage countries are going to suffer even more*" (Sardar Ahmad Nawaz Sukhera) [118].

The last part of the event was dedicated instead to the LINCOLN project, that will be deeply discussed forward. In this part, the agenda of the treated topic was the sequent:

- Maritime 4.0: the LINCOLN perspective;
- Methods and technologies benefits for innovative vessel design;
- Data analytics advantages for maritime operational services;

- The technological journey in the maritime sector;
- Research and policy digital journey.

The presentations of this part of the event were interactive: a lot of questions were made to the audience and two round tables with experts were made. This event was fully dedicated to the maritime industry and the authors had the chance to interview some of the experts present to this side event.

3.2 THE WMF 2019 REPORT

This paragraph is fully dedicated to the WMF 2019 report, in which are present several studies about the emerging topic of skills development for industry 4.0. The subsequent pages are dedicated to summarizing the content of the report.

The main problem faced in the report was that the lack of, and inability to acquire the necessary skills and competences amplify the skill gaps that the workers have. In addition to this the industry is having increased difficulty in finding the necessary talent to fill manufacturing roles.

This lack was mainly due to a rapid pace of technological innovation that was continuously changing the required skills sets in the manufacturing industry.

The skills development approach adopted was not solving this problem, the lack of skills was continuously growing since the technological innovation pace was higher than the skills development one. In fact, acquiring new skills and competencies required new inventive approaches and collaboration among different actors. While approaches such as outsourcing and new employee recruitment were prevalent, the report focused on training and education to develop the skills and the competencies in the manufacturing workforce internally. This because the outsourcing and the new employments are short term solutions, the focus should be on a long-term solution.

3.2.1 Promoting Education & Skills Development for Societal Well-Being

The fourth Industrial Revolution was introducing to manufacturing new technologies, the disruption caused by these new technologies calls for new solutions that result in a change of the skills and competencies that are required to manufacturing workers.

The new machines and new generation of computers that were introduced will require employees to understand and operate on an equally intelligent level. The skills necessary to excel in this new environment are rapidly switching from manual to cognitive based skill sets to manage intelligence systems such as robotics, AI, and Advanced Manufacturing.

This lack of skills described above was not only faced by the workers but also the students were facing this problem, the education system did not provide the correct skills and competencies that were necessary to fill new roles.

In order to help current and future students, the WMF report highlighted the key nations' role: they must promote and improve education programs in order to meet the new skills requirements.

For the student was no longer enough to learn one process or technology; the continuous self-learning and adaptability was a key aspect for the worker of the future, students must prepare themselves to be exposed to constant change and learning within the manufacturing sector: become flexible future workers that are able to adapt and excel in order to work with new technologies and innovations.

3.2.2 The Skills Gap

It is important to define the term skill gap before proceeding forward: "*it refers to the difference between the actual skills possessed by the employees and the skills required on the job.*"

In order to define and to assess this gap the companies have to ensure that the workforce is well-trained, knowledgeable and better equipped to perform the job and also provided the employees the opportunity to identify the missing skills and work to learn what is needed.

3.2.3 The Skills of the Future

The report provides a full and detailed overview on the necessary skills of future manufacturing employees. They consist in a real competitive advantage not only for manufacturing companies, but even for the single employee. All the ten identified skills are summarized in *Figure 34.*

Figure 34. The ten necessary skills for Industry 4.0. Source: WMF 2019 report

DIGITAL LITERACY

As previously discussed in the literature review, the report confirmed the necessity to develop digital literacy among all the workforce, at any level. The workforce is not only required to have a sufficient level and confidence with a new technology but, since they know more about the machines they use, they are also asked to innovate and propose new solutions. For example, predictive maintenance can be directed by the workforce basing on intuitions.

AI & DATA ANALYTICS

In the future, manufacturing will produce significantly more data. On one side, this offers many chances for optimization and increased prediction that will allow processes to become more efficient and effective. On the other hand, this increase in available data could overcome the capability of human operators to understand and interpret the data without sophisticated tools. These tools provide insights from large amounts of data, particularly big data, are mainly based on machine learning and AI.

CREATIVE PROBLEM SOLVING

These new technologies not only will automate the more dangerous and repetitive tasks, but they will also increasingly automate cognitive tasks.

Thanks to this the operators will be required only to solve the most complex tasks, as a consequence of the utilization of new technology the complex tasks will become more complex than in the past, the creative problem solving will be a key skill in this new environment.

ENTREPRENEURIAL MINDSET

The creativity, proactiveness and the ability to think outside the box that characterize the entrepreneurial mindset are highly required from the workforce, these skills include an interest with the overall company strategy and a willingness to work in new areas where the employee is not comfortable.

WORKING SAFETY & EFFECTIVENESS

This skill has to be acquired from the operator in order to let him being physically and also psychologically safe. For example, when wearing an exoskeleton, the system might have a delay in reaction that causes some human operator stress as it feels like there is a lack of control. Being able to work with these systems and at the same time ensuring that the human operator is empowered instead of reduced to a human robot was a skill that needed to be carefully developed.

INTER-CULTURAL & -DISCIPLINARY INCLUSIVE ORIENTED MINDSET

As will be furtherly confirmed by the interviewees in the ***Section 4.2: Case Studies: the interviews*** some countries are facing a shortage of workforce so they need to hire people from other countries, while some aspects might be addressed with technology, such as multi-language operating systems or training materials using visuals and AR, the skill to navigate such a diverse environment as well as efficient and effective communication will be key to sustainable operations in manufacturing companies.

PRIVACY AND DATA MINDFULNESS

The digital transformation in manufacturing leads to more data and information, integrated digital communications through platforms, as well as the digital thread from design to manufacturing, use and recycling. Several new problems about the security of this data are arising, the manufacturing workers needed to be mindful of data and information and understand that these are highly sought-after resources that needed to be handled with care. If these data go in the wrong hand it could cause problems for the company, the operators have to deeply understand the importance of this aspect and always keep it in mind.

TO HANDLE INCREASING COMPLEXITY

As already stated before, the manufacturing processes became increasingly complex and interconnected, while continuously providing more information and connectivity. The manufacturing workers are now required to cope with these new complexities and to carry out several tasks at the same time.

EFFECTIVE COMMUNICATION SKILLS

The future manufacturing environment will be characterized by increased connectivity and real-time exchange of data, in addition to the current physical system. Thereby, effective communication skills will become key factors. The authors involved will be humans, IT and all the set of internal or external stakeholders. IoT cloud-based platforms and other technologies enable real-time communication and exchange of data. Moreover, increasing the complexity of the systems to be managed, a useful internal communication to properly explain the activities' execution and relative problems will become necessary.

OPEN-MINDEDNESS TOWARDS CONSTANT CHANGE

This exponential digital revolution will generate a constant change within the working environment, and the workers need easily adapt themselves to these changes. The supports systems among the peers will become a key element where mentoring or reverse-mentoring system are avenues to address this constant change. New workers or digital natives might mentor a seasoned technician on the use of a new cloud-based visualization tool on a tablet while the technician trains the younger colleague in safety procedures of the laser cutting process.

3.2.4 New Roles: The Digital Mentor

Since the workplaces were continuously being transformed by newer technologies changing the nature and execution of tasks, IT know-how such as the use of digital peripherals to communicate virtually or to support other tasks had become indispensable. The digital mentor helped personnel across the organization to be comfortable working with technology. Special focus may be given to boost the confidence of older workers who may be hesitant to learn how to use new digital tools. A different path is adopted to introduce different technologies to different workers in order to obtain the best result possible from this introduction to new technology.

The responsibilities of a digital mentor would be:

- conduct regular trainings on the use of essential IT hardware and software to personnel;
- Provide training on Ise of virtual, augmented reality, and other wearable devices;
- Educate employees in importance of data mindfulness or privacy.

His necessary skills and competences instead should be the sequent:

- Knowledge and proficiency of digital tool or peripherals;
- Empathy and patience towards others;
- Intercultural mindset and openness to diversity;
- Strong communication/listening skills.

3.2.5 Communication is the new Deal

The industrial manufacturing world was running in the following way: information and decision process were software-based and the physical production process were machine-based. The manufacturing-process needed to be monitored (software-based). However, for monitoring to work well, it must be closely connected with the sensor technology of the machine (machine-based). The challenge was: how can a software developer come up with a perfectly fitted solution for a machine, when there is rare communication between the machine-engineering and software development department? Both parts can create the most beautiful piece of software or machine, but without them being in symbiosis, the output for the customer will never live to its full potential.

The cooperation between these two departments was the key point in order to have the best solution that get benefits from both side (machine and software).

3.2.6 Skills Assessment and Skills Development

Each country, sector, company, team or individual must be able to thrive in future manufacturing. To this end, developing a strategy and roadmap (a clear and methodical process of understanding and appraising the skills and competencies of people) toward the skills of future manufacturing was a crucial and urgent priority for all stakeholders. The overall assessment's goal was to gain an accurate gauge of the level of skills possessed by workers. Skill assessment is a valuable tool that could highlight the path that the firm has to follow to growth, it is not just a pointer to the weak areas of the firm.

SKILLS ASSESSMENT

Skills assessment could help manufacturing companies uncovers learning and development needs, prepare purposeful workforce plans and budget effectively. It could also positively impact attractiveness, as well as engagement in the company.

It helps individuals understand where they stand and, when matched to personal goals, professional profiles and career aspirations, to identify any further learning for personal and professional development.

As stated by executives surveyed by McKinsey in 2018, companies cannot afford to wait for others to find a solution for skill problems, but instead must take the lead in exploring and exploiting new approaches. The collaboration with governments, education/training systems and other stakeholders, was a key point also in this in order to close the gaps and address development needs, in order to achieve future strategic objectives as well as human and societal well-being.

PHASES OF THE SKILLS CYCLE

To enhance employees' preparedness for the future, companies should consider the four phases of the skills cycle (*Figure 35*).

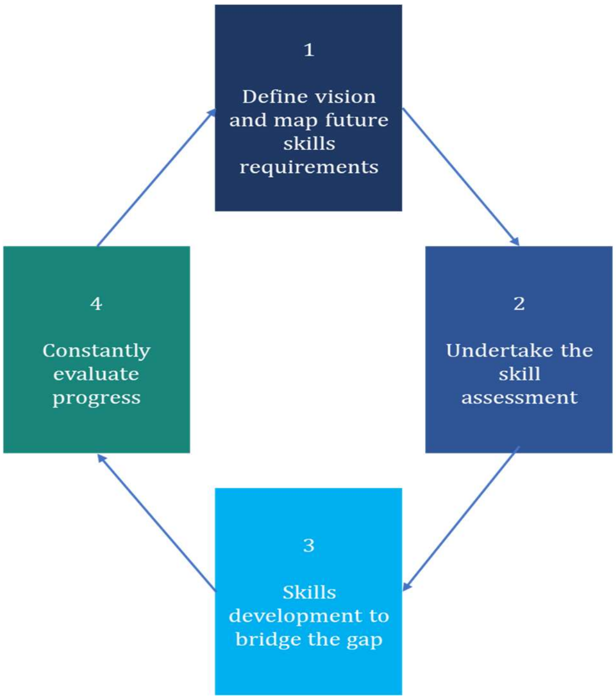


Figure 35. The skills cycle. Source: WMF 2019 report

The first step is skill mapping, which aims to provide the organization with a forward-looking overview of the necessary skills to fulfill its future targets and the gap (that will be defined in the second phase). Skill mapping could be done for the organization as a whole or for a specific department or job family. Anticipated changes in technologies, processes and tasks as well as design decision about the future organization of work must be considered.

The second phase is skill diagnosis, meaning an assessment of the situation of the skills and equivalent proficiency level that employees possess. A skill gap analysis was also essential in this phase, in order to highlight workers' strengths and potentials, identify and prioritize the gaps between the type and level of skills that employees possess in comparison with those required in future

Skill development was the third phase and deals with the formulation of the plan to bridge the skill gap, scheduling and implementation of learning and development activities in the short, medium and long term, so as to improve the types and/or proficiency level of people skills, according to the previous two phases, the method developed by the authors helps the firms to formulate this plan.

The last phase is the monitoring of the skills, namely the continuous evaluation of the results achieved by skills development, the transfer of learning into job activities, and the impact on individual, organizational and community outcomes.

THE SMEs PERSPECTIVE

The SME landscape is diverse, but it is still possible to generalize and say that often they tend not to have enough information, financial time and resources, demonstrate occasional skills assessment, and more difficulties with recruitment of skilled workers, and organizing training.

Industrial associations, clusters and competence centers could play a pivotal role in supporting SMEs all along the skill cycle and the assessment process though simple and practical instruments, easily accessible, affordable and quality services on strategic issues, and fostering SME cooperation in skill development rooted in the local ecosystem. SMEs could find a range of services related to digital jobs and skills, from assessing skills needs, to training, financing and networking opportunities.

SKILLS DEVELOPMENT

For what concerns the skills development methods and benefits of the different methods, the report is fully aligned with what the authors found during the literature review and with what the experts said during the interviews, as will be shown in the next chapter.

Here are reported some interesting cues about the skills development topic coming from the report:

One interesting point was related to the benefits coming from the investment in skills development: while the initial investment in skill development programs is a major barrier, the benefits pay off in the longer term as productivity increases and workers stay with those organization longer.

The role of governments is also essential in coordinating initiatives to create national and international strategies with visions and roadmaps to tackle the skills gap as a societal and evolutionary phenomenon.

This requires continuous and long-term efforts involving all manufacturing stakeholders.

E-LEARNING AND FLIPPED CLASSES

The impact of ICT and the internet on training programs delivery was tremendous, most notably with the emergence of online learning platforms and massive open online courses (MOOCs). Recent developments in E-learning systems enabled more effective courses delivery using learner-centric approaches. Also Politecnico di Milano started to use this new educational method through the "Flipped Classes": the students can watch MOOC classes whenever they want and wherever they want before physical classes. Then, in the physical lecture, the professor will add some comments and examples about the theoretical part learned thanks to the video-classes. This method enables an increase interaction between peer learners.

Many organizations have developed their own global learning platform with on-demand, modular programs to enable country-wide strategies for skills assessment and development.

The perception of E-learning is that "it can be a support solution but will never be a real substitute of the classic training" (Renate Hornung-Draus) [119]. Online learning platforms and E-learning should not be considered as a full replacement for traditional teaching methods, especially considering cultural differences when in-person training is still preferred over digital medium. The flexibility and independence provided by E-learning must also be balanced with meaningful learning outcomes and learning experiences often requiring a mix of teaching methods, such as mentoring and classroom-based training. In addition, E-learning must fit with institutional strategies (rather than implemented ad-hoc) to ensure that it fits with the company's needs, and is integrated with other essential features for feedback, continues learning, performance assessments, and certification systems.

TRAINING BARRIERS

Online courses, especially MOOCs, provide freedom for learners to pursue new knowledge in their own terms and when they have time. On the other hand, E-learning is supposed to encounter many barriers to be fully implemented by companies, because of some its negative aspects:

- The **quality of learning outcomes** of online courses could vary greatly, especially since it could be a superficial solution to fulfill skills gaps;

- In addition, as demonstrated during the literature review, the **dropout rate** is, on average, higher as the learning content might not match the learners' expectations or abilities, and some courses do not provide opportunities to create a community;

- One of the main criticalities and barriers, is the **investment** to develop and maintain an online platform, only the bigger firms have the necessary financial availability to implement it.

- **Older workers** can constitute a physical barrier in the implementation of a digital learning platform. The reason behind it, is that these employees are "digital immigrant" and not "digital natives". The difference is not trivial at all, even in the adoption of user-friendly software.

After these barriers, it was reported a summary of a survey conducted on a sample of employers to show which are the barriers for training in their personal opinion (*Figure 36*).

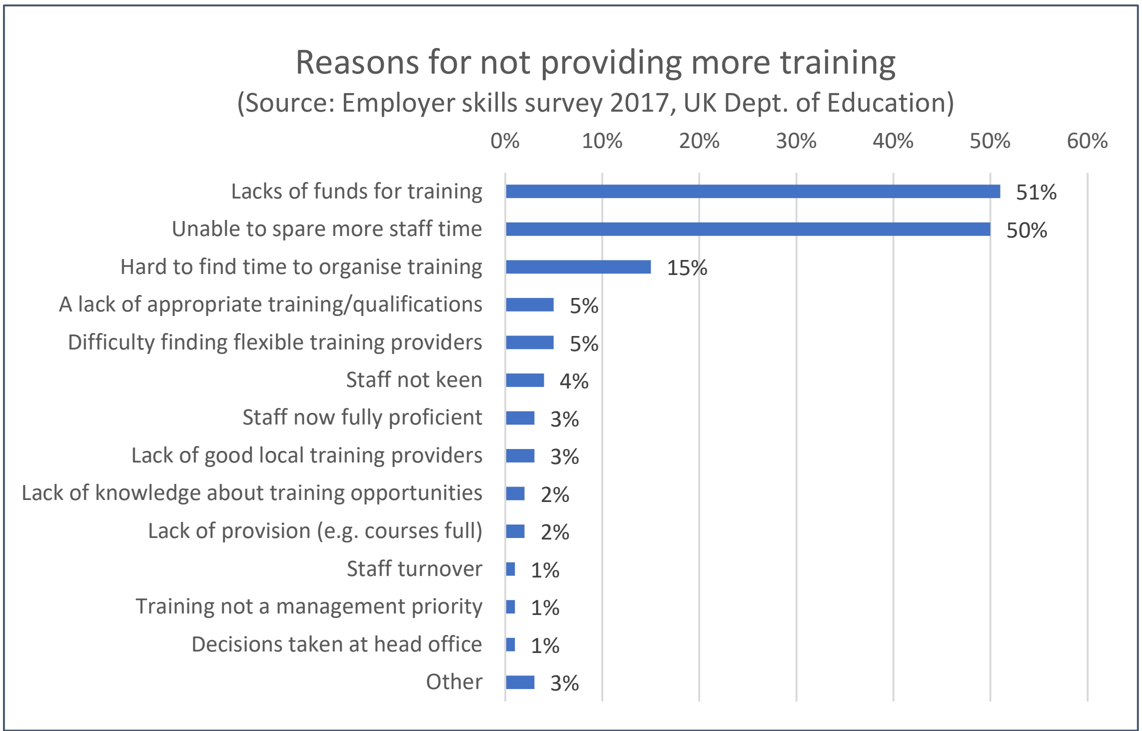


Figure 36. Barriers to training and Skills development. Source: WMF 2019 report

3.3 LINCOLN PROJECT

LINCOLN stays for Lean Innovative Connected Vessels. It is an EU Horizon 2020 research project with a 36-month duration (1st October 2016 – 30th September 2019) the aim is the one to use an innovative design methodology and the adoption of new technologic tools for the creation of three type of vessels. In this process of development of the completely new vessels (i.e. Multi-platform Catamaran, High-speed Patrol Boat and an Emergency Response and Recovery Vessels series for Coastal Rescue activities), LINCOLN applied:

- A **lean fact-based design model approach** which combines real operative data at sea with lean methodology, to support the development and implementation of the vessel concepts;

- **IT customized tools** to enable the acquisition and usage of field data, coming from an IoT platform;

- **High performance** computing simulating to demonstrate feasibility of the 3 vessels concept a fluid dynamics and structural simulation test, using high performance computing, will be performed on each of them [120].

Several partners were involved in LINCOLN project: shipyards, design studios, weather forecast companies, research and development companies, ICT solutions providers.

There were a wide range of firms involved from a small company with five employees to a multinational company with more than 2.000 employees from different countries.

This diversity required a skills development process that was able to take into account this different company size. Many differencies were present among these firms as the different knowledge they had about technologies before the project started.

3.3.1 Lincoln Technologies

The objects of this project were:

- **Lean Design**: the object is to extends the lean thinking to SME shipbuilders. Some practical objectives are providing designers with a comprehensive view of the whole design process, continuously improve all the process in order to better meet the customers' needs and integrate product usage information and design parameters;

- **Edge gateway**: it is a modular data acquisition device that collects all the data coming from all the devices present on the vessels and integrates all the data in a unique dataset. This dataset could be use in the design phase and in the developing phase;

- IoT Platform: an IoT platform for all the maritime stakeholders, the real time data exchange will provide all the IoT benefits above mentioned to all the involved actors;

- Portweather: it is an application that provides information about the short-term local weather forecast. It improves the safety of the transportation, especially during the rescue operations in risk sea;

- LCPA Software: it is an application that compares reference scenario with one or more innovative alternatives, its aim is to asses products and processes under an economic and environmental point of view;

- LincoSim.

It is important to deeply specify what LincoSim is because it will be used many times during the interview as example, here a short description of what LincoSim is: A 'virtual towing tank' environment dedicated to the design process of planning hulls by means of Computational Fluid Dynamics (CFD) runs built on top of High-Performance Computing (HPC) infrastructures.
It is mainly applied in the early stage of the design process, and its main benefits of LincoSim are:

- **Interactively usable by everyone** (on the website there is a free user Guide and a tutorial that show how to use LincoSim that allows to get familiar with the tool for the non-expert users);

- **Automatic and transparent** respect to CFD modelling concepts and HPC facility deployment;

- **Robust** to different hull shapes and working conditions;

- **Effective** with respect to required key parameter indices used in hull hydrodynamics computations;

- Entirely realized with **open-source** software, **cost-effective** and **easily customizable.**

3.3.2 Project Objectives and Expected Results

Here are reported some future impact of the expected LINCOLN results:
LICOLN usage creates benefits in terms of costs (20% vessels design cost reduction) and in terms of vessel lifecycle (it includes sustainability dimension since the very early vessel concept and design stage.
Thanks to LINCOLN the maritime sector will be provided with new tools that will increase the overall value chain capabilities. SMEs will benefit most from the introduction of these new technologies into the market.
The introduction of these technologies in these SMEs would have been very difficult without a project like LINCOLN, due to the high economic availability required for the adoption of new industry 4.0 technologies.
These new technologies allow the arise of new business models (e.g. improving services, like maintenance and after-sales vessel features upgrades based on usage, personalizing insurance contracts). The SME will be also introduced to advanced design and sustainability methodologies, having the change to improve their professional skills. This is demonstrated by the fact that where SBCE has been properly adopted, the design engineers have improved their skills. This design methodology has the potential to contribute to the development of new knowledge and efficiency in the maritime sector, both at professional and corporate level. The final impact will be then an improved overall offer to the market of companies adopting the LINCOLN solutions, resulting in increased competitiveness [121].
The LINCOLN project is a clear example of new technologies implementation within the maritime industry by means of a collaborative network. The LINCOLN partners

have been an essential source of information for this thesis, together with the contents extrapolated by the LINCOLN's team.

The content of this chapter helped to complement the authors' knowledge base as much as possible. Finally, it is possible to elaborate some Research Questions (RQ) that will find response through the case studies interviews.

3.4 RESEARCH QUESTIONS

The systematic literature review and the WMF 2019 experience, helped the authors to develop a well-balanced knowledge base about all the three research fields of the thesis. The direction of the thesis needs to be defined.

The following research questions are the result of the work done from the authors until this point. They are the starting point to properly plan the interviews with maritime experts involved in the LINCOLN project. The case studies will be faced with the objective to provide good responses to these listed questions:

- RQ1) Are there effectively digital gaps in the maritime sectors?
- RQ2) Are the current skills embedded in maritime companies congruent with the development of digital solutions?
- RQ3) Which methods of skills development are more proper to foster the implementation of technologies in the maritime sector?
- RQ4) How can maritime companies successfully implement a skills development plan for industry 4.0 technologies through the years?

4. CASE STUDIES

Once the knowledge base was built and the research questions were developed, the authors approached the case studies. The case studies consisted in semi-structured interviews carried out with six different subjects working in the maritime industry and associated to the LINCOLN project. Before facing the interviews, it was needed to firstly assess the best possible approach to the interviews through a tailored literature review, in order to face any possible unforeseen scenario in front of the interviewees. After the semi-structured interviews definition, in this chapter will be presented the specific interview's structure and the results provided by the subjects, in order to conclude with some related comments.

4.1 METHODOLOGY

To be as much prepared as possible, a methodology of approach has been applied firstly through a contextual literature review and then through the development of the interviews structure.

4.1.1 Specific Literature Review

Interviews are the most widely used method of data collection. Like craft makers use their hands, researchers use interviews to collect and construct data [122].

INTERVIEW TYPOLOGIES

But, before facing interviews, it is needed to understand what an interview really is. Sandy et al. [123] distinguishes three macro-kinds of interview:

- *Structured interviews:* the structured, or standardized, interviews consist in asking a series of pre-established questions, allowing only a limited number of response categories, facilitating the collection of quantitative data. All interviewees are asked the same questions in the same orders with the same answers list. Basically, they are face-to-face conducted surveys.

- *Unstructured interviews:* these reflect the opposite end of the previous ones. This method aims at making the interviewee feeling unassessed through an informal session. The unstructured interview proceeds from the assumption that the interviewers do not know in advance all the necessary questions. The interviewers become in this way empathetic listeners exploring the inner view of interviewees. Interviewers do not prepare a rigid list of questions, but they just know the topics on which they have to stress, leaving complete freedom to the speakers.

- *Semi-structured interviews:* the intermediate space between structured and unstructured interviews is occupied by the semi-structured ones, which are the most common applied qualitative research method. This method consists in a prepared and guided interrogation through themes identified in a consistent and systematic way. The aim is to guide the interviewee through a pre-designed questioning path to elicit more elaborated responses. This method acquired popularity because it is flexible, intelligible and capable of disclosing hidden contents. It allows the prepared interviewers to modify the style, pace and ordering of questions depending on the proceeding of the interviews, leaving to the interviewee a high degree of freedom. A possible technique consists in scheduling questions drilling down specific questions relative to a particular topic, adapting the interview to the received answers.

After the analysis of the possible ways to develop an interview, the authors opted for the semi-structured interview method, because of its flexibility that is extremely suitable to the different characteristics of the subjects to interview. In fact, as will be shown in the next paragraphs, the companies to which the interviewees belong presents many differences.

SEMI-STRUCTURED INTERVIEW GUIDE

At this point, it was needed to understand how to create the most effective semi-structured interview guide. To do that, the authors took inspiration from the framework developed by Kallio et al. [124] which divides the semi-structure interview into five phases, as depicted in *Figure 37*. The phases are going to be presented together with the relative activities carried out by the authors:

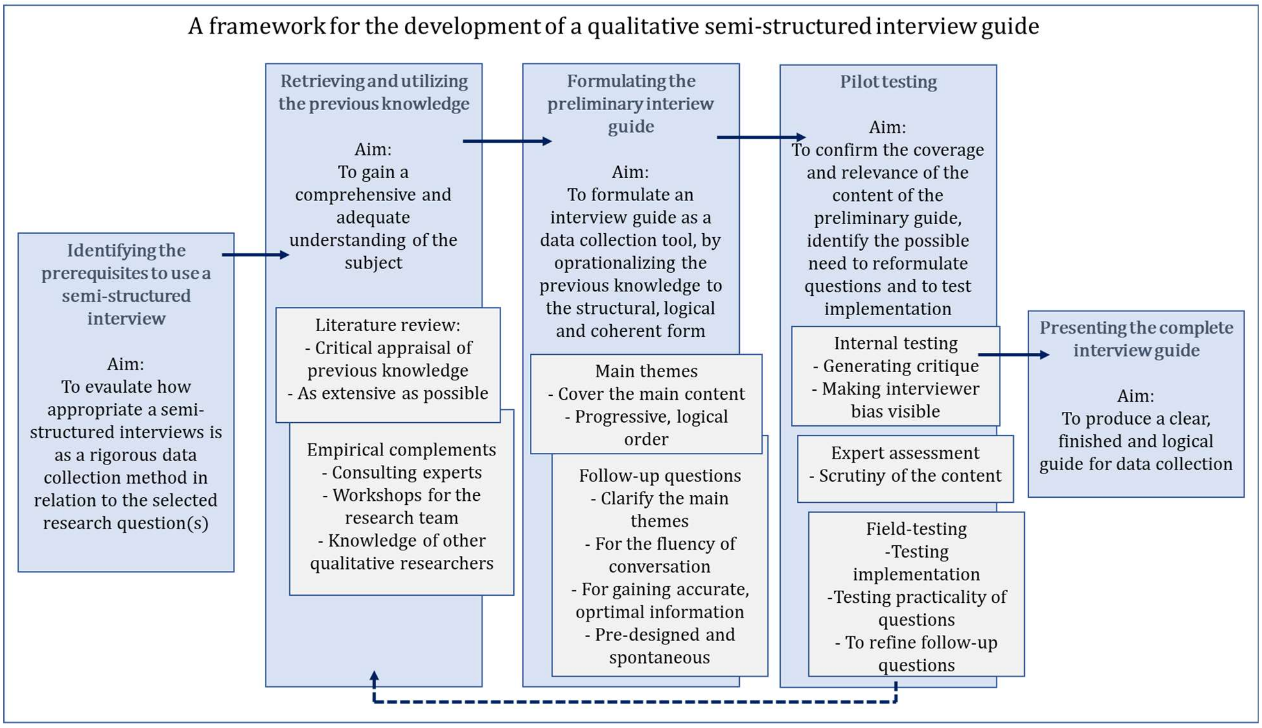


Figure 37. Semi-structured interview guide. Source: Kallio et al. (2016)

- *Identifying the prerequisites:* in the first phase, it was necessary to evaluate the appropriateness of the semi-structure interview as a right method to collect the information in relation to the selected research questions. As stated before, this method was considered proper by the authors, especially in situations in which participants had a low level of awareness of the argument, allowing diverse perceptions to be expressed;

- *Retrieving previous knowledge:* in this phase, it was necessary to obtain an adequate understanding of the treated topics through an extensive literature review, possibly aided by complementary empirical knowledge. This phase was already carried out by the authors, as witnessed by the two previous chapters;

- *Formulating the preliminary interview:* In the third phase, the semi-structured interview guide had to be defined by the authors. It consists in a list of questions which directs conversation towards the research topic during the interview, thanks to the opportunity to change the order of questions depending on the perceptions of the interviewer about the interviewee awareness. This was the most neuralgic phase in relationship with the quality of the data to collect. The path followed by the authors will be discussed below;

- *Pilot testing of the interview guide:* This phase consists in the assessment of the interview guide, basing on a pilot testing. The authors carried out an assessment within the research team to optionally reformulate some questions;

- *Presenting the interview guide:* in the last phases, it was needed a physical reproduction of the result of the previous phases. The authors prepared PowerPoint slides to accompany the subjects during the interviews, with all the questions appearing through a cascade effect, and considering different scenarios of reply.

This framework resulted extremely compliant with the procedure naturally followed by the authors until this point.

4.1.2 Interviews Structure

The interviews were conducted with subjects working in the maritime industry in companies involved in the LINCOLN project.

The aim of the interviews was the one to collect information keeping the interviewees close to the file rouge developed by the authors through the previous research phases, considering a time window of one hour of interview.
To fasten and facilitate the interviews, a pre-emptive online research has been carried out looking for information present either on the companies' websites or on the LinkedIn profiles of the subjects. In this way, trivial initial questions have been avoided, leading to time savings. Despite this trial, the information collected on the Internet were not exhaustive, even because of the limited dimension of the companies under evaluation.
To create an effective and time efficient questions schedule, the authors did a prioritization of the information they wanted to collect during the interview, and basing on the research fields of research, they developed the interview into four distinct levels.

The first one was dedicated to general introductive questions. Then, because of the maritime industry's heterogeneity coming from the literature review (Logistics, Shipbuilding, Design Studios, Port etc.) and considering that it was already known the sector in which the interviewed subjects operate, it was decided to give the lowest prioritization to the maritime research field, relying on the extensive literature review conducted on the characteristics of this sector. Thus, the focus shifted on the other two areas.
Since the skills to be enhanced are a direct consequence of the implemented technologies, it was decided to first perform a technological investigation, and then inspect the skills development process chosen by the company until today.
This prioritization strategy was aimed at avoiding losses of significant information in case of long-lasting replies.

Q1) GENERAL INFORMATION

After collecting all the available data, the interview was supposed to start with a first part that covered the missing data about the general information of the company and the interviewee.

Here below are listed the questions that were asked in this first part, together with their purpose:

- *Role and functional area:* in order to understand the interviewee's span of control and subsequently his or her Company's organigram;

- *2018 Revenues*: with the aim to have a perception on the Company dimension;

- *Number of employees and roles distribution:* in order to have some hints about the skills expected to be already embedded in the Company;

- *For how long have you been working in this Company?* this question was asked to have a hint about the interviewee's knowledge about the specific Company;

- *For how long have you been working in this sector?* this question was asked in order to have a hint about the interviewee's knowledge about the maritime sector.

At the end of the general information it was expected to obtain a general overview on the Company, in order to get useful information to assess the Company's capability to invest in infrastructure for the skills development and to get some information related to the expected set of technologies to enhance or to introduce (e.g. if a Company had few employees it would have no sense to invest in wearable devices for tracking).

Q2) TECHNOLOGY INVESTIGATION

In the second part of the interview, aimed at collecting the information on the industry 4.0 technologies, it was decided to adopt a "vertical" approach rather than a "horizontal" one, thus approaching each technology individually. In fact, there were eight technologies coming from the literature review to be touched, and instead of asking generic questions and then listing all the technologies, the authors wanted to leave the interviewee the freedom to focus on each specific technology, touching all the perceptions he or she had about it. The technology to be inspected were the ones coming from the literature review:

- Cloud Computing;
- Internet of Things;
- Big Data;
- Artificial Intelligence;
- Augmented Reality;
- Virtual Reality;
- Additive Manufacturing;
- Simulation software.

Concerning Big Data, the authors preferred to refer about this technology by speaking about Database Management Systems (DBMS), in order to facilitate the comprehension of the subjects about this technology and to have a more adherent vision of their companies.

A process map was designed with an optimizing mindset (*Figure 38*), in order to cover all the aspects to inspect without losing time by asking questions that could have been avoided. For instance, instead of firstly verifying the interviewee's awareness on a specific technology, it was immediately asked if his or her company ever used that technology, assuming that if the company adopted the technology the interviewee would have been aware of it.

Drilling down the interview guide to the next steps, two different scenarios were created, the one in which the Company of the Subject implemented the technology and the opposite scenario. Following the first case, the planned questions were intended to fully understand the overall implementation of the specific technological solution. Starting from the moment in which the company embraced the solution, through the reasons behind its adoption until an overview on the initial expectations, reached benefits and met criticalities. As last piece of information, the authors wanted to gather a further insight on the cost and the profitability related to the investigated technology.

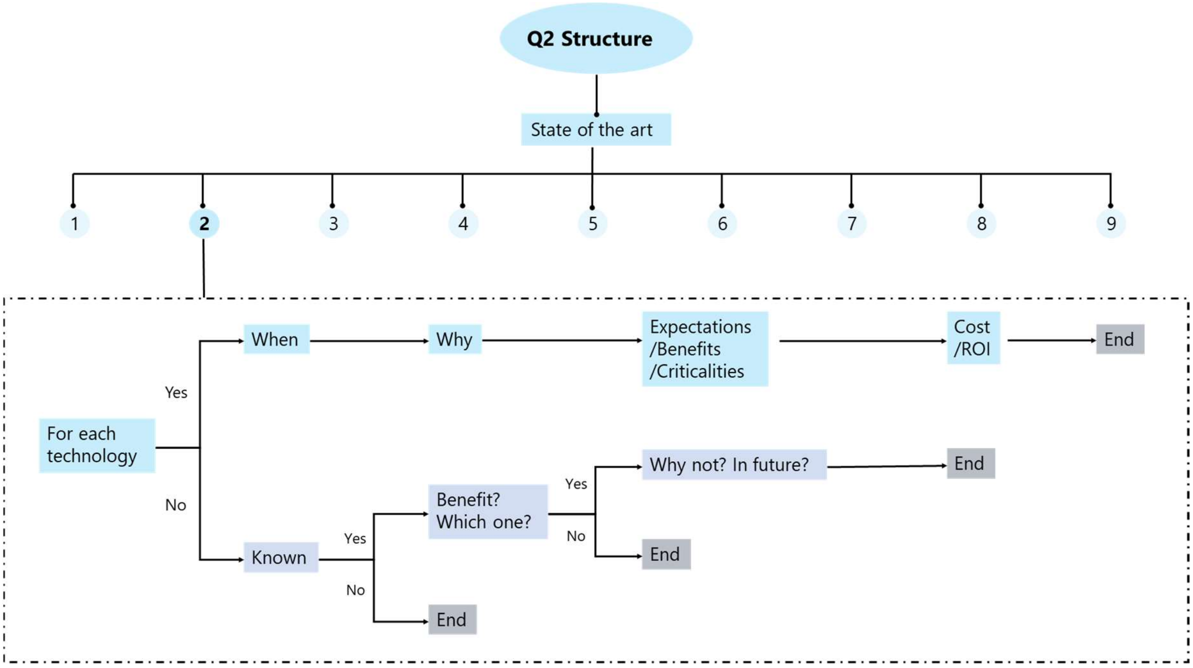


Figure 38. Process of technological investigation in interview

Considering the scenario in which the Company did not implement the technology, it was asked to the interview if he or she knew the technology. In the case of a negative answer, the interview would have passed to the next technology, otherwise other insights were asked. More in depth, the authors wanted to inspect if the interviewee had positive perceptions related to the technology in terms of provided benefits (the interview would have been conducted with the list of potential benefits for each technology obtained through the literature review). In both cases of positive or negative perceptions, the interviewee was asked about the reasons behind his or her opinions. Finally, in the case of positive perceptions, the last question was dedicated to the possibility of a future implementation of that technology within the Company.

Thanks to the flexibility given by the nature of semi-structured interviews, if the subject was not confident on the concept of industry 4.0 in general, thus providing approximative answers on the specific technologies, the interviewers were free to

directly show the overall list of technologies, asking the interviewee to comment the ones on which he was feeling more confident about. This shift from the aforementioned "vertical" to an "horizontal" approach provided good results, especially with the subjects coming from the smallest realities.
Once the interviewee commented all the technologies, it was asked if his or her company was developing other innovative technologies, in order to collect additional clues about the company itself.

The last question was intended to obtain a prioritization given by the subject to all the faced digital technologies, in order to compare the interviewee opinions with the information gathered during the literature review.

Q3) SKILLS DEVELOPMENT INVESTIGATION

After the assessment of the implemented technologies, it came the moment to verify how the Company reached the right level of competences to introduce the new solutions, so the skills development activities were inspected.

This part of the interview was divided in different layers of detail, as depicted in *Figure 39*: at the level zero there is the skills development itself, which was the focus topic of this section. The first level instead was referred to the specific method of skills development chosen by the Company to enhance the skills set (e.g. training). Eventually, the second level of detail was the one linked with the specifications of implementation related to the chosen method of the first level (e.g. e-learning as a way of training).

The Q3 session was intended to cross these three layers in the mentioned order. In fact, the first question was explicitly referred to the chosen way to enable the skills development process, while the second one was oriented to obtain a further level of detail related the chosen method. From this optic, the authors expected different possible answers coming from the literature review, that were classified in:

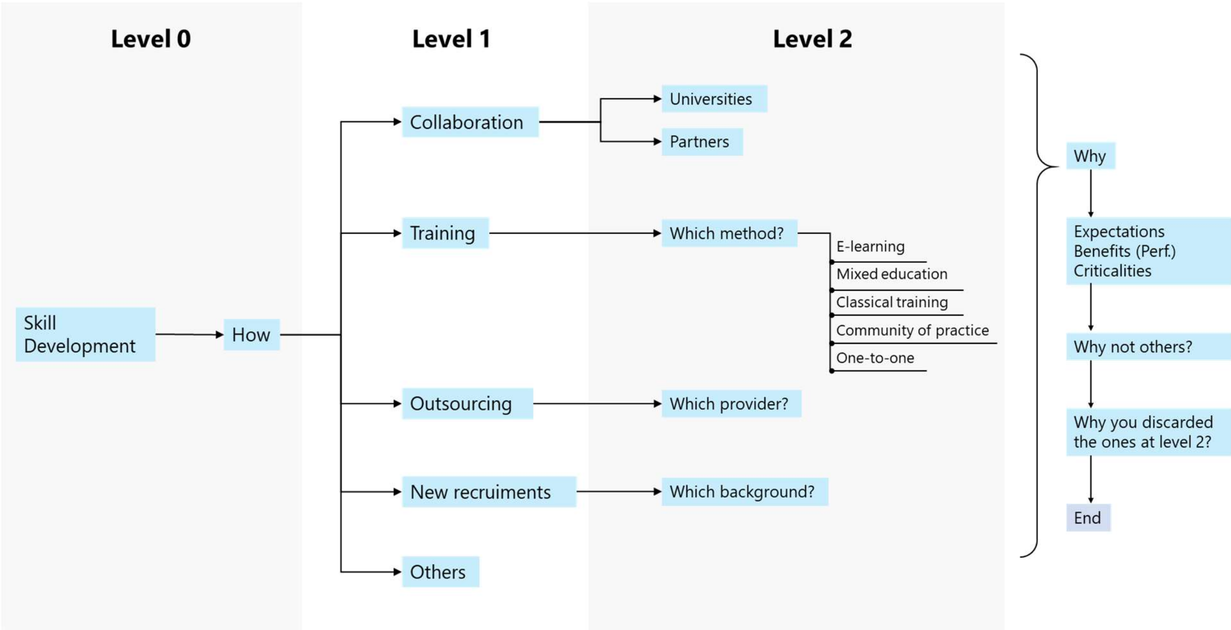


Figure 39. Structure of the skills development investigation in the interview

- *Training:* possible through different methods (physical, e-learning, flipped classes…);

- *Recruiting new talents:* if the Company acquired new skills by hiring new profiles, with different possible backgrounds;

- *Collaboration:* skills enhanced thanks to strategic partners or universities;

- *Outsourcing:* when the Company refused to implement the overall set of skills, relying on a set of external stakeholders and on their assistance.

- *Others:* different possibilities experimented by the Company, even considering the choice to not perform skills development at all, because of a sufficient current skills level or because of low interest.

During this procedure, similarly to what performed in the previous section, the interviewee was asked to provide the reasons behind the Company's choices, the expectations, the effective outcome and the criticalities met during the skills development implementation.

At the end of this drilling down process, the authors wanted to inspect the reasons behind the discarded options, firstly on the second level, and then on the first level of detail, In a sort of reverse flow. For example, if the Company under investigation has performed skills development through Collaboration, the Subject, after having explained the reasons behind this choice, was furtherly asked about the reasons why his or her Company discarded Training, New Recruitments and Outsourcing as options to perform skills development.

The aim of this was to understand not only what they did, but even which was their mindset about all the possibilities, to investigate if there was mismatching between his or her perceptions and the findings provided by the literature review.

As last question, the subject was asked again to create a prioritization, this time of all these methodologies previously listed depending on their effectiveness.

The real objective of this section was the one to create a full understanding on the criteria to which a maritime company opts for one method rather for the others.

Q4) VISION ON THE MARITIME SECTOR

The very last part of the interview consisted in two open-ended questions. In the first one, the Subject was completely left free to comment his perceptions related to the maritime sector in relationship with the discussed trends. The goal here was to identify if, in his or her opinion, the maritime sector is presenting a skills gap nowadays relatively to the digital technologies implementation.

In the second one instead, the interviewee was asked about the impacts of the LINCOLN project on his or her Company in terms of preparedness to the new technologies of industry 4.0.

These interviews were carried out in two different modalities. The first modality was a web-call interview; the desktop of the interviewer was shared with the interviewee, to simultaneously show the PowerPoint presentation prepared by the authors with all the questions showed through a cascade effect (in order to allow the interviewee to analyse each technology individually without seeing the others). The overall PowerPoint slides with the questions are reported in the appendix *Section 8.2: case studies' interview.*

The second type of interview was a face to face interview. In this second type of interview the process could have been customized not only to the replies but also according to the interviewee's behaviour: if the authors though that a specific topic was particularly relevant for the interviewee and he or she wanted to speak deeply about it, then the interview focused more on the specific topic in order to have as more information as possible from a knowledgeable person.

The time window of the interviews was approximately of one hour, but in every interview the Subjects were available to add further comments, enriching the content of the interviews in exchange of additional dedicated time.

4.2 CASE STUDIES: THE INTERVIEWS

All the six interviewees' companies are summarized in *Table 12.* Summary of all the belonging Companies of the interviewees. For each of them, interview's content will start with an identikit on the Subject and the Company, progressing then with the explanation split among the previously described sections (*Q1, Q2, Q3, Q4*).

COMPANY	INDUSTRY	NR OF EMPLOYEES
Company A	Shipyard	≅25
Company B	Design Studio	≅100
Company C	Shipyard	≅5
Company D	Research centre	≅2.000
Company E	Design Studio	≅10
Company F	Research centre	≅20

Table 12. Summary of all the belonging Companies of the interviewees

As it can be noticed from *Table 12,* the interviewees belong to three different kind of realities. Shipyard are Companies which produce physical vessels (in blue), Design Studios are Companies which work for Shipyards to provide them with the vessels' design (in green) and Research centres work to develop new digital technologies for the maritime context.
For each of them, at the beginning of the description it will be presented an "identity card" with all the introductive information about the subject and the reference company.

4.2.1 Company A – Shipyard

INTERVIEW PROCESS

The interview was carried out by a web-call on September 25 from 10:30 am to 11:30 am with Subject A that is Company A Industrial Designer.
The interview started as planned by asking the general missing information (Q1). the designed horizontal approach for the Q2 was not able to create a successful interview because Subject A, working in a small firm, was not confident with most of the technologies, so the approach shifted from horizontal to vertical: all the listed technologies were explicitly shown to the interviewee, leaving him the freedom to choose the ones on which he was more confident about. In this way, Subject A deeply described only the ones that he considered more influential for his company, avoiding time wasting. In this case, the semi-structured interview showed its adaptability advantage: depending on the interviewee's company characteristics if the interviewer realizes that a detailed approach for each technology is not effective, it could be possible to shift to an integrated approach.

Q1) COMPANY INTRODUCTION

The specificities of the Company and the interviewed Subject are illustrated in *Figure 40.*

SUBJECT A

Role: Technical manager and past as product developer

Experience: Working in the company since 2001

COMPANY A

Nr of employees: around 25 workers

2018 turnover: around 3 million €

Country: Norway

Description: Company A started in 1985. The company's strength has always been to develop fast and efficient speed boats, for use in pleasure and racing. Today the company is evolving tremendously.

Figure 40. Identity card of Subject A

Q2) TECHNOLOGIES INVESTIGATION

As stated before Subject A was not so confident with the listed technologies: he did not have a clear idea about Cloud Computing even if in his company it is used for some inter department activities, logistic and for some reporting software; he was introduced to DBMS and AI thanks to the LINCOLN project as for the IoT.

For what concerns AI the Subject A thinks that it is too complex for a small company like Company A, technology like AI requires at least some years of usage before get some benefits out of it and it requires a considerable investment to get the competences and the skills, he saw AI very premature for his business but he finds the technology interesting and he is currently looking forward that the level of knowledge about AI will be more widespread in his industry in Norway.

Subject A is very familiar with VR, they used it for two purposes: in the development phase the designer is able to "walk" in to the 3D file and directly evaluate the design, the functionality and the aesthetic of the interior of the boat in order to find better solution, this is not possible through a flat screen. The second purpose is the one to use VR as a selling tool, since Company A is producing expensive boats it would be hard to sell them without having a physical product to show.

Company A noticed that through VR the potential customer appreciate this solution and they could discuss about the customization without having a physical boat, this saved also time and money to Company A.

They fully met their expectations and reached the objective savings, while the main criticality is that 3D files are very detailed and they need several hours of work before they can be used, in order to use them they also need expensive equipment and high computational power. He noticed the potential benefits of Cloud Computing into this aspect.

In Company A the Simulations are run for hydrodynamics, aerodynamics and strength calculation but the software needed, and the competences required are not affordable for a small company like Company A. Despite this, he sees a lot of potential in LincoSim.

Q3) SKILLS DEVELOPMENT INVESTIGATION

As consequence of the Norway's maritime industry trend to move the whole facility to the low-wage countries there is a shortage of skilled people in the country, it is very hard to find person with the needed skills and the possibility that an employee moves from a company to another one is very low because the companies try to keep this resource within them.

There are very low chances that a skilled person moves from another country to Norway; because of that it is applied mostly a One-To-One Training: a new employee followed by an educated and trained person, both for production workers and engineers.

For what concerns the engineers Company A tries to find mechanical or construction engineers and training them for the boat industry.

The One-To-One Training is adopted also because of the firm size: they found as main benefit a low payback time of the new resources, by doing this training the new employees started to create value for the company very soon.

Company A used to train people directly on the production line, this means that the trainee starts to do value added activity in the very early stage of his training program and the trainees are provided with more tasks and more responsibilities gradually, according to the trainees' progress in order to always challenge him or her.

Furthermore, the Company A nowadays hires one person at a time in order to give the best training possible to each one. Because of this there are no chances to create a class and to fulfil it of trainees. Moreover this solution would be impossible also in terms of investment that the company has to sustain since, also coherently with the training directly on the production line in order to have the payback time as short as possible, a small company like Company A does not have enough resources to invest in employees' training.

They also tried to avoid the situation in which an already trained employee realizes that the boat industry does not fit him or her. To face this issue, employees make training directly on the daily task and in the workspace. In this way, the trainee can immediately realize it and both the time and money invested in his or her training are the lowest possible.

Also the engineers are trained in the production line in order to leave them acquire the physical sense and avoid the possibility to design something that is not physically feasible.

All the solution adopted minimize the investment and start to create value (for the company, for the trainee and economical value) in the very early stages of the training.

Subject A saw the potential of the E-learning especially for the theoretical part of the training and also for the teaching of the maritime industry regulations to the engineers; they tried to adopt this solution, but they were not able to implement it.

Q4) MARITIME SECTOR & LINCOLN PROJECT

About the maritime sector in general, Subject A stressed the current Norwegian situation: in the 2000s, more than 3.500 people were employed in the Norwegian

leisure boat industry, and it was more than 10.000 counting all the employees around the business.
The current situation is completely different since the largest part of the Norwegian maritime companies moved the production to East Europe, this because the Norway has a very good reputation for premium knowledge and quality and the increasingly demand required more production hours.
The main idea was to move only the production and keep all the skills (design, developing) in Norway but then most of the companies move the whole enterprise to the low-wage countries, with all the skills and skilled people with them: now in Norway the number of people employed in the leisure boat industry decreased to around 350.
Company A was very satisfied about the LINCOLN project, they have been approached to new technologies like IoT and sensors, since they are new technologies for the company and it was starting to adopt some of them, it was needed a way to train the employees for the new needed skills.
The collaboration with other companies or universities was seen as solution for the fulfilment of this lack of skills and was also feasible in terms of needed investment.

4.2.2 Company B – Design Studio

INTERVIEW PROCESS

The interview was also carried out by web-call on September 25th from 11:30 am to 12:30 am with Subject B that is a Company B Engineering Manager.
This interview was compliant with the scheduling thanks to the promptness and conciseness of the Subject B replies that was confident with all the technologies. Furthermore, thanks to his deep maritime knowledge the authors collected very useful insights about the maritime sector.

Q1) COMPANY INTRODUCTION

The information of the company and of the subject are summarized in *Figure 41.*

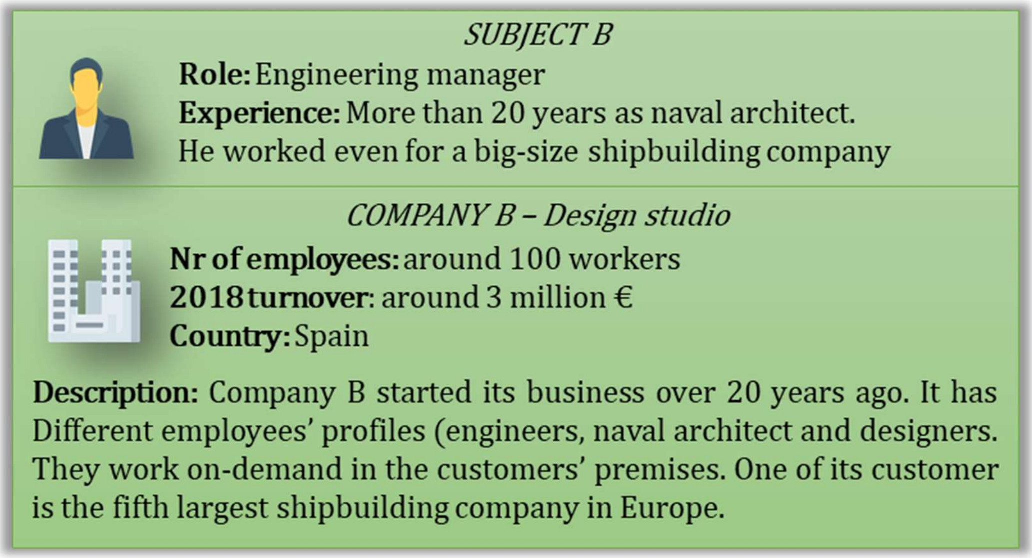


Figure 41. Identity card of Subject B

Q2) TECHNOLOGY INVESTIGATION

As stated before, Subject B was confident with all the technologies presented, with the exception of the AR devices since they as a company knew about this technology but they did never use it. These were the results:

- *Cloud computing*: The adoption of these solution is strictly connected to the technological development of the customers; the higher the customers' investments on this technology, the more the employees interact through Cloud Computing. They do not deploy this technology internally, but they are confident with its usage. The necessity satisfied by this technology is the possibility to work remotely, enhancing the connection between Company B and its customers through shared systems or database, this is a key point for them since they have customers all over the Europe and the chance to work in the Company B facility instead of moving the whole team to the customers' facility is a big benefit. Unfortunately, its use entails a decrease in the overall quality, due to the reduced control of the systems: you as a company are not anymore responsible of the storage, security and integrity of the data but a third party is in charge of it. Not all the companies rely at 100% on this solution to the point to store on the cloud all the information or have just the cloud as unique information storage.

- *DBMS*: internally the Company organizes the data through excel files, but, similarly to what happens for Cloud Computing, the employees have confidence with this systems because of the tight collaboration with the customers. In fact, they usually relied on systems to organize the data. What Subject B underlined was that this kind of solution is strictly correlated with the size of the projects carried out by the Company. At the moment of the interview Company B was starting to encounter some organizational issues related to the enlargement of the company, leading to an increase in the complexity; so, they would need this kind of solution. The bigger the company, the higher the complexity, and coherently with them also the need to properly manage the data.

- *IoT:* they were not used to manage this technology; in fact, their first contact with it was coming from the LINCOLN project. The interviewee highlighted the need to use this solution because of the outstanding benefit coming from the data collected by connecting the vessels. The problem of the adoption of this solution is related to the supply chain more than to the single company. More in depth, the investment in these technologies, especially by a SMEs, can be fostered only if the other actors of the supply chain are already introduced to it, because it is not possible to fully implement IoT appliances if there is not a mature market behind it. "*We need to implement, not to develop this kind of solution".*

- *AI*: Company B has been investing in AI for a year, but they did not develop it internally yet. They relied on external providers, implementing this technology according to the complexity and the dynamics of individual projects.

- *VR*: Similarly to what mentioned above, Subject B stressed the necessity to develop and frequently use these solutions in the future, but he pointed out that at the moment of the interview, for a SMEs, it was better to invest individually and rely on external providers by commission. The potential benefits are several, especially related to the customers' involvement.

- *Simulator:* he explicitly showed his enthusiasm related to this technology, because of the immediate and concrete advantages that it could bring to the Company. It is a real objective of Company B to integrate digital simulations, especially in the preliminary stages of the design process because "*you spend one tenth of what you need for the physical simulation in terms of time and money, it will substitute significantly or totally the traditional way".* He even identified a skills gap related to this technology, but he had clear idea regarding the knowledge to embed. The problems come at the beginning of its adoption: firstly you needed to accumulate data to better configure the simulator, secondly it was missing a solution to test the simulators themselves. Once it will be possible to validate the different offered solutions, the Simulators will bring huge advantages.

- *Additive Manufacturing:* they are starting to apply Additive Manufacturing, for instance in the production of the model for the towing tank test. The problem of this technology was that it relies on the size of the machines and on the quality of the production concerning the details and the materials used. On the other hand, being the current promised quality low, even the cost is low.

Generally speaking, what came out from the analysis of Subject B is that the overall set of technologies offered by the industry 4.0 are useful and could generate value for the Company and for the specific user, with a special priority given to the software simulators for the specific field of Company B. What Subject B and the company are doing is trying to implement this solutions parallelly, in order to integrate all of them in the company's processes in the future.

Q3) SKILLS DEVELOPMENT INVESTIGATION

First of all, it is useful to explain that, being Company B an ETO company with a tight relationship with the customers, the internal skills development was limited to the skills necessary to run the customers' project.
Considering the specificity of the scopes in which Company B operates, the only two ways taken into account until the moment of the interview to enable skills development within the company were Internal Training and Collaboration with third parties or customers.

Regarding the internal training, the problem stressed by Subject B was referred to the environmental conditions relatively to the Spanish job market. In fact, the Spanish naval sector has become increasingly dynamic, with a high employees' turnover rate of companies. Within this scenario the Internal Training has become an investment without any return because of the limited available payback time: the trainee has to provide value to the firm immediately or, at least, before he or she changes company in order to have back the benefits from the training investment; but maritime companies have to deal with this problem in order to create a common knowledge base among their employees, fostering quality in the long term. A possible solution to this problem is E-learning.
Company B is implementing a solution of this type: they have online videos for training employees regarding specific knowledge. The criticality related to E-learning is the setting of the specifications for the videos and for the shared knowledge. Once you are able to set precise specifications, you could rely on an E-learning platform.

Furthermore, Subject B stressed on the fact that there is not a best way of skills development within the presented portfolio, because the right way to foster digital knowledge depends on the maturity of the technology to introduce. If the technology is not mature enough (e.g. Additive Manufacturing) it has no sense to invest for internal training because of the uncertainty of the returns. In the case of low maturity, it is better to cooperate with customers or external providers with an extensive knowledge of the tools. On the other hand, if a company became very confident in the use of a tool, and relies on the maturity of the technology, it is more proper to invest on the staff training (e.g. simulation software with a validated utility).

Q4) MARITIME SECTOR & LINCOLN PROJECT

Subject B's view of the maritime sector Is promising for the future, but quite uncertain for the present, due to this digital turbulence which does not depict a clear direction until today. In fact, he identified a delay of the maritime sector relatively to industry 4.0, and he justified such lag through the specific conditions in which the vessels producers operate. Practically, if we consider the implementation of IoT for the individual travelling vessels, the Sensors are more difficult to be implemented in comparison with a static manufacturing plant. These specific conditions and the specific signals to be caught from a vessel make the new technologies implementation harder.

Regarding the LINCOLN project, Subject B confirmed that it contributed to create awareness in the sector, enhancing the focus on further skills rather than the only calculation. He stressed that through the implementation of Simulation software, it will be possible to have a holistic view on each design project, and that the focus will shift on the simulation skills rather than on the calculation ones (that will be kept anyway).

4.2.3 Company C – Shipyard

INTERVIEW PROCESS

The interview was carried out face to face during the WMF 2019 on September 27th with Subject C1 and Subject C2 that are the Company C's owners.
In this interview the authors had an approach similar to the one adopted with Subject A since the interviewees didn't show deep confidence with each of the listed technologies, furthermore the two engineers were very proactive and available, so

they took their own path starting to speak about their favourite arguments: unfortunately it was quite hard to direct them to the designed interview path, even if they kept compliance with the main theme. On the other hand, through this way they added several useful information that reflect their own ideas.

Q1) COMPANY INTRODUCTION

The general information of both the subjects and the company are summarized in *Figure 42.*

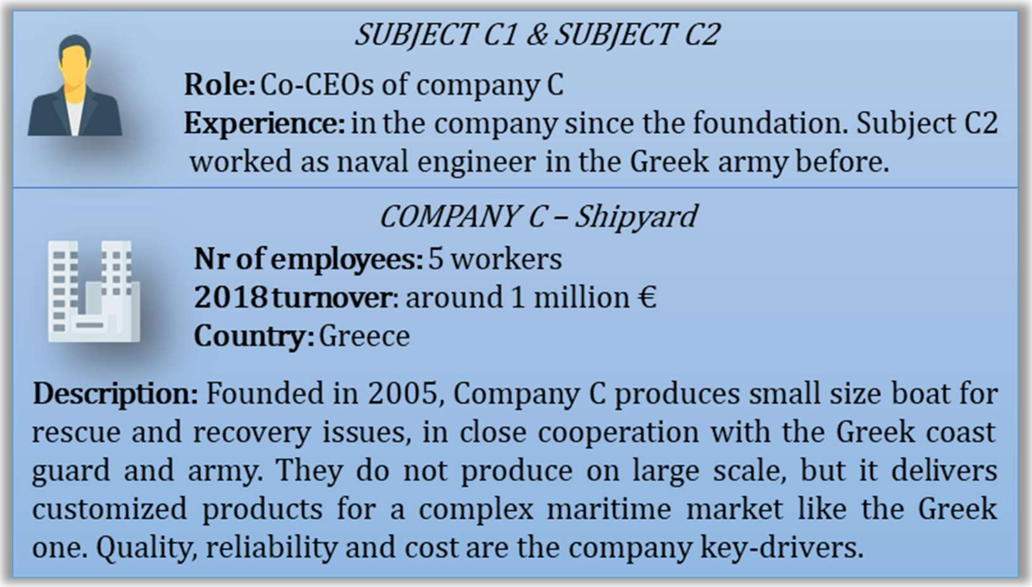


Figure 42. Identity card of Subjects C1 and C2

Q2) TECHNOLOGY INVESTIGATION

Company C is not a capital-intensive company and it did not invest in any of the exposed technologies until the moment of the interview. Basically, it relies a lot on third parties, and this situation leaded the company to not make huge investments in new technologies. Despite this fact, through the interaction with the outsourcers, they are starting to interact with some new technologies which are coming out, such as the electric engine that, in their opinion, will "*entirely substitute the current ones with a 10 years delay in comparison with the automotive industry*". Generally speaking, the two entrepreneurs are interested to invest in new technologies only if these are able to generate cost and time savings in the very short term, even if they look quite sceptical about the complete implementation of the overall exposed set of technologies.

A technology coming from the LINCOLN project on which they deeply trust for the future is the Simulator. It allows to make a good preliminary design before the production of the model for the tow tank test, providing a good virtual visualization of the boat and a good degree of flexibility to change the internal and external conditions (e.g. higher possible speed in comparison with the tow tank test). Unfortunately, at the moment they do not consider this technology mature enough and, moreover, relying on the facilities provided by a partner Greek university for testing activities, they do not see much impact of changing the current standards in the short term. Moreover, despite the precision embedded in the digital twins, Subject C1, who is closer to the production issues, prefers to rely on his decennial experience and clinical eye by inspecting the physical model by himself before going to the production phase.

Another technology which has met their enthusiasm was the implementation of IoT on the boats, due to the fact that their main customer is the coast guard. In fact, considering the width of the Greek coast and the connected difficulties to properly control the sea, the coast guard would be extremely interested in a technology which enables real time control on the boats. It is not just about the location of the boat, but a lot of other information such as the temperature, the state of the engine, how many litres of gasoline are still present in the boat that has to be rescued, the route taken by the crew and so on. It would be a huge advantage for any kind of rescue intervention: this new available data could help the coast guard in the decision making, especially in the tough situations.

The other technologies instead did not look so much interesting for them. VR, for instance, is seen just as a marketing instrument without any practical advantage. The DBMS, even if considered useful, is seen as a not feasible investment for a company with just five employees and without short term results.

What emerged from the interview, was that they were interested about investments which could increase the attractiveness of the products in the eyes of customers, rather than investments which would facilitate and improve the internal processes, because, as already said, it is not a capital intensive company that has enough fund to invest in this direction. This is the reason why they wanted to freely speak about a technology on which they wanted to invest in the short term: a system able to keep the boat in the same position thanks to a system of pumps that releases water flows without anchoring. In their opinion this technology will increase safety and reduce the environmental impact because of the damages created by anchoring to the seabed (erosion of the protected seagrass Posidonia).

Q3) SKILLS DEVELOPMENT INVESTIGATION

As a consequence of the policy of Company C connected to Outsourcing, the skills development process within the company was not considered as crucial. More in depth, representing them an intermediate company which consistently relies on the competences of the third parties, they prefers just to be aware of the current trends and opportunities in the market, in order to subsequently select the providers basing on the skills and the technologies needed to run the projects. Thus, what they did until the moment of the interview was to participate to Exhibition Centres to catch new trend/ideas. If they identify any potentially useful technology, they both start to look for potential outsourcers trying at the same to embed low level skills through Self-Learning thanks to Open Sources Platforms. "*The problem connected to the open sources knowledge is that there is a too wide range of potential sources, and it is difficult for us to filter them and to identify the most reliable ones*". This is the reason why a good platform providing instant knowledge would be very useful for Company C (E-learning platform). The problem was that, even if they identified the utility of such application, the company was too small to seriously invest on a similar solution.

To conclude, Company C was not a company interested to invest: if an investment does not produce any immediate return on one of the company's key drivers (quality, reliability and cost reduction), they would be reluctant to develop/adopt the specific solution and, as a consequence, to develop skills. On the other hand, this approach increased their focus on the curiosity, awareness and readiness of the company on any external opportunity. An example of this was provided by the LINCOLN project, which brought them to believe in technologies not even considered in the past (e.g. IoT).

Q4) MARITIME SECTOR & LINCOLN PROJECT

In their opinion, maritime sector is living a digitalization slower than the one of other similar industries. They found as a reason the fragmentation of maritime industry and the lower investments that the players can afford. Subject C1 strongly thinks that shipbuilding sector will be subjected to the same transformation of the automotive sector, but with a delay of ten years. For instance, electric engines for boats are becoming new today for Shipyards, but in the automotive the electric cars are present from many years.

Regarding the Lincoln project, the subjects admitted that without it, they would not even know the technologies of industry 4.0 today. Thanks to it they develop a certain awareness about the future, always keeping distance because on difficulties to implement the technologies right now.

4.2.4 Company D – Research Centre

INTERVIEW PROCESS

The interview was carried out face to face during the WMF 2019 on September 27th. In this case, the Subject D has been interviewed together with Subject E, so the authors developed further knowledge by seeing the interaction of two subjects simultaneously involved.

Both of them showed different personalities: Subject D was really proactive and made a lot of observations, questions and reasoning while Subject E was passive and intervened only at the end of Subject E's replies or only when the question was directly addressed to him.

This approach created value thanks to the continuous comparison between the two different firms. Generally speaking, the double interview was compliant with the designed scheduling, even if there could be a slight distortion due to their interactions. Despite this, the interaction between them provided further hints to understand which were the topics on which both actors strongly believe.

Q1) COMPANY INTRODUCTION

The introduction to Company D is summarized in *Figure 43.*

SUBJECT D

Role: Research scientist in the technology management dept.
Experience: Working in the company since 2001

COMPANY D – Research centre

Nr of employees: around 2.000 workers
2018 turnover: around 300 million €
Country: Norway

Description: Company D is a research organization founded in 1950 and working in 75 different countries. They provide research in many different industrial fields, and one of them is the maritime one It creates value through knowledge generation and development of technological solutions that are brought into practical use.

Figure 43. Identity card of Subject D

Q2) TECHNOLOGY INVESTIGATION

Subject D was confident with all the technologies since their core activity were to research on them.

Each Company D's project related to one of this technology follows the sequent path: they are used to start with a literature review of the state-of-the-art, then on the basis of what is already available in the market and what is missing, they are used to develop something that creates value and had a specific application. After the developing there is the test phase, they usually try to use the specific technology with new settings or in a different way than the usual in order to collect as more information as possible for a further upgrade of the technology in order to deliver the best solution.

In Subject D's point of view the main criticality of a specific technology implementation has to be found in the people that carry out the implementation process: if they believe that the technology could solve everything, whichever is the context in which this technology is introduced, without considering the company, the people that are going to use this technology and all the aspects related to this entities and the link between them, the implementation could not be successful.
There are several promises of the benefits of the adoption of a new technologies but the "equation" is usually composed by those three factors: technology, company and people, if you focus on just one you find problems and the technology does not bring the expected benefit to the company.
Subject D made also a consideration about the state-of-the-art of the technology implementation: every company wants to adopt new technology but they sometimes forget to ask themselves: "*who is going to fill the system with the needed data?", "what it is going to be used for?*", "*who is going to use this technology?*", "*How they are going to use this technology?*".
He said that in some firms there is no necessity to implement the newest technology because they do not need it. Some firms are fine with just some adjustments with the current assets but they just want to use a brand new technology without considering the cost/benefit ratio.
He divided then the company in more levels from the companies that are more passive and they just need to be prepared once a new technology takes the market to the companies that know the best of a specific technology, thus driving innovation.

Q3) SKILLS DEVELOPMENT INVESTIGATION

Concerning the skills development methods, what he considered as the best way is doing a google research about "how to do something" and then learn by "trying and failing". He witnessed that he acquired his programming skills in this way.

Collaboration with other companies is also very important in his opinion because you could acquire knowledge and skills from people that does the specific task every day and they could teach you their experience. But the best way is through a collaboration project in his opinion also because when you learn by doing you learn more.
Company D has an internal school that offers occasional training and project management training. They consist in physical classes but also E-courses that were more personalized compared to the physical one.
In Company D 30% of the time was dedicated to developing new skills, you could do it on your own or with someone else.
Subject D even pointed out that is very important to customize the e-courses on the basis of the skills level: a basic course for a skilled person is completely useless and everyone has his own learning style/method in order to get the maximum from the training this factors should be considered otherwise the trainee is not motivated.

In Company D they have compulsory training online session for all the employees and in there are some contents not related to the specific trainee (for example how to behave in labs: some employees never went and will never go in the labs). They tried to monitor how employees made this compulsory training and the result was that almost all of them were running the videos mute, in order to acquire the certificate that they attended them. This was due to the lack of motivation to watch some contents and this made the full course be skipped.
Customization and motivation keys in the success of that course but they are usually not even considered.
Another point that Subject D raised was that even if a person is really motivated there could be the possibility that there is nothing available, the only possible way is Self-Learning in this case.

Q4) MARITIME SECTOR & LINCOLN PROJECT

About the maritime sector he specified that this sector is too wide to be uniquely clustered. There too many different actors in terms of dimension that will be subjected to a different technological evolution. Despite this, he admitted that industry 4.0 will be extremely pervasive and so that any player will be touched in some extent. Moreover, he added that the only companies that are going to survive in a long-term view are the one oriented to a "green" production.

Subject D appreciated the LINCOLN solutions, especially relatively to the benefits providable by LincoSim for a manufacturing centre: better analytics simulations, faster simulations that are running at the same time different type of concept.

4.2.5 Company E – Design Studio

INTERVIEW PROCESS

The interview has been conducted together with Subject D, thus to understand the interview process, the reader is invited to see *Section 4.2.4: Company D – Research centre*.

Q1) COMPANY INTRODUCTION

The introductive information are depicted in *Figure 44.*

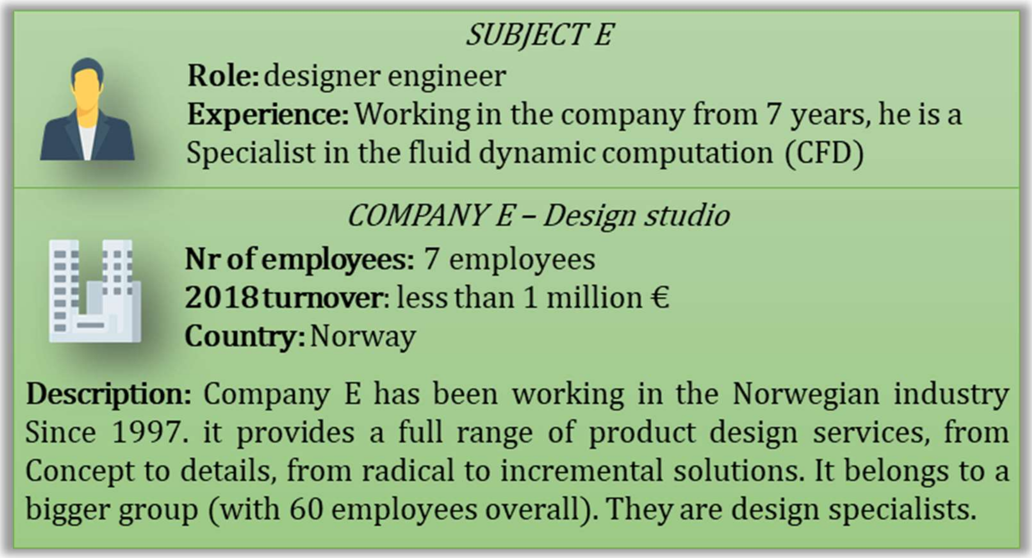


Figure 44. Identity card of Subject E

Q2) TECHNOLOGY INVESTIGATION & LINCOLN PROJECT

Since Company E is a small company their funds are limited regard new technology implementations, so they tried to adopt cloud computing but they could not manage to sustain the investment. The LINCOLN project opened new possibilities for the company in this term, considering the Cloud based IoT platform. They saw a lot of potential in this solution and they wanted to deepen its development.

The main challenge in the implementation of the LINCOLN project was the communication between the actors, everybody had to understand and to work not just to leave the work to be done but to create value for everyone. In the whole developing phase who is going to utilize the solution has to keep this in mind in order to not develop something not feasible or useless.

Q3) SKILLS DEVELOPMENT INVESTIGATION

If they found necessary, they took a Course (Physical Class or E-Class) but the main source of skills development is the Collaboration with the experts of the different industry segment that they work with.

Subject E pointed out that education is not enough when you are an expert in a certain field, you have to rely mainly on the Self-Learning because at a certain level you become the expert and you cannot ask to anyone (due to the specificity of the problem), the only help that you could have is from another expert that work with you or in a product/project very similar to the one that you are work on.

This is also the best method in his point of view because it is an “active” method where you have to put commitment. You do not have to learn from someone who is telling you (physically or digitally) how to do it.

Q4) MARITIME SECTOR

From his point of view, maritime sector is too diversified to make general definitions about the digitalization level. Referring to the Norwegian environment, he said that there are some high-tech companies which are able to interact with new technologies, like Company D itself for instance. He declared that his company is able to deal with almost all the new presented technologies, despite the limited financial resources and dimension.

4.2.6 Company F – Research Centre

INTERVIEW PROCESS

The interview was carried out by web-call on October 8th from 3:30 pm to 4:30 pm. with Subject F that is a Company F Marine & Industrial Manager.

This interview was compliant with the scheduling thanks to the promptness and conciseness of the Subject F replies except for the skills development investigation (Q3) where the interview did not follow the designed path because of the low knowledge and utilization of skills development method in Company F.

Q1) COMPANY INTRODUCTION

Figure 45 provides the reader with all the general information about Company F which is a Spanish naval research centre.

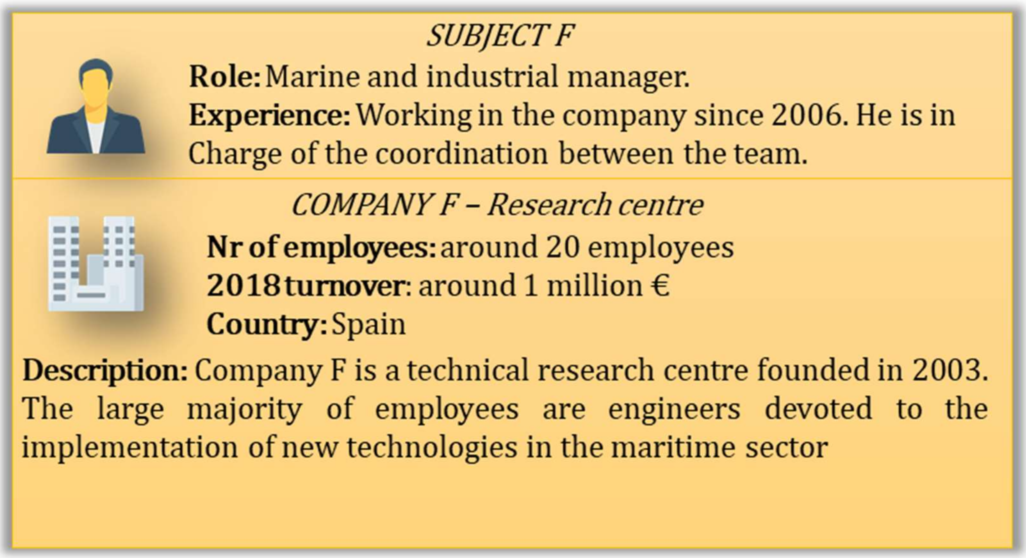


Figure 45. Identity card of Subject F

Q2) TECHNOLOGY INVESTIGATION

Subject F was very confident with Cloud Computing, they were using internally since more than 2 years: they moved all their file system to the Cloud. This technology was the most important in his opinion because it could make all the other working together, it was cheaper and safer: they were not anymore in charge of the data security because the cloud provider was.

He appreciated the flexibility of this technology: he travelled for work very often and thanks to this technology he had the same access to all the data as in Company F facility wherever and whenever he was.

Company F did not calculate the ROI of the adoption of this technology but in Subject F's opinion it is positive, mainly because there are less costs than before and time savings.

Instead, Company F partners were not able to work with Cloud Technology because they worked with the military sector and the security restriction did not allow and external data storage and security provider.

In Company F there were no use of DBMS, they still used excel sheet to manage data but he pointed out that complexity was increasing and it could be not possible anymore to manage data in that way, he also said: "*when you need to work with a lot of data it starts to be quite chaotic and complex. In the future we need to understand how to manage it and to move to one of this kind of platform. If you want to continue to work and be competitive, we need to integrate this technology because the complexity will be higher and higher.*"

Regarding IOT Company F was not internally use this solution but it was working on some project related to this, mainly with Sensors, but the main concern was the cost of this technology and they way to fund these projects. There was also a change resistance problem in the implementation in Subject F point of view: employee thought that this new adoption was going to put the company in a tough situation.

AI was not present in Company F, he saw this technology as too premature to be adopted in his sector that was late respect to other that already adopted it.

Subject F 10 years ago was in charge of the Simulations, but they still do not use it for core activity because their opinion was that for very complex system the physical test must be done while for simple system the Simulation could be enough, here there were again of change resistance with the designers.

Additive Manufacturing has a very important role in Subject F point of view: they has a small 3D printer and they use it since some years, it brought cost and time savings and the key aspect was to control the technology in order to achieve good quality result in a reasonable amount of time.

The technology prioritization in terms of time and importance was the following in his opinion: Cloud Computing, IoT, Additive Manufacturing, VR and then the others.

Q3) SKILLS DEVELOPMENT INVESTIGATION

Company F relied only on specific Personal Training and Self-Learning
The first one was an industry size problem: since they were a small company they did not have enough budget to invest in other method of training even if they saw the need to do it to be able to remain competitive in the future, but Subject F said that this view was not so popular in his sector, usually company saw the training as a cost and not as an investment.

While for a big company is the opposite: they faced less cost in the develop or adoption of an E-Training platform compared to the Physical Training considering also the maintenance and the constant upgrade of the platform.
Self-learning was very important in Company F for the soft and the hard skills, they incentivized and motivated the employees to research in Open Source Platform to acquire the needed skills.

Also the Collaboration with partners was adopted as skills development: "*When we work with a partner at the end you are learning how they work, what they are doing.*

In LINCOLN project I was working together with Company B and use technology that I never used and never seen before."

Q4) MARITIME TRENDS & LINCOLN PROJECT

Subject F stressed out again the resistance to change present in this sector, mainly because it was an international sector, so the focus had to be on the increase of the awareness of the technology benefits.

About the LINCOLN project he highlighted that the knowledge about the new Simulations software LincoSim and the IoT have been the major takeaways of the project. About LincoSim he hopes that the implementation of the ready technology will come soon, while about IoT he confirmed that many investments are needed and it is too soon to afford them. The real objective is to demonstrate that a technology can provide returns, otherwise its implementation will never be afforded: *"If we have the way to demonstrate that the technology at the end of the investment will have a positive ROI the cost will not be a problem, but the problem now is to demonstrate that positive ROI ".*

4.3 FINAL CONSIDERATIONS ON THE CASE STUDIES

Once interviews were finished, it was necessary to draw some conclusive and overall considerations about all the content obtained, in order to define a comprehensive overview.

Before presenting the data, it is necessary to remind to the reader the complexity to identify quantitative data from qualitative interview. Being semi-structured interviews based on interactions between people, they entail difficulties to direct all the interviewees on the same arguments. Thus, differently from what could happen with an online survey, the operation of collecting quantitative data comprehends a higher degree of uncertainty and complexity. Despite this, the authors tried to be as more precise as possible.

This section will firstly examine the results obtained in terms of technology and secondly the ones in terms of skills development methods.

4.3.1 Technologies Data & Comments

First, a technological assessment is necessary. To get reliable data, Company D was discarded because, even if it was interviewed, it is not a pure maritime reality. It is a multinational research centre composed by a maritime dedicated division inter alia. Thus, the information related to this company's technological implementations are not significant for this research. Different speech can be made instead for Company F, which, even being a research centre, is working in close contact exclusively with other maritime companies, providing them new technological solutions. Thus, its opinion has certainly a higher weight compared to the one of Company D.

To summarize the content of the interviews in terms of implementation, the authors decided to dedicate first time to inspect the awareness that the interviewees had with this set of technologies. As showed in *Table 13,* the awareness about the technologies is high, with the exceptions of Artificial Intelligence and Augmented Reality. The first is little known in the maritime, while the second is mainly associated with Virtual Reality. It is dutiful that, with the terms "awareness" the authors intend a complete knowledge about the potentialities of the proposed tools, not just to have heard those names. The table reports only the maritime companies ordered in terms of specific industry specialization. The blue ones are the Shipyards, the green ones the Design Studios and the yellow one the Research Centre.

Into the table it is reported the contribution provided by the LINCOLN project to these companies in terms of awareness. In fact, thanks to the project some subjects got in touch with technologies never even heard before, such as IoT and the Simulation software. (The technologies known thanks to the LINCOLN project are reported with an "L" close to the confirmation marks).

		CLOUD	DBMS	IoT	AI	VR	AR	SIM	AM
AWARENESS	Company A	■	■	■		■		■	■
	Company C	■ L	■	■ L		■		■ L	
	Company B	■	■	■ L	■	■	■	■ L	■
	Company E	■	■	■ L		■	■	■	■
	Company F	■	■	■	■	■	■	■	■

Table 14. Matchings between technologies and subjects' awareness with the LINCOLN project impact

After the analysis provided in terms of awareness, the implementation of these technologies has been inspected. As it is witnessed by *Table 14,* the situation in terms of implementation is completely different. The Subjects got in touch with these technologies, but, for different reasons, they are not able to still implement these technologies. The LINCOLN project in this case successfully act only for what concerns LincoSim into Company B, which is trying to implement it.

		CLOUD	DBMS	IoT	AI	VR	AR	SIM	AM
IMPLEMENTATION	Company A			■		■			
	Company C							■	
	Company B	■						■ L	
	Company E	■						■	
	Company F	■						■	■

Table 13. Matchings between technologies and subjects' implementations

To have a more immediate perception of the differences between the knowledge and the implementation of industry 4.0 technologies, it is possible to observe the radar chart showed in *Figure 466*, which compares the areas of knowledge and of implementation by distinguishing the technologies. To understand which ones of the inspected companies more pioneers and which ones are more traditional, a further radar chart is provided in *Figure 477* with an opposite view of the one aforementioned. In fact, the lines in this case report the sum given by the known and implemented technologies.

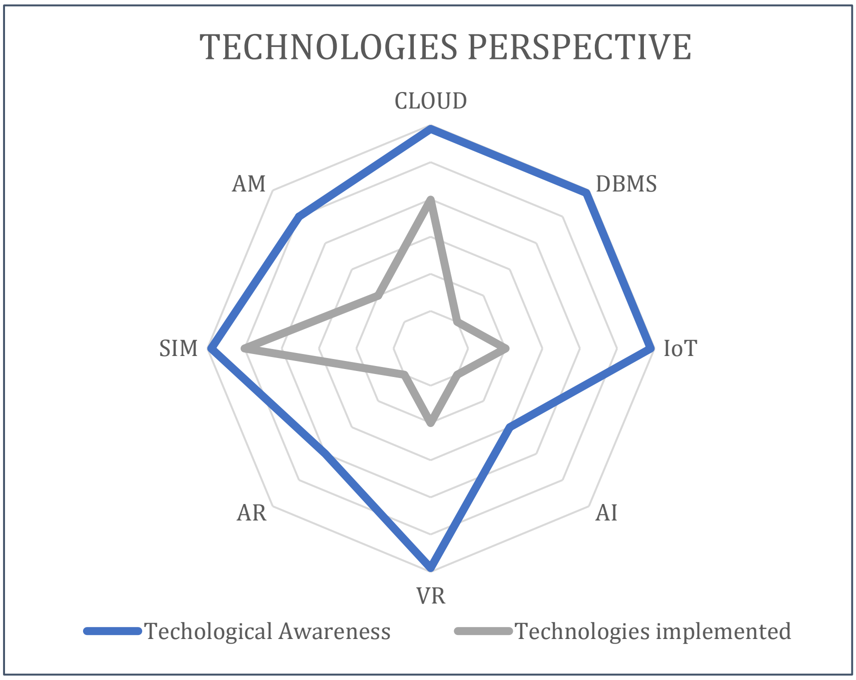


Figure 47. Radar chart on from technologies perspective, awareness vs implementation

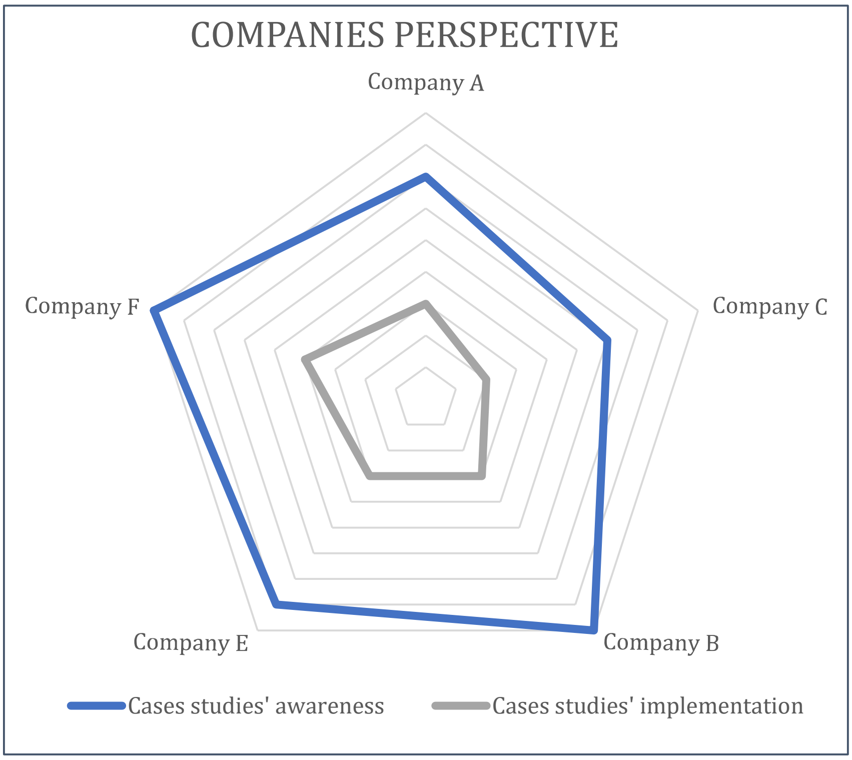


Figure 46. Radar chart from Companies perspective, awareness vs implementation

After the technology investigation the only technology that were known and adopted by almost all the companies was **Simulation**, this was due mainly to the nature of their business: in the maritime sector even if you are a Design Studio, a Shipbuilder or a Research Organization some hydrodynamics or structural analyses are compulsory in order to create or design a safe, usable and regulations compliant boat.

Simulation is not fully trusted by all the interviewees but its clear benefits in terms of time and cost saving were clear for all of them. The companies that did not trust to much the simulators have been used to exploit them only for the early stages of the ship designing, where a small error on the results of the simulation does not affect the final quality of the project. These rough and initial simulations consist in a CAD representation of the boat, subsequently aided by a physical prototyping stage: the towing tank test. This test consists in the realization of a physical reduced-scale model of the boat, to simulate its behaviour on water. LincoSim instead provide a complete simulation, avoiding the physical simulation test. This is the real reason why Company B is firmly convinced by this technology, and it is currently steering towards its full implementation.

The main concern about the Simulation software is the validation of the model and of the simulator itself. A Simulator could be validated for a specific simulation on a specific model with some specific parameters, but every time that the Simulator, the model or the parameters changed and they went out from the range validated it should be validated another time, but this validation requires time and resources so not always this validation is done but most of the time it is assumed that the simulation is still valid.

Concerning **DBMS**, the need to manage large amount of data is not needed in the faced cases studies companies. In fact, they are small actors (with the exception of Company D, that is not a maritime company), thus there is no need to manage Big Data. Some of them, like Company B or Company F, which act as providers for big shipbuilding companies, interact with some DBMS when working in the client's facilities, but none of the companies deployed an internal DBMS.

Cloud Computing is well considered, as the most proper way to deliver services to the customers. This is the reason why the design studios and the research centre started to implement it both internally and externally to manage and provide services. In fact, all the firms saw the potential of Cloud Computing, and most of them confirmed that in the future the data produced from the smart machines will growth exponentially and the handling, storage and analysis of this data will be fundamental.

AI, AR and **Additive Manufacturing** are not mature enough in the maritime sector to be fully exploited. Some of them are not even known. AI is many times confused and it is not a diffused technology in the sector. AR is usually confused with VR, and its utilisation for the maintenance and enhancement of the visual overview on the products are underestimated by the Shipyards. Additive instead is difficult to be adapted in the maritime sector because of the complexity and dimensions of the products. Company B identified potentiality in this technology especially for the realization of the small prototypes, while Company F is the only one company which is acting in that direction to provide solutions for its customers. Despite this, its full implementation is still considered far from reality.

VR is basically seen exclusively as a powerful selling tool because the Shipyard companies found many difficulties in the past to sell boats without having anything to show to the client. With the VR you can show to the client the final results of the boat construction without having the physical boat yet, this improved the selling process and also the communication process. In this way, the final customer can immediately see if there are some expectations that were not met, he could immediately communicate to the Shipyard and thanks to this the Shipyard can just modify the project without wasting time and money (the product were not even produced yet). By the way, the technology's potentiality in terms of aid to the manufacturing system is not even considered.

Finally, **IoT** acquired great success thanks to the LINCOLN project. The potentialities are considered enormous by almost all the actors, especially by the Shipyards. Despite this, the investments to be performed in this direction are the most relevant ones, and SMEs find great difficulties to adopt these solutions and to install Sensors on their products. The only pioneering company for this technology is company A, that is trying to implement sensors on the boats. Company A is even adopting VR as a selling tool for the top-quality products. As it is confirmed by *Figure 47,* the two small Shipyards are quite reluctant to invest, while the service companies are already oriented on the implementation of these technologies with the aim to satisfy the increasing needs of their customers.

To conclude, what is qualitatively easy to address in this analysis, is that the companies involved in the project are in a stage in which they know the advantages of the new technologies, but they are not still keen to invest on them, because of both objective constraints (e.g. reduced financial availability) and subjective constraints (e.g. reluctancy to disrupt the status quo and taking risks). Being the maritime sector mainly composed of small firms, it is possible to approximate this analysis to the overall sector, which is thus facing a slower digitalization that the one faced by other comparable industries.

4.3.2 Skills Development Data & Comments

After the analysis dedicated to the technologies, the second part had to shift on the skills development methods adoption. Skills development is not considered a priority in the industrial world in general. The authors deduced that this "myth" is applicable even to the maritime context, at least concerning the interviewed companies. In fact, the subjects were pretty less keen to speak about skills development, compared to the digital topic. They had less information to share about it and less comments to add.

Despite this aspect, the authors had to inspect the skills development methods adopted in these companies. Company D this time has been inserted into the analysis, to have a very reliable benchmark given by a multinational company devoted to the research.

Table 15 depicts all the practices that companies have been applied in past and present experiences. *Figure 48* instead provides a comprehensive view on the most applied methodologies.

	TRAINING	1 TO 1	E-LEARNING	PLATFORM	SELF-LEARNING	COLLABORATION	EXHIBITION CENTRE	NEW HIRING	OUTSOURCING
Company A		■				■		■	
Company C					■	■	■		■
Company B	■	■	■			■		■	
Company E		■			■	■			
Company D	■		■	■	■				
Company F	■				■	■			

Table 15. Skills development methods applied by companies

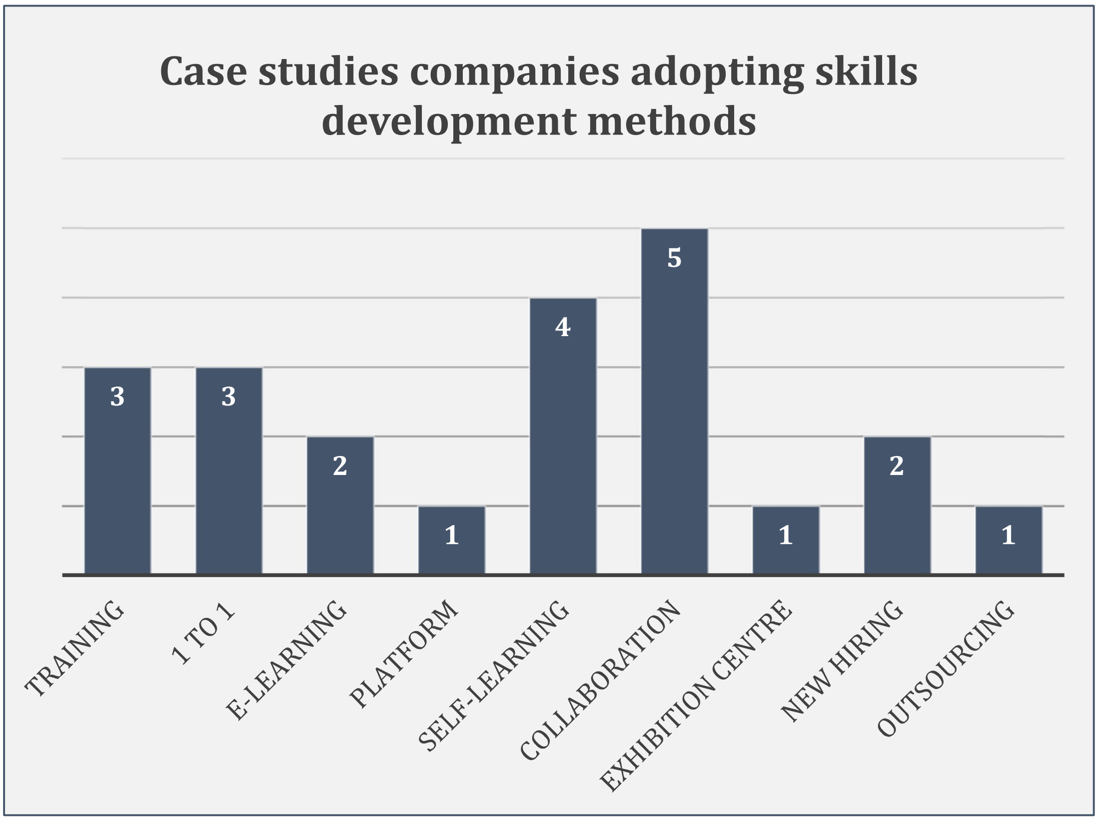


Figure 48. Skills development methods: Number of adoptions.

Before analysing the content of the graphs, it is worthy to say that the companies interviewed were a heterogenous pool from all over Europe, with different business type in order to have real data not influenced by a specific country.

From the list inspected by the authors, there was some additions provided by the case studies interviews:

- The first was **Exhibition centres**, coming from Subject C1 and C2. It is not a proper skills development method, but just a way to stay aware on the new technological trends of an industry. It consists in participating to events promoting innovative products to try to catch as much information as possible (e.g. "Salone Nautico" of Genova). The authors wanted to add this method because the two Subjects strongly confirmed that this is the real way through which they understand which is the direction to get in terms of digitalization.

- A more common practice instead is **Self-learning**. It consists in an autonomous research on the Internet, looking for information or tutorial videos, which can make an employee in touch with new skills. This kind of method depends heavily on the motivation of the single employee and it is a way usually chosen alternatively to E-Learning.

From *Figure 48*, it is possible to notice how important is the **Collaboration** and the participation at projects for the firms that do not have any industry 4.0 solutions, or just have few. This aspect highlights the importance to collaborate with firms that have a wider digital knowledge in order to collect information about daily use of technologies. In this way, companies can understand how to take the most benefits out of a technology and for the most skeptical firms they can see with their eyes the real benefits brought from these technologies. A further advantage of this practice is considered to be the distributed economic effort between the involved parties.

These results refer to the Collaboration, but not always the firms are open to participate to a Collaboration process, especially the one that are in an advanced stage in terms of industry 4.0's technology.

When the Collaboration with other firms is not possible another possible solution is the participation at Free Projects or the Collaboration with Universities.

An issue possible to encounter when a company goes for Collaboration, is the disclosure level to be kept in comparison with other possible competitors. To create a network means sharing information with other parties, without knowing *a priori* what the positive impact of the other practices on your current state will be. In depth, collaborating could be interpreted as disclosing your intellectual property in exchange of a “black box”. It entails surely a certain risk.

Classic training, despite being still a very common practice in the industrial environment, is applied by just the 50% of this sample. This is due to the fact that not all the companies are big enough to fulfil a class with an adequate number of trainees, in order to make the investment justified by the number of trainees. Generally speaking, the Classic Training is seen as overcome by the E-learning by the firms for what concern the more standardized skills, while for the most technical ones, One-To-One Training is seen as the best method to grow.

One-To-One Training is indeed adopted as alternative solution to the Classic Training. This skills development method is seen as the best effective if done directly on the place where then the skill will be needed and also the best in term of customization and real time adaptation on the basis of the trainee capacity and knowledge. A continuous assessment of the trainer could allow changes in the program if some parts are already known by the trainee while some other parts could be done with a deeper focus if the trainee had a lack on the specific part.

E-learning is slowly gathering success even in the maritime sector. Even if it is applied by few, all the actors agreed about the potentiality of E-learning especially regarding standardized tasks. An agreed advantage is given by the possibility to consult the training content “anytime, anywhere”. The barriers that the subjects identified about this technology is the lack of involvement of people and the exclusion of individuals with no “digital literacy”.

For this reason, **Mixed Solutions** met the interest of some subjects, even if the knowledge and the practice of these methods are almost null (this is the reason why they are not reported in the graphs).

Communities of Practice was a similar solution which met their interest because through them you can ask for a help to colleagues that could have faced the same lack of skills or the same problem in the past. The problem for these companies in the implementation of such solution is the number of employees. To exploit the advantages of these platforms it necessary to be able to exploit positive externalities given by the high number of adherences. Indeed, only Subject D (2.000 employees) is deploying a similar solution.

The **Self-learning** is a very common practice within this sample of companies. This is due to the dimensions of the companies involved. In fact, it is suitable for small realities in which the individual contribution is more visible. In big realities instead there is the risk to generate a lack of the involvement of the individual employee due to the feeling of dispersion given by the "big" company. Despite this, Company D is still an example of how big companies can involve on individual curiosity and motivation to steer innovation, confiding on the Self-learning practice among its employees.

The methods treated until this point are mostly internal skills development methods. If a company does not want to generate internal knowledge, could rely on external sources to embed the right competences. These external resources consist in New Recruitments and Outsourcing.

Concerning **New Recruitments**, some differences between country, size and culture came out during the interviews: first of all it is important to say that this kind of solution was seen by all the companies as a short term solution but not properly a definitive solution, "*you get the job done but you did not faced the problem how to develop the skills*". In fact, even if by hiring a company makes a long-term investment on a new human resource, it is not a real way to defeat the problem of the lack of internal generation of development.

Furthermore, the job market can radically change country by country. The authors found several difference also due to the different cultures: the Norwegian companies did not use this kind of method because the migration of the production to the low wages countries, at the end, moved also all the remaining part of the firms, and the skills with it; it is very difficult to find a maritime expert that is unemployed and the ones that are already employed are almost impossible to be captured.

In Spain instead, there is a high turnover of employees in the companies. The employees are used to change company very often, because of that the training is also a risk more than a proper investment since the firm could invest into the training of one specific employee before losing him or her.
Moreover, the case studies companies must deal with the higher attractiveness related to bigger players than them. In fact, many human resources today are "stolen" by big multinational shipyard, ruining the possibility of smaller companies to develop the human resources in the long-term.

These threats bring small companies to rely on more flexible and instant solutions to deliver value, like the Outsourcing. This method is not really applied by the companies of the case studies for the reason that most of them are providers, thus usually other companies go for Outsourcing with them. The only company which exploits it is Company C, which is a Shipyard, thus an end-product producer. The reason behind their choice is that they are not interested in investing on the full knowledge about the overall production of a boat, because their intent is the one to add value to the boats, not to produce them all. The reason to go for Outsourcing usually are the listed ones:

- The Company had zero knowledge about that specific skills and the only way to let the trainees acquire the skills is to call a third parties company that carries out for the first time the development and the execution of the training, then the company will be in charge of it for the future training.

- The Company could not fail this training, there is a high risk related to this so they could call a third-party company in order to diminish the risk an let them manage the riskiest part of the development, implementation or both of them.

- The Company had strictly time constraint and could not finish it within the delivery day, in order to speed up the whole process the company could as to a third-party companies which its core business is the skills development or to a consultant firm to develop and implement the skills developing method for them, they will have a delivery date of the project and the responsibility of that shifted from the company to the third-party provider.

To conclude, what is evident is that none of the interviewed companies relied on just one skills development method, this because for different technologies and different trainees the best solution in order to have the best results from the training could be different.

The investment capacity obviously influences the portfolio of skills development methods within the company: Company B and Company D are the two with the highest turnover, also the size of these two companies was bigger compared to the others, this was translated in a higher fund availability for the skills development.

The size of the company not only influenced the fund capacity for skills development method but also the feasible solution for the company: if we take into account company C that was the smallest one, methods like Classic Training, Communities of Practice and E-learning developed internally make no sense for them, because of the reduced number of employees.

Other reasonings can be done referring to the specificity of the content to deliver to the workforce. In fact, different skills entail different suitable skills development approaches.

At this point of the research, the authors collected enough qualitative information in order to try to map them developing some findings which will help the development of a final model.

5. MODEL DEVELOPMENT

In order to develop a model, first it was needed to assess what discovered from the case studies and to match the relative findings with the knowledge base previously developed. At this point, the objective was the one to develop solutions aimed at satisfying the needs come out from the interviews, thanks to the information collected during the literature review and the analysis of the state of practice. To do this, the authors opted for the development of three different models, in order to respond more effectively to the specific needs of all the companies. From the previous analyses, a huge complexity emerged, requiring the setting of deeper investigation through structured findings.

5.1 FINDINGS

These findings are basically considerations aimed at answering the research questions listed in *Section 3.4: Research Questions* through the knowledge captured from the interviews.

- RQ1) Are there effectively digital gaps in the maritime sector?

Considering the maritime players involved in the case studies, the authors perceived a general feeling of digital lack of the players. Despite their attempts to get in touch with most of the technologies through the LINCOLN project, the perceptions they have about industry 4.0 resulted quite fragmentated.

For instance, company C, even if involved in the LINCOLN project, looks not fully aware of the potentialities that the newer technologies can offer. Other subjects instead look keener on the technologies, but their financial availability is too limited to fully embrace industry 4.0, because of their company dimension.

Therefore, the relationship that companies have with the technologies of industry 4.0 depends a lot either on specific characteristics of the companies themselves or on the opinions of the subjects (that reflect the opinions of the companies' management).

Furthermore, the interviewees witnessed a general lack in the digitalization of the maritime sector in comparison with other similar ones. This is related for them to the specific characteristics in which maritime companies operate, and to specific physical constraint (e.g. necessary proximity to ports, size of products…). Despite this, for these experts, maritime sector is going to be reshaped by the newer technologies, but with a delay in comparison with the automotive one for example.

- **RQ2) Are the current skills embedded in maritime companies congruent with the development of digital solutions?**

Another concrete constraint of the digital development is given by the current digital skills level present in maritime companies. In fact, the subjects witnessed that at the moment it is extremely difficult to find employees with both a high digital confidence and a high maritime experience, especially for SMEs. The experience in the sector is considered crucial by the maritime companies, having a huge impact on the core business of the companies themselves. But what is perceived is that the digital skills need to be enhanced to enable the implementation of the new technologies, otherwise the businesses of maritime companies in general will never change.

Everyone agrees on the fact that to foster the implementation of technology, a development of the skills is necessary, but few of the actors has clear consciousness of how to realize the right plan to develop.

- **RQ3) Which methods of skills development are more proper to foster the implementation of technologies in the maritime sector?**

As demonstrated through the literature review, skills development is a crucial necessity to implement new technologies. Despite this fact, the companies of the case studies look not much keen on invest on skills development, being a practice without a clear and immediate Return on Investment (ROI). Actually, they find issues to assess the ROI of the digital technologies themselves, thus the ROI of the necessary skills development is well far from being known.

The interviewees' companies, similarly to what assessed in the technological examination, approached until today skills development through different methods depending on multiple aspects, which can be both objective or subjective characteristics.

An objective constraint is a physical barrier which does not allow a company to invest on new technologies. Possible objective constraints are the financial availability of the company, the too limited number of employees or the maturity of the technology to introduce. Explaining the latter, if a company wants to adopt a new technology, but this digital technology is not mature enough yet, it can be extremely risky to embrace it, especially if the company is a SME.

A subjective characteristic instead is a barrier which derives from the reasonings of the decision-makers involved. A typical aspect influencing the decision of a specific skills development method is the specificity of the task to execute through these developed skills. For instance, Subject E revealed that usually the most applied method within his company (small firm) is the One-To-One training. Through this kind of training, employees can firstly individually absorb knowledge from the outside, and secondly transmit this specific knowledge to their peers. But if the company needs to train its employees on a standard and non-complex skill, they usually rely on Self-Learning, thus by learning from the Internet. He furtherly said that an e-learning platform would be useful for its company, but that it is too small to invest on E-Courses.

Another influencing aspect affecting the choice of the skills development method, is the relative company strategy: if a company does not want to focus on new technologies, and does not want to expand its business (e.g. Company C), it will opt most of the times for external resources, without investing in the long term. Instead if a company believes in new technologies and it has the availability to invest on those technologies, it will practice long-term oriented skills development plan by internalizing the necessary skills (e.g. Company B is trying to internalize programming skills for simulation).

The authors identified other possible aspects influencing the choice of the skills development method, which were not directly coming from the case studies, such as the available time to embed the skills, the time necessary to acquire the skill, the employees' resistance, the employees' digital readiness.

Depending on these aspects, companies in general choose the most suitable option, and maritime companies, belonging to a sector which is late in comparison with the others, are forced to not make mistake in this choice to shorten the digitalization process as much as possible.

- RQ4) How can maritime companies successfully implement a skills development plan for industry 4.0 technologies through the years?

This last research question needs to find an answer into more practical solutions, which aim at guiding maritime companies in the right direction to facilitate the digital technologies adoption.

5.2 THE THREE MODELS

Starting from the findings and the considerations developed until this point, the authors tried to assemble the overall information in order to develop one or more practical frameworks.

In this attempt, the authors generated three different models: the first one had the target to provide general guidelines to help any generic company to choose the most proper skills development method, depending on its specific characteristics. The second model instead was though in order to distinguish different stages that a generic company meets in approaching a specific technology. The third and last one instead, is a procedural map aimed at generating a practical skills development plan for a maritime company, taking into considerations even the individual profiles of the employees.

5.2.1 Skills Development Matrix

The first model has been called Skills Development Matrix, consisting in a matrix that suggests the most proper skills development method depending on two dimensions, represented by two axes:

- **Company dimension or number of employees:** the first axis influencing the companies' choice, is a physical and objective characteristic. Depending on the company size, the financial availability can vary and with it even the possibility to create mass skills development rather than individual. Companies have been grouped into three categories basing on the factors defined by the European commission which distinguishes companies depending on the staff headcount:

    - *Small company*: less than 50 employees (e.g. Company A, Company C and Company E);

    - *Medium-size company*: less than 250 and more than 50 employees (e.g. Company B and Company F);

    - *Big company*: more than 250 employees (e.g. Company D).

- **Standardization level of the tasks:** the skills to develop are extremely connected to the kind of tasks they are intended to support. By increasing the complexity of the tasks to perform, the needed skills' complexity will increase accordingly. The higher the complexity, the lower the standardization level of the tasks and so the lower the specificity of the skills themselves. As previously explained, if the skills to embed are high-level skills, the method to develop them will be more intensive and tailored. The reason why the authors decided to start from the tasks as decision-making variable, is for the immediateness to understand the specificity of the task instead the one of the necessary connected skills.

To differentiate the types of tasks, the authors referred to the already mentioned article of Huynh [24], which reported three distinct levels of tasks complexity by referring at her time to a report of the Organisation for Economic Co-operation and Development (OECD) [125]. These levels are:

- *Level 1 tasks:* Tasks in which the goals are explicitly stated and in which a limited number of operations are needed in a single and familiar environment, including email usage or spreadsheets consultation.

- *Level 2 tasks:* Tasks with several steps, a small number of applications and occasional unexpected outcomes.

- *Level 3 tasks:* Tasks that involve multiple applications, a large number of steps and that require full knowledge about the commands in a novel environment.

Once the axes have been defined, the matrix structure is composed, as depicted in *Figure 49.*

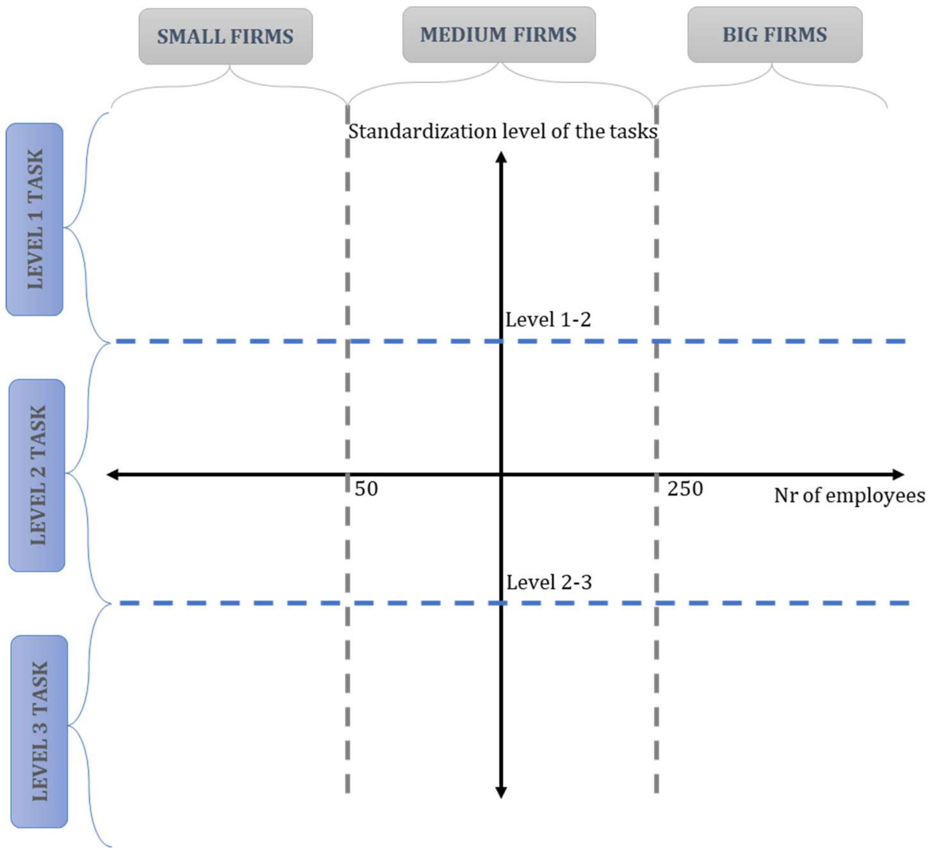


Figure 49. Empty matrix. Definition of the axes

The matrix had to be filled with the skills development methods inspected in the overall research. The final matrix is the one depicted in *Figure 50*, of which every area is going to be commented.

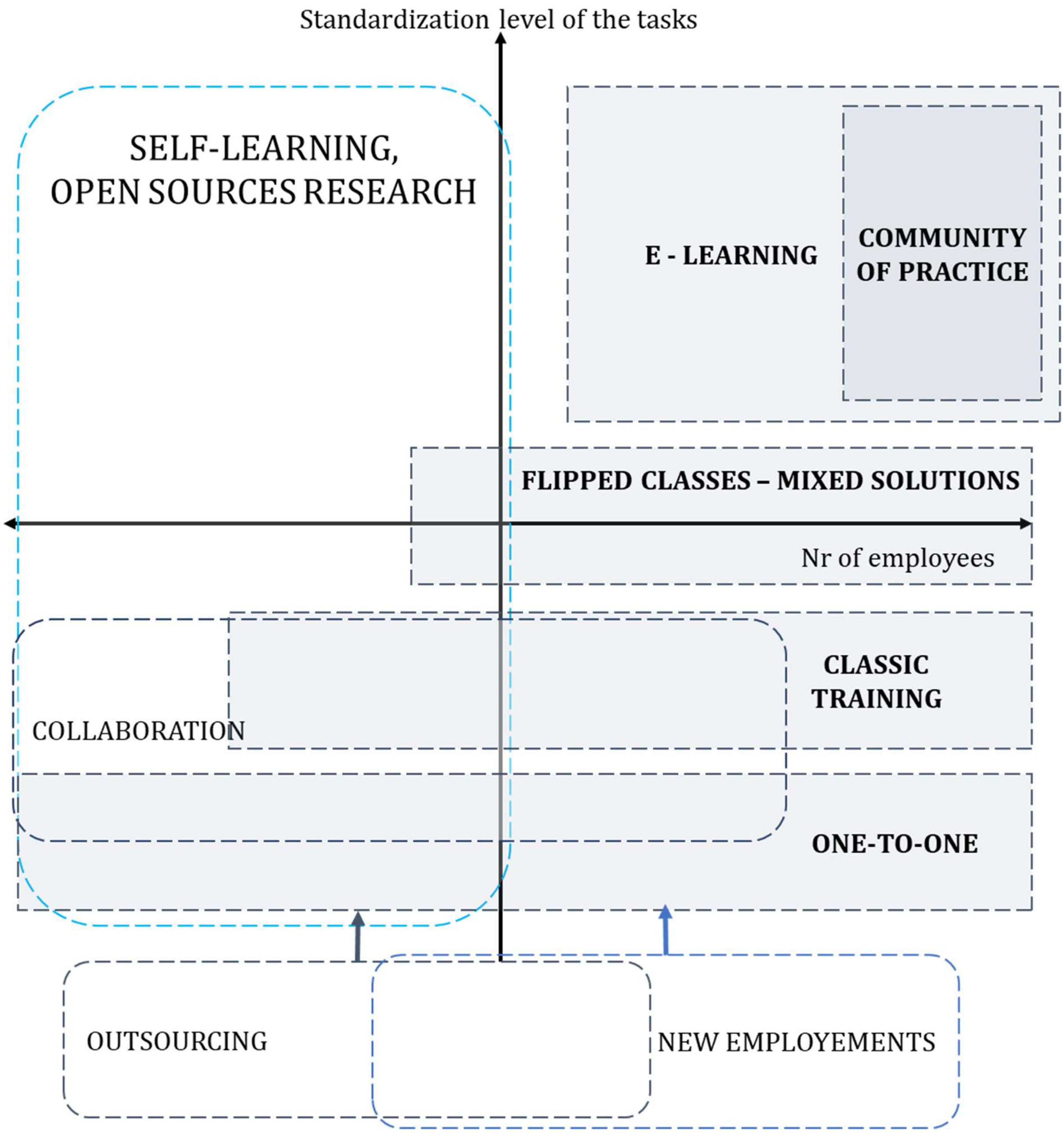


Figure 50. The Skills Development Matrix Model

The training methods are the ones included in the grey boxes. The kind of training change by changing the specificity of the skills.

One-To-One Training can be approached by each company in terms of dimension (even in Company C which has 5 employees), but it is more proper to be used for highly specialized skills to transmit, being extremely time-consuming. In fact, it requires to stop one standalone employee (if the training is done with an external expert) or two employees (if the training is done internally between the employees) to just train one person, without exploiting effect of scale.

Classic Training instead is an evolution of the One-To-One Training in which it is possible to group two or more employees to form a real class, and in which the skills to be trained are going to be less specific.

The bigger the company, the higher the possibility to invest on digital instruments of teaching. This assumption came from the case studies, even if always more knowledge platforms nowadays are available even for small companies. Then, the higher the virtualization of the teaching, the lower the specificity of the skills that can be taught. This assumption instead came from the WMF event, because, many experts think that the **E-learning** is never going to be a full substitute of physical training, despite the increasing effectiveness of the digital training. **Community of practice** instead is a further evolution of E-learning, in which, thanks to a huge number of employees it is possible to finance the development of a knowledge sharing platform. **Flipped classes** instead have to be seen as a sort of intersection between Classic training and E-learning.

As can be noticed, **Self-learning** is an extension of E-learning for small and medium companies, in which each individual can look for knowledge in the Internet without the necessary involvement of the company.

Collaboration, instead, is a practice which enables SMEs to get in touch with technologies and the subsequent specific skills, without requiring huge investments. Thus, basically, it represents a sort of step to probe the ground. The LINCOLN project is an example of this kind of collaboration in which SMEs get in touch with specific skills. The big companies have been excluded for disclosure reasons. Indeed, The bigger the company, the more the tendency to be independent in order to not incur in the risk to disclose company’s confidential information.

As complementary solution to make skills development, the **Outsourcing** and **New Recruitments** are method that look for the resources from the external environment. In these cases, the knowledge that can be "bought" can be very specific, but the level of involvement of the company is different. The bigger the company, the higher the availability to invest on new talents as a long-term investment. Small companies instead, to avoid risks, prefer to undertake single purchases to cope with the missing skills.

5.2.2 S.A.I.L. Model

The second model is an evolution of the previous one, taking into consideration the relationship between a specific technology and a specific company.

When a company gets in touch with a technology, it is supposed that this company will encounter different stages of confidence with this technology. The authors classified four different stages of confidence:

- **Skeptical**: in this stage a company gets in touch with a technology for the first time. Of course, before the propension to invest on that technology could emerge, the company needs to build trust on the benefits of the technology.

- **Aware**: the company becomes aware of the potentiality of the technology, and it is keen to invest on that technology. Unfortunately, the company cannot afford such investments yet, because of physical constraints like the complete lack of necessary skills or the lack of financial resources.

- **Illuminated**: in this stage a company is fully keen to invest on a technology, but the technology is not fully mature or suitable for the company under investigation. This is a sort of pioneering stage in which a company tries to internalize a technology together with the related skills. A possible instrument to assess the maturity of a technology before investing on it and on the necessary skills is the Gartner Hype Cycle (*Figure 51*), which is a model published every year by Gartner which assesses the maturity of technologies dividing their lifecycle into five stages [126].

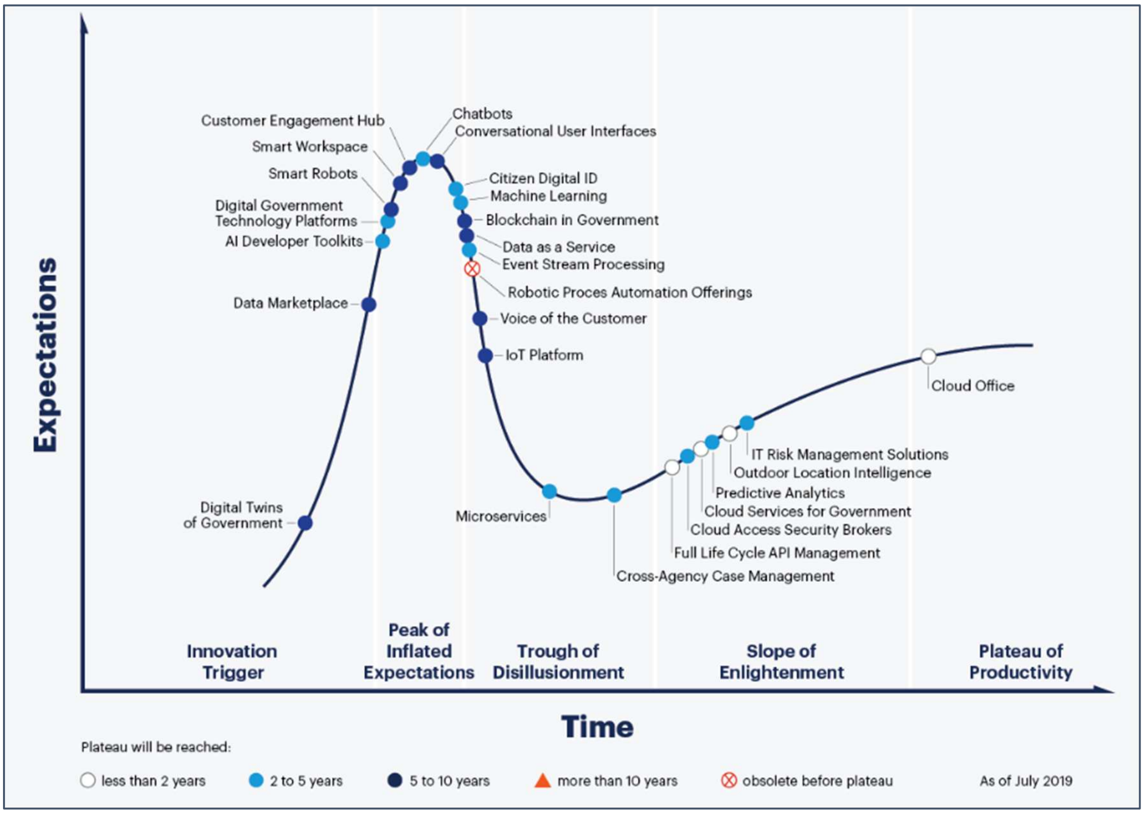


Figure 51. Gartner Hype Cycle of 2019 technologies for governments. Source: Gartner (2019)

- **Leader**: this is the last stage of growth, in which a company has fully implemented a technology and now it is only monitoring the work and assessing the most standardized way to deliver training to its employees. Usually the companies at this stage are big companies which can fully afford the needed investments.

The structure consisting in four distinct levels came out during the interview with Subject D, and the authors tried to schematize such company development process.

At the end of this cycle, if the technology is going to be substitute by another one, it can happen the disposal of the technology followed by the running of a new cycle for the substitute technology. *Figure 52* represents the initial configuration of the S.A.I.L. model explaining the four stages.

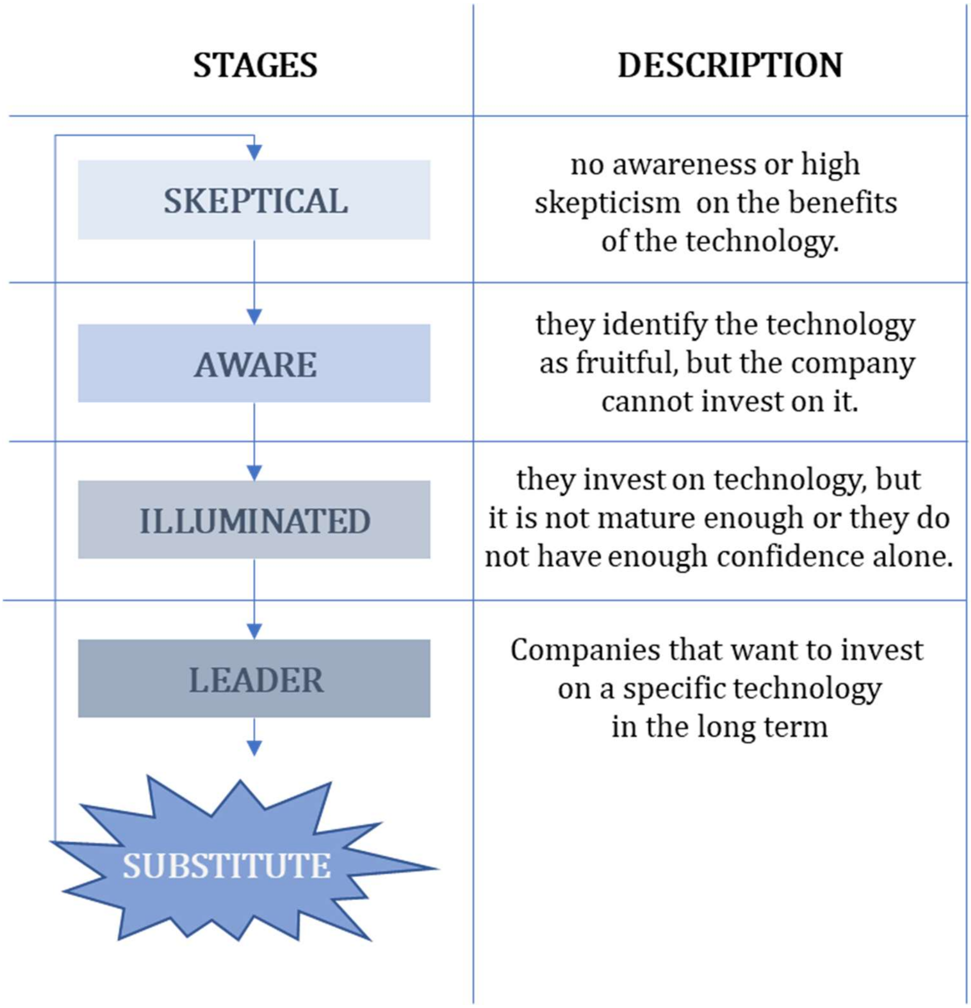


Figure 52. S.A.I.L. Model, the first two columns

A company can be in different stages for different technologies. For instance, it can be that a company is skeptical about VR but illuminated about IoT. The stages to which a company can belong depend on structural characteristics of the company itself (e.g. financial availability). This concept will be remarked by *Figure 54* where the projections of different technologies through different stages of confidence are represented.

Depending on the stages that a company is facing, there can be more suitable options to approach the skills development for the specific technology. At this point, the link between technologies and skills development methods comes out, as depicted by the final representation of the S.A.I.L. model in *Figure 53*, in which to the first two columns, the third and last one has been added.

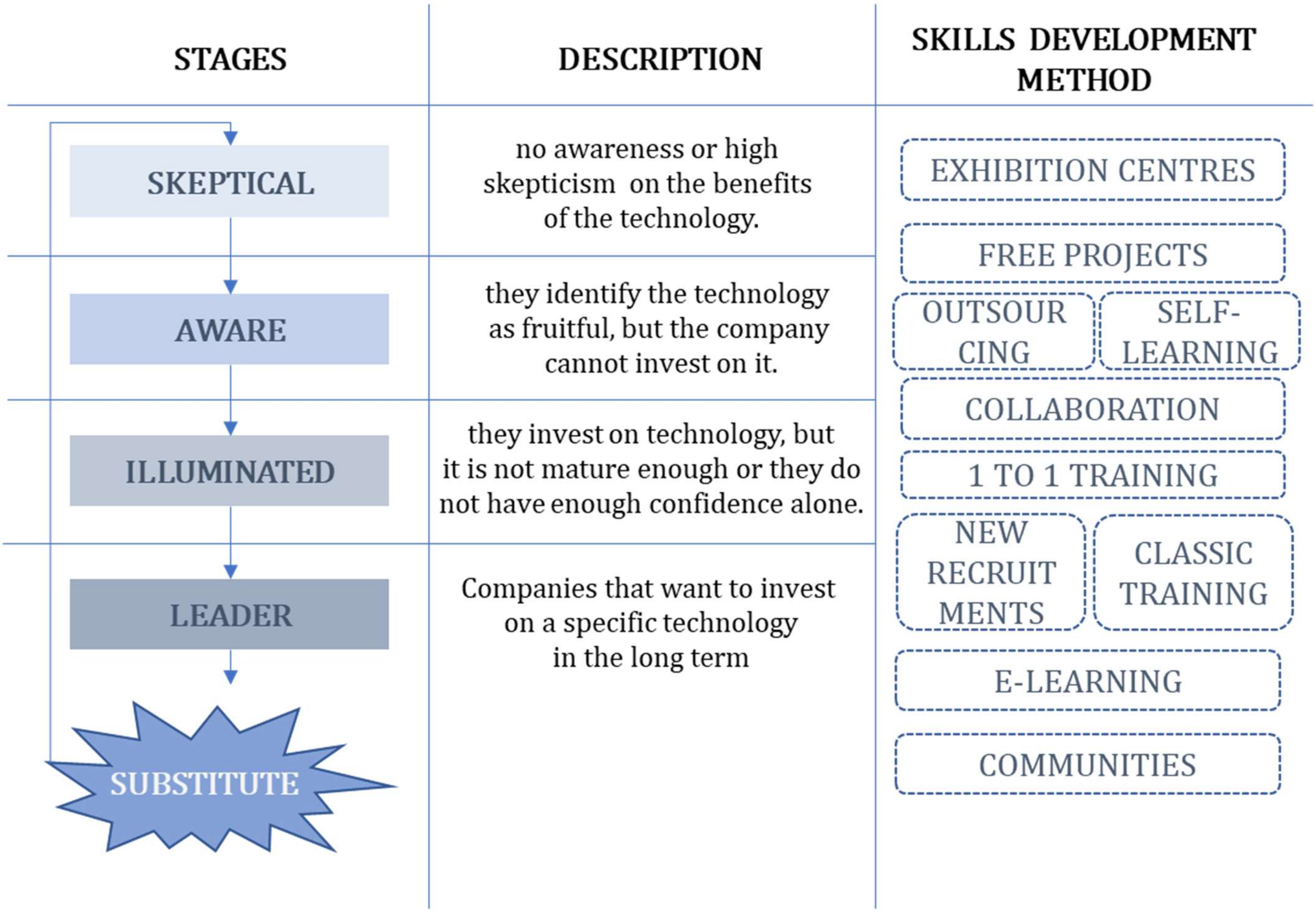


Figure 53. S.A.I.L. Model

The skills development method column is the one that suggest the most proper methods to adopt in each stage and in the transient between one stage and the next one (e.g. Collaboration between the Aware and the Illuminated stages).

To the sample of current skills development methods, the authors added the **Free projects**. This add is just a different way to perform Collaboration. Free projects are collaborating projects in which the economic involvement of companies is close to zero. The LINCOLN project is a clear example of this category.

What distinguishes the methods to apply in relationship with a specific technology, is the level of involvement of the company for the technology itself, that derives from the company strategy. If a company strongly believe in a technology, it can introduce specialized courses on a knowledge platform or recruit new suitable profiles, performing a long-term investment. If a company instead is Aware regarding the benefits of a technology, but still has some barriers for its full implementation, Outsourcing and Self-learning are approaches which require an almost null risk. If another company instead is skeptical about the adoption of a technology, it would reasonably not invest immediately on that technology, but firstly assess the benefits by participating to exhibitions centers and free projects.

For instance, the LINCOLN project helped some of the companies to skip from a stage to the next one. Company B was Skeptical about the IoT platform but Aware of the possible benefits provided by a simulation software. At the end of the project, the same company revealed high interest concerning the IoT platform and became "Illuminated" about the LincoSim software, starting to invest on the dedicated skills. Company C instead exploited the LINCOLN project to generate internal awareness, but it is still far from the full implementation of these technologies. *Figure 54* summarizes these shifts generated during the project.

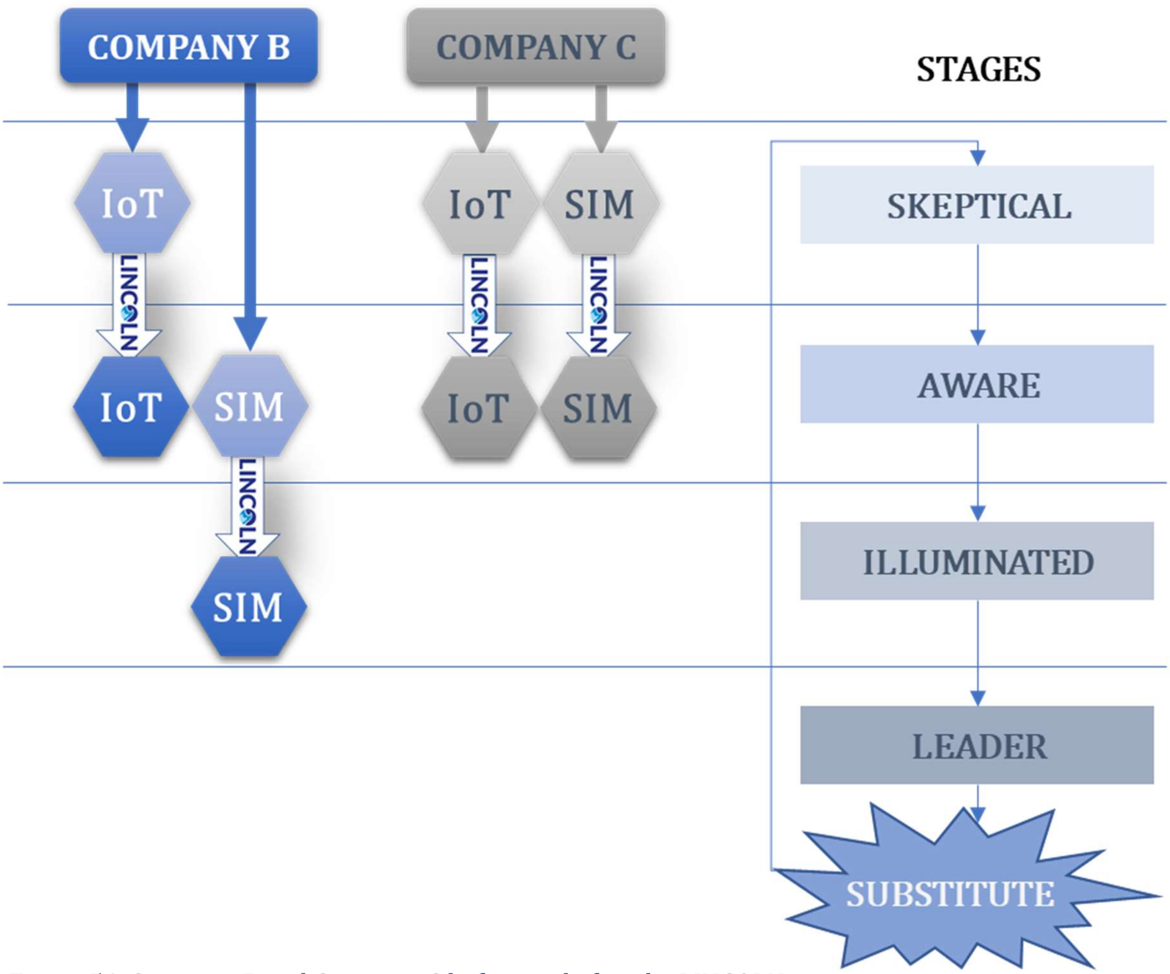


Figure 54. Company B and Company C before and after the LINCOLN project

These concrete examples were verified before the S.A.I.L. Model was available, thus providing an immediate validation of the methodological approach adopted by the authors.

This model is a useful tool with the goal to make companies understand to which stage they belong, setting up their goals for the next future depending on which confidence level they want to reach with each technology.

5.2.3 Employees Development Map

After having provided guidelines about the skills development method and the related digital confidence of any generic company, the authors wanted to generate a more practical model focused on the maritime industry. At this point, it came out the need to create a detailed map to concretely help maritime companies to get prepared for industry 4.0.

The baseline to face this model is given by the first two models. Companies need to be aware of them before being involved in the process.

The map was drawn with the intent to generate a flexible process able to adapt itself to the characteristics not only of the company, but even of the specific employee's profile to develop.

The goal of this model is the one to allow companies to align their embedded competences before implementing a new technology, in order to eliminate that current digital skills gap of the workforce that today is acting as a barrier for industry 4.0 in the maritime sector.

Therefore, the scenario that is going to be considered starting from now is the one of a maritime company which wants to make internal skills development (thus without resorting to the external sources such as New Recruitments or Outsourcing) to prepare its workforce to start training about new digital technologies. The overall model is represented by *Figure 55.*

The process is aimed at producing as output a detailed skills development plan.

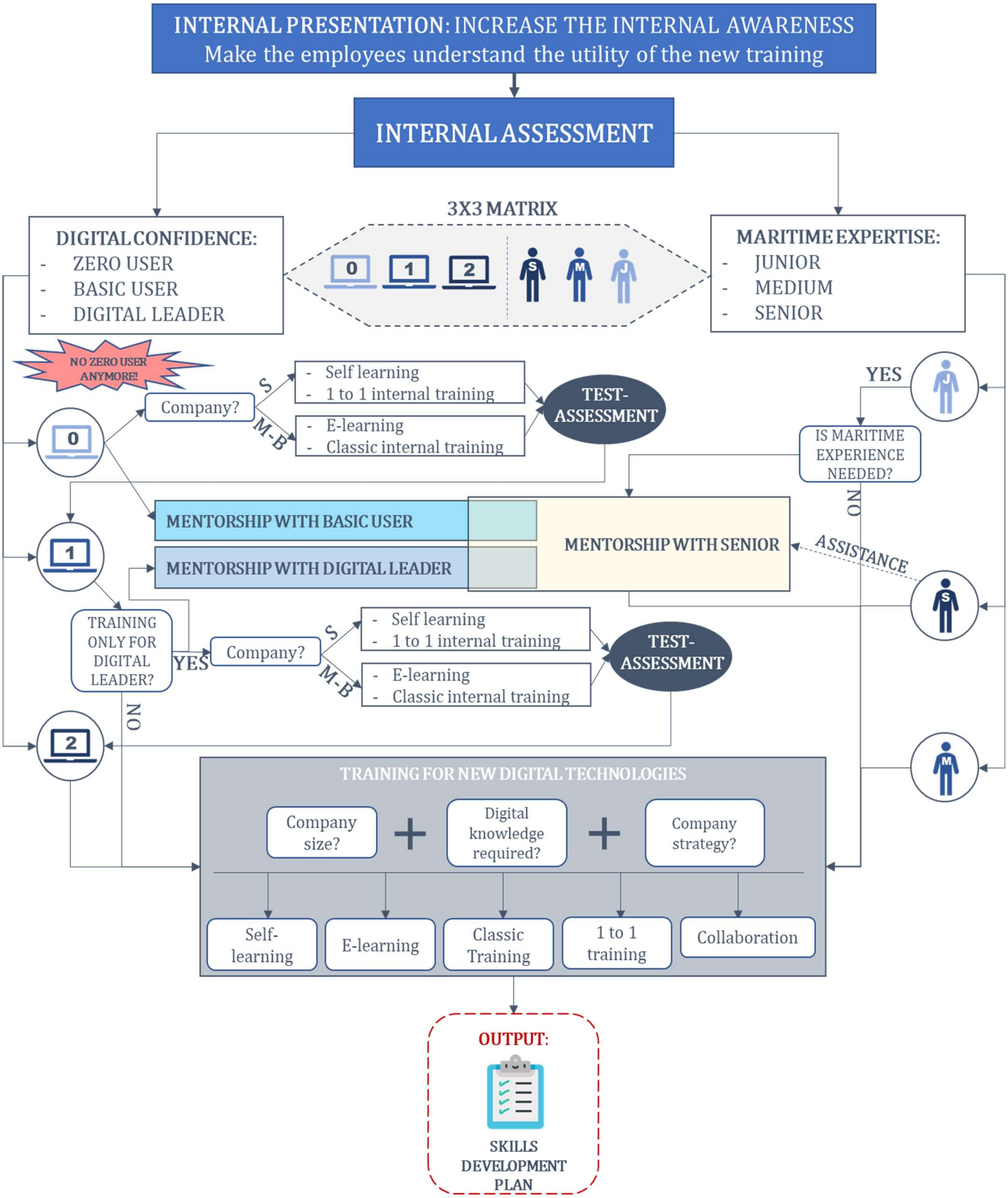


Figure 55. The Employees Development Map

THE PROCESS

The first step consists in an internal presentation about the technology that the company wants to adopt to the workforce to train. The goal of it, is the one to reduce internal resistance to change by generating internal awareness about the benefits provided by this technology, not only to the company, but even to the specific employee's skills set. The reason behind it is that the authors extrapolated from the literature review and from the case studies that the motivation of the workforce can act as an enormous barrier to the digital transformation.

In the second step, the company has to assess the maritime expertise and the digital confidence of the employees to train. These two dimensions generate three sub-categories each. The boundaries came from the already discussed (see ***Section 2: Literature Review***) digital skills of Huynh et al. [24] for the digital confidence, and from external suggestions of Subject B for the maritime expertise:

- Digital confidence: capability to interact with digital instruments, that can be categorized in the sequent way:

- *Digital zero-user:* it is an employee with baseline digital skills, thus just able to approach a pc, using browsers and communicating through ICT. It is a completely passive role;

- *Digital basic user:* an employee with workforce digital skills, hence able to perform his or her daily routine with the computer (e.g. using spreadsheet or making data entry);

- *Digital leader:* an employee with professional digital skills, thus able to create, not only to use. This can be for instance a programmer, software developer, machine learning engineer or data scientist.

- Maritime expertise: the years working in the maritime sector have a huge impact on the work performed by an employee, who, basing on the judgment of Subject B, can be classified in:

- *Junior employee:* An employee with an experience lower than three years in the company or in the maritime sector;

- *Middle employee:* an employee with at least three years of experience but less than seven in the company or in the maritime sector;

- *Senior employee:* an employee with seven years or more of experience in the maritime sector or in the company.

Once this assessment has been performed, there are nine possible different profiles that can be generated, as depicted in *Figure 56*. The process is customized for each of them.

Figure 56. Different possible profiles after the internal assessment

The first result that this tool aims to obtain is the elimination of the digital zero-user profiles before starting the industry 4.0 training. As it can be noticed by drilling down the process of *Figure 55,* if an employee starts as zero-user, he is not allowed to conclude the process until he becomes at least a digital basic user.

The process of augmenting the digital level consists in a period of specialized training together with the beginning of a mentorship program. The training to increase the digital confidence can be performed trough One-To-One Training or Self-Learning if the company is small (less than 50 employees), otherwise through E-learning or Classic Training if it is medium or big (more than 50 employees). This training period does not have a fixed duration, because it is going to finish at the passing of a final test.
The **mentorship program** instead has a fixed duration, which can be previously assessed by the company. The authors preferred leaving a certain degree of flexibility to the specific company to dimension the duration of this program depending on its needs. What is suggested, is a period of six months in which a zero-user needs to be followed by a basic user to learn how to interact with digital technologies. In this period, weekly checks are performed with the mentor and the zero-user needs to participate to projects always with at least a basic user in the team (preferably with the mentor himself).

At the end of this digital enhancement, the employee under training is supposed to become a basic user. At this point, a bifurcation appears. If the basic user employee needs to furtherly enhance his or her digital confidence, he or she will restart a similar program to become a digital leader. In this case, the mentorship program needs to be executed together with a digital leader.
A problem of this passage is the possible lack within the company of a digital leader. In this case, it is needed to train some well-dedicated employees in external environments (e.g. specialized training centers) to create digital mentors that will share their knowledge within the company. As seen in *Section 3.2.4: New roles definition*, digital mentors are crucial for the success of digital skills development.

Parallelly to the digital enhancement, the maritime expertise needs to be increased accordingly. Differently from the digital confidence, maritime expertise is exclusively coming from working years. To accelerate the maritime expertise acquisition, another mentorship program was though for the junior employees. If maritime expertise is considered relevant by the company before starting the training on a new technology, the junior employee under examination will start another mentorship program with a senior employee. This program will conclude after six months in which the junior employee needs to conclude at least one naval project, to work in projects always with middle or senior employees, and to be in close contact with a senior employee through weekly assessments.

The added value of this framework is given by the intersection of the digital and the expertise mentorship program. If an employee is both basic user and junior, he can run the process performing the mentorship program with a digital leader senior employee (if available), to minimize the processing time.

At the end of this double process map, it is time to start the training on the industry 4.0 technologies that the company wants to embed. At this point, the other two models find utility. According to the considerations previously done, the company will choose the most proper internal skills development method depending on the company size, skills specificity and company strategy (i.e. Collaboration, One-To-One Training, Classic Training, E-Learning and Self-Learning).

The final output of this overall process is a complete skills development plan which a specific employee (belonging to any of the nine profiles defined in *Figure 56*) will need to follow to be fully trained.

5.2.4 Implementation Cases

To provide higher physical evidences about the results provided by the three models, but especially of the last one, a qualitative simulation has been performed considering three different cases:

- *Employee A:* new young recruit digital native and highly specialized in programming/digital skills, but with an almost null maritime expertise;
- *Employee B:* Senior employee with no confidence at all with digital tools;
- *Employee C:* Senior employee with good confidence with digital tools.

All these profiles are summarized in *Figure 57,* to allow the reader to follow the explanations.

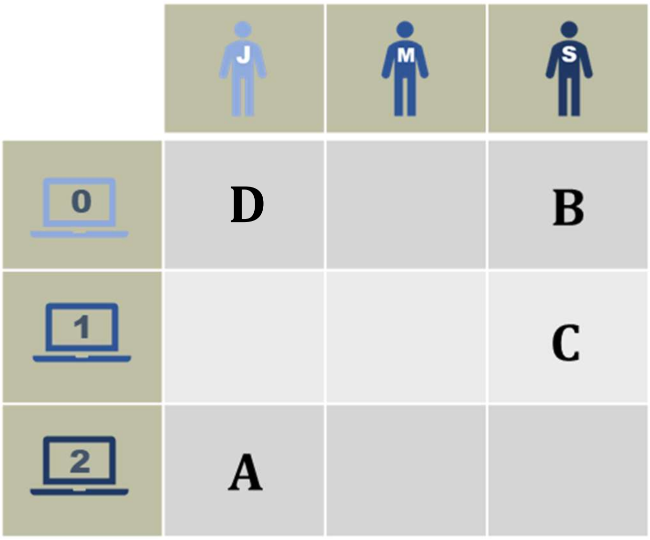


Figure 57. Different employees: practical cases

The two inputs that the Employees Development Map needs to receive are provided by the Skills Development Matrix. They are two inputs that need to be defined *a priori*, namely the company size and the Digital level required to start the running of the Employees Development Map. Before understanding which method of skills development officially select to start the Industry 4.0 training, a further help is needed by the S.A.I.L. Model to consider the company strategy relatively to the technology to intensify. *Figure 58* summarizes these conceptual steps.

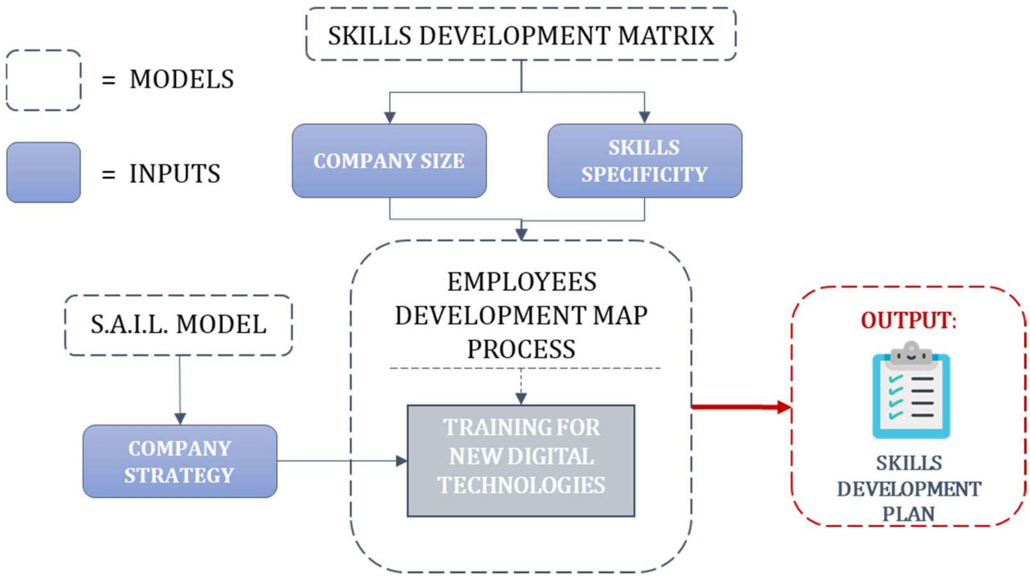


Figure 58. Combination of the models

The reference case that is going to be taken into account is the one of a small company (less than 50 employees) that wants to investigate a new Simulation software which allow to run CFD simulations (high digital skills level required: programming skills). The company wants to prepare Employee A, Employee B and Employee C to start the training about that new digital technology, thus it wants to be sure that they will be aligned in that sense.

EMPLOYEE A CASE

In the case of the Employee A, thus with a high digital competence but low maritime expertise, the skills development plan will be intended to strengthen this last pre-requisite. The skills development plan to be followed by the company will be:

- *Presentation on the Simulation Software:* the company will have the duty to motivate its employees presenting them the company strategy about the new digital opportunity to exploit. To do this the company will stress on the benefits provided by the technology to the company itself and to the employees' curricula.

- *Mentorship program:* the employee will follow a dedicated mentorship program in which he will be followed by a Senior employee. To program will consist in:
    - ➢ At least one naval project concluded;
    - ➢ To stay always in team with more expert profiles until the end of the program;
    - ➢ Six months period of weekly checks with the Senior mentor (controls about the work performed in the week, checking the adherence of simulated programs with the boats specifications…).

- *Skills development through Collaboration*: at the end of the preparation period, the employee will start a skills development program that, according to the company strategy, will consist in a collaborative project with universities or other partners.

EMPLOYEE B CASE

In the case of Employee B, thereby an employee with almost null digital confidence and at least 7 years of expertise in the sector, the plan will be devoted exclusively to an intensive digital skills development period:

- *Presentation on the Simulation Software:* the same procedure of Employee A;

- *One-to-one internal training or Self-learning:* period of training with another internal employee that will act as a professor, or Self-learning period about the digital basics;

- *Mentorship program with a basic digital user:* Employee B will be followed by a basic digital user (e.g. Employee C) through weekly checks on the new digital capabilities acquired during the week through the One-To-One Training, and he or she will always participate in projects with basic users until the accomplishment of the test;

- *Test-assessment:* test to verify the passage to the status of digital basic user;

- *One-to-one internal training or Self-learning:* period of training with another internal employee or Self-learning period about digital advanced skills (i.e. CFD programming skills in the specific case);

- *Mentorship program with a digital leader:* Employee B will be followed by a digital leader (e.g. Employee A) through weekly checks and he or she will participate to projects with at least a digital leader until the accomplishment of the test;

- *Test or assessment:* test to verify the passage to the status of digital leader;

- *Skills development through Collaboration:* similarly to what concluded for Employee A, Employee B will strengthen his or her competences through Collaborative projects, according to the company strategy.

EMPLOYEE C CASE

In the case of Employee C, the treatment will follow the same logic of the previous one, considering only the second part of the skills development plan, thus:

- *Presentation on the Simulation Software;*

- *One-to-one training or Self-learning;*

- *Mentorship program with a digital leader;*

- *Test or assessment:* in order to become digital leader;

- *Skills development through Collaboration*.

By looking again to *Figure 57,* it is possible to understand that the longest possible skills development plan to generate would be the one dedicated to Employee D, that is a new entry employee with no digital confidence at all.

5.2.5 Concluding Remarks

The Skills Development Matrix aids this processing plan at the beginning, assessing the size and the specificity of the tasks to complete. Then, furtherly aided by the S.A.I.L. model that will provide hints about the company current situation and strategy, it will direct the concluding part of the Employees Development Map to define the most proper way to tackle the new technologies.

The strong point of the Employees Development Map instead, is the inner ability to address a specific skills development plan considering any possible employee's profile in terms of maritime expertise and digital level.

At this point it is possible to conclude that all the models cooperate in order to provide precise guidelines to maritime companies to execute an effective skills development plan.

6. VALIDATION

Once the models have been developed, the last necessary step was to validate them. In this chapter it is going to be illustrated the validation process, consisting in further interviews with two of the experts previously interviewed.

The subjects involved in the validation process were Subject A and Subject B. In this way, the validation considered both a Shipbuilding Company and a Design Studio, in order to have an overview as much complete as possible.

This chapter is structured in order to firstly show the applied methodology for the validating interviews and then the results obtained.

6.1 VALIDATION METHODOLOGY

The validation consisted in web-call interviews with the two Subjects. Similarly to what previously performed, the authors showed in real time some slides to the subjects during the interviews (by sharing the screen). These interviews were pretty much extensive in comparison with the first ones; indeed, both of them lasted approximately two hours.

The interviews structure has been previously defined by the authors in order to direct the subject on the relevant arguments. The structure consisted in three layers of interview, in order to get the validation of all the three models. The mindset behind the preparation of the PowerPoint slides was the one to bring the subjects to say what has been concluded by the authors, without directly showing the models. To have a full view on the content of the slides, the reader is invited to consult the appendix *Section 8.3: validation interview*.

6.1.1 Skills Development Matrix Validation

To bring the subjects to validate the skills development matrix model, the first step was the one to summarize what discussed during the first interview with the specific subject, by asking him again which skills development method his company adopted until today.

Then the interview consisted in listing all the existing methods to develop the skills that have been used to fulfil the matrix together with a list of possible criteria that can affect the company's choice of the method. The criteria were:

- Company size/number of employees;
- Time available to embed the skills;
- Skill specificity (for a standard or specific task);
- Tool maturity;
- Time necessary to acquire the skills;
- Employees digital readiness;
- Digital benefits awareness;
- Employees workload;
- Employees resistance;
- Employees awareness on the benefits given by the skills.

The subjects were asked to give a prioritization of this criteria by selecting the most relevant five criteria. The objective was the one to receive a confirmation on the relevance of the two criteria chosen by the authors, thus company size and skill specificity related to the tasks to perform.

The first step was finalized to confirm the chosen axes, the second step instead had the aim to fulfill the matrix. To obtain the fulfillment of the matrix following the opinions of the subjects, an empty 3x3 sub-matrix has been shown to them together with the list of the methods (*Figure 59)*. For the sake of simplicity, the authors preferred to call the tasks in a simple way (i.e. standard tasks, specific tasks, very specific and complex tasks) to facilitate the interviewees' comprehension.

	STANDARD TASK	SPECIFIC TASK	VERY SPECIFIC AND COMPLEX TASK
SMALL COMPANY			
MEDIUM COMPANY			
BIG COMPANY			

Figure 59. Sub matrix submitted to the interviewees to be fulfilled

Then they were asked to put all the methods inside the cells of the table, in order to obtain a fulfillment of the matrix. At the end of this step, the results provided by the interviewees were compared with the actual framework, and the subjects was asked about further comments to obtain possible hints to adjust the model itself.

6.1.2 S.A.I.L. Model Validation

The second model's validation has been though using the same logic of pro-active fulfilment adopted in the first model validation. The four stages did not need any validation because they were directly suggested by the interview with subject D. Working in a research organization, the idea coming from Subject D to divide the approach to technologies into four steps was already considered trustable. The thing needed to be validated was the connection between the skills development methods and the specific stages.

To do that, the first two columns of the S.A.I.L. model (*Figure 52*) were shown to the subject, while the logic behind the subdivision of the four stages was explained. In the same slide the list of skills development methods (with the addition of exhibition centres and free projects) was shown to the interviewee, and he was asked to provide an order of implementation considering the initial scenario of a traditional low-tech company.

Finally, the answers provided by the subjects were matched with the complete model, collecting in the meanwhile any further consideration.

6.1.3 Employees Development Map Validation

The third model was quite more complex to be validated. The validation consisted in five questions aimed on the assumptions performed to develop the overall map proposed in the model. The objective was to one to find agreement on the modalities through which maritime companies can create internal skills development by themselves in most proper way. The questions were:

- *How would you treat the different profiles of your employees before facing skills development? Would differentiate them before the training?*

- *Would you differentiate employees in terms of digital capabilities creating three distinct classes?*

- *Would you differentiate them in terms of experience in the maritime sector creating three distinct profiles?*

- *Do you consider necessary for the employees the achievement of digital independence and maritime experience before facing training on a industry 4.0 technology?*

- *Would you consider useful to make an internal presentation to increase the awareness regarding the benefits introduced by a new tool before its implementation?*

Through these questions the authors intended to find possible alternative assumptions on which the overall map could be built. Moreover, possible different boundaries could have been identified in terms of digital confidence and maritime experience of the single employee.

Then, the overall map together with the examples of the three hypothetical profiles' skills development plans (*Section 5.2.4: Implementation cases*) were shown to the subject to collect confirmations and other hints.

The last step of the validation was a comparison between the plan generated by the model and the plan effectively applied by Subject B to develop his employees, that was delivered ex-post by e-mail. Thanks to this the authors could implement some possible changes to the drawn models.

6.2 VALIDATIONS CONTENTS

What emerged by the interviews was an overall validation of the three proposed models, complemented by further comments and suggestions about specific parts.

The interview structure demonstrated to be fruitful in terms of validations achieved.

6.2.1 Skills Development Matrix Validation

Regarding the skills development matrix, both the interviewees agreed about the axes chosen by the authors. In fact, the two elected criteria (i.e. company size and skills specificity) have been classified by both the subjects as two of the most impacting factors in the skills development method choice.

The table of *Figure 59* fulfilled by the subjects was adherent to the fulfilment of the matrix decided by the authors in both the interviews, with few misalignments.

Subject B confirmed that the lower the specificity of the skills to acquire, the bigger the sample of employees to which dedicate the training. He argued this sentence with two reasons. Firstly, he considered the economic advantage given by investing on standard contents to deliver to the whole workforce (i.e. lower investment per person). While for very specific skills, it is more suitable to focus the training on a limited sample of employees, until the individual One-To-One Training. Secondly, he added that the people who are in charge of very complex tasks are few (at least in the SMEs); thus, it makes sense to reduce the investment by focusing on these specialized profiles.

Subject A fully confirmed the authors' results in terms of Classic Training and One-To-One Training using as example his own company. He stated that Company A is too small (25 employees) to organize real classes and he confirmed that One-To-One training should be devoted for very specific tasks accomplishment, requiring the commitment of two employees to train just one employee.

A suggestion that the Subject B gave to the authors was to consider not only the company size in terms of number of employees but also the department size or the team size, depending on which entity is involved in the training. Thus, team size can be an alternative to company size, especially if a skill is not needed for the whole company.

A further suggestion coming from the Subject B was to evaluate the performances related to each skills development method previously adopted. In this way the future choices of the most suitable methods would have been aided by the past experiences, in relationship with the specific working team ore department. Thus, the collection of relevant data would complement the proposed solution.

When the interview has shifted to the E-learning topic, both the subjects showed their enthusiasm about this practice for the next future. Subject B spoke about his past experiences with Classic Training. He stated that for standard tasks a Classic physical Training would have been a waste of resources. Thus, Company B opted for E-learning regarding this kind of simple related skills. E-learning demonstrated all its benefits in terms of:

- Cost;
- Multi-location;
- Number of participants;
- Maturity of the platform through which dispense the courses.

In his opinion E-learning is the best way to learn because you can adjust the pace of learning according to your previous knowledge and capabilities, you can "rewind", move forward depending on what you need in the specific moment. From his words, "*E-learning is a powerful tool at least to create a common knowledge base, it cannot fully substitute the general training, but a lot of parts can be done through this with the benefits above mentioned*".

Subject A added that E-learning is not anymore a practice only for big companies, but it can be provided through the Cloud in an accessible way even to small companies. The real problem of E-learning is the customization degree, in fact it is difficult to identify provider which developed e-courses on the specific content you looked for.

The Subject B confirmed all the benefits and hypotheses about the Communities of Practice, and he said that this kind of tool is useful especially for standardized tasks.

Then, Subject B added some considerations about the Self-Learning practice. He said that in many small companies, Self-learning is likely to be the only one available option to perform skills development. In this way, very small entities will always have difficulties to refine a high-level skill because of this practical constraint. Thus, the only, some alternatives need to be found, because Self-learning is not suitable for very specific and complex tasks accomplishment. "*In small companies you have very qualified guys in terms of capabilities, they are very capable to do a lot of stuff but maybe they are not so qualified in a specific one, because Self-learning is the only available option".*

Subject A focused on Collaboration, by pointing out that "*the problem is that you have to share your knowledge, that could be your competitive advantage. It is difficult that a big company share this information with others, the small companies take the more advantage out of it (the collaboration could vary from standard task to specific but not too specific because it could be a company secret)*". Thus, collaboration has be confirmed to belong in the right area.

To conclude, the only exceptions found from the considerations of the validators are the areas occupied by Self-learning and E-learning. Self-learning was previously put even for very specific task under suggestion of Subject D. But probably, this consideration was influenced by the fact that he was a research specialist. Regarding E-learning instead, thanks to the Witnesses of Subject A, the authors slightly enlarged its area in the quadrant considering even the small companies, because of the easy accessibility of the E-learning platforms witnessed by Subject A.

From *Figure 60* it is possible to identify the slight changes applied on the model after the experts' considerations. As it can be noticed, the Self-Learning area has been restricted in both directions, while E-Learning has been shifted slightly towards smaller companies. The areas marked with a star are the ones subjected to modifications.

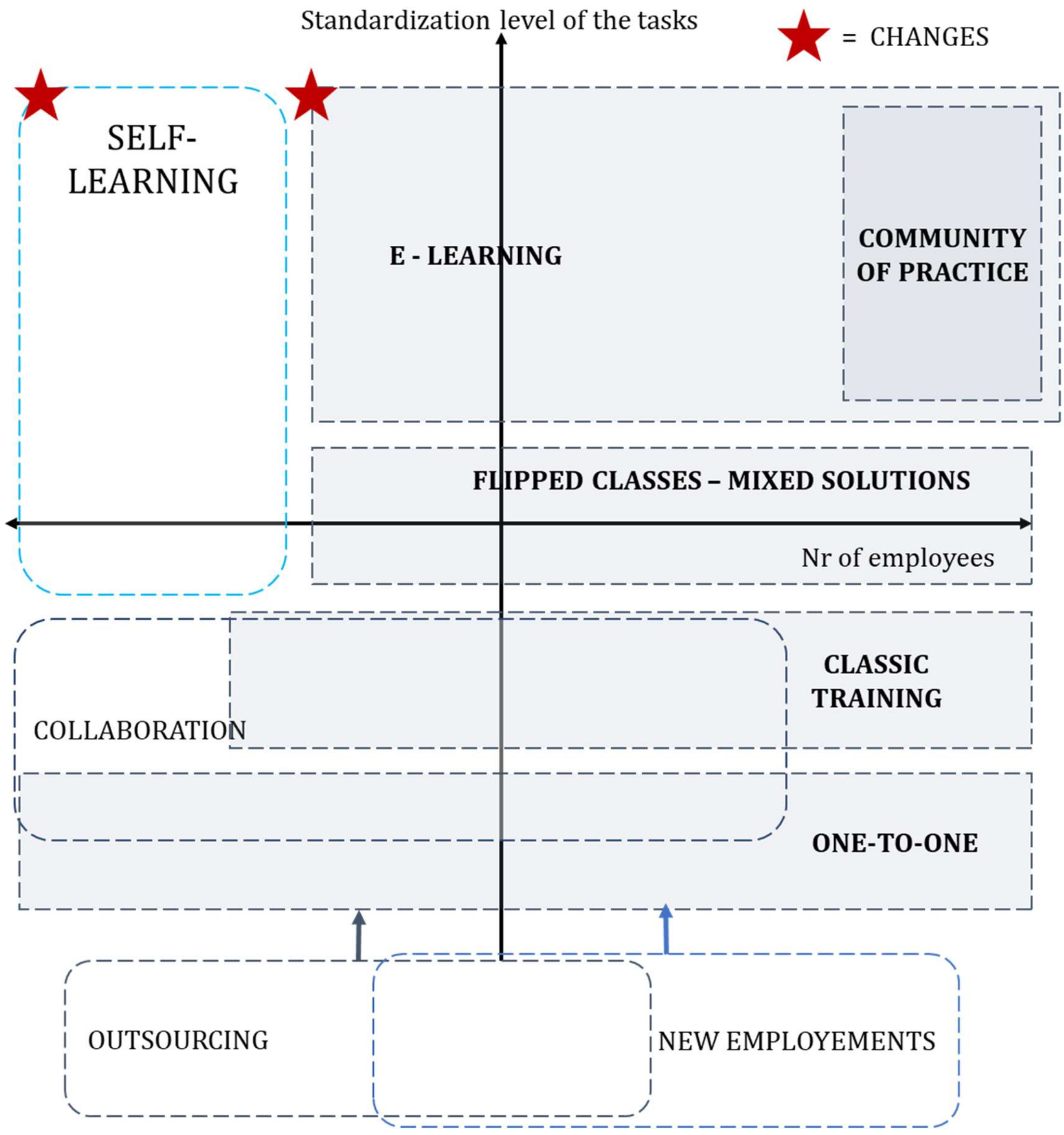


Figure 60. Skills Development Matrix after the validation review

6.2.2 S.A.I.L. Model Validation

Both the subjects generally agreed on the subdivision into four theoretical phases proposed by the S.A.I.L. Model. The most discussed topic was the one referred to the most suitable skills development method for each phase.

Subject B pointed out that Free Projects are useful in all the stages. This practice, in his opinion, is not merely connected to small companies for new technologies, but even for medium and big firms that want to collaborate for free with smaller realities, in order to investigate new modalities to implement the technologies. Considering a reasonable level of disclosure, Free Project can be extended even to the other phases.

Another reasoning that came out was the one of the risk factor, as the authors said before, the Outsourcing could be used also when the firm is dealing with a risky project on which they do not have competences in the implementation of the skills development process and they could not fail or they have a rigid time constraint.

He also said that Outsourcing is a viable option especially for SMEs, when resources are impossible to be already embedded at all. Thus, this practice can be useful not only for Aware companies by even for the Illuminated ones.

Concerning Collaboration Subject B generally agreed on the positioning of this method in the S.A.I.L. model by saying that Collaboration is very useful "*only in the case of new technologies that you cannot implement by yourself or something that is not mature yet, the general trend is to do as much as possible by yourself*"

Another interesting point that the Subject B highlighted was the fact that an illuminated firm when it has a clear view about the market and the situation it has to invest immediately. The best is that this company invest by itself and not in a shared investment because it could lose the competitive advantage that the specific technology could bring to the company. Thus, at the stage of Illuminated, a company can sustain investments on the skills with more courage. Despite this, he fully agreed on the maturity of the toll as a difference between the illuminated and Leader stages.

Subject A agreed with all the model structure, without providing particular cues about it. He agreed with the consideration stated by Subject B about Outsourcing. As further consideration, Subject A made a consideration about the Exhibition Centres by saying that "*Exhibition centre is good place to find new trends without any investment but at the same time is not the most important place where to find the new trend. If you find the new trends there you are too late, because someone is already at a higher stage about the specific technology.*"

Figure 61 summarizes all the considerations pointed out by the interviewees in terms of skills development methods to associate with the steps of the S.A.I.L. Model. The modifications, marked by the stars, have been done regarding the Free Projects and the Outsourcing expanded to more stages. The others were not changed, being considered proper by the validators.

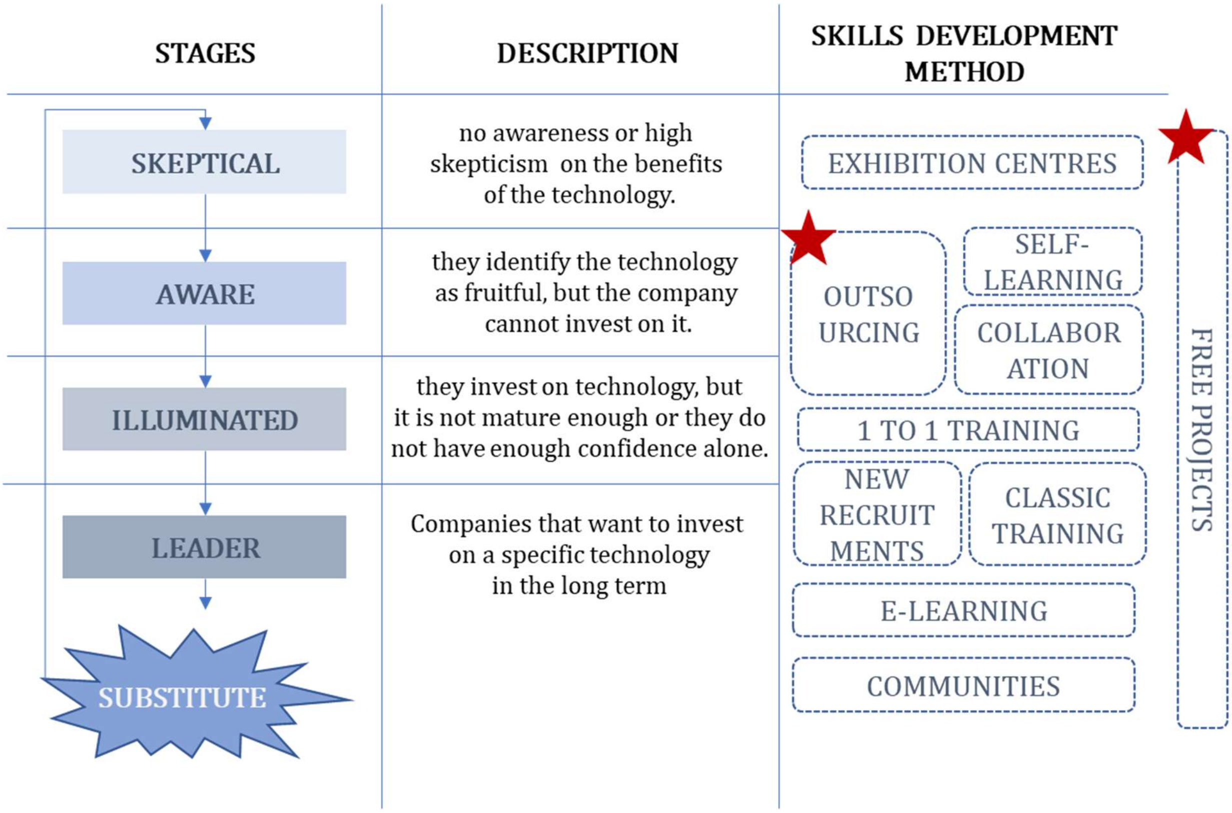


Figure 61. S.A.I.L. Model after the validation review

6.2.3 Employees Development Map

Regarding the Employees Development Map model, the two subjects agreed in most of the parts.

First of all, they confirmed that, especially regarding digital technology, the internal resistance to change is a strong barrier, thus they found interesting the idea of proposing a presentation to enhance the internal awareness about the benefit brought by new technologies. To this part, Subject B added that he would not extend this presentation to the whole workforce, but he would make customized presentations depending on the circumstances in which employees work (sector, team, projects etc.). Taking his own words "*with low qualified people maybe it is better to start working and let them check by person the final results (for instance thanks to a workshop). Let them discover by themselves the capabilities is the method that creates the best motivation. With the specialist employees is the opposite, a general presentation is enough. With less qualified you need to show the results as soon as possible*."

Subject A agreed on the idea of customized presentations and especially training method. He considered more effective to leave the employee the choice to select the way he or she prefers to obtain the right knowledge, independently from the company strategy (but always considering reasonable constraints).

Subject B confirmed the fact that even maritime companies need to strengthen the digital literacy of employees, thus he agreed on the idea of eliminating Digital zero-users. What Subject B suggested to modify was the possibility to by-pass the strengthening process of the Junior employees through the mentorship program. In fact, as it was possible to observe from the designed map, the authors considered a first assessment of the need to have a high maritime experience or not. He highlighted that maritime experience is always necessary, so he proposed to force the mentorship program for each Junior employee within his or her skills development plan.

The last propose of Subject B entailed the addition of potential economic benefits or bonuses for the most noteworthy employees in terms of achieved skills and for the mentors. In his opinion, the individual contribution to internal digital skills development should be awarded.

In *Figure 62* it is possible to observe the model after the subjects' suggestions, which consisted mostly in the elimination of the previous cell called "Maritime experience needed?" and in some adjustments in the first step: the internal presentation.

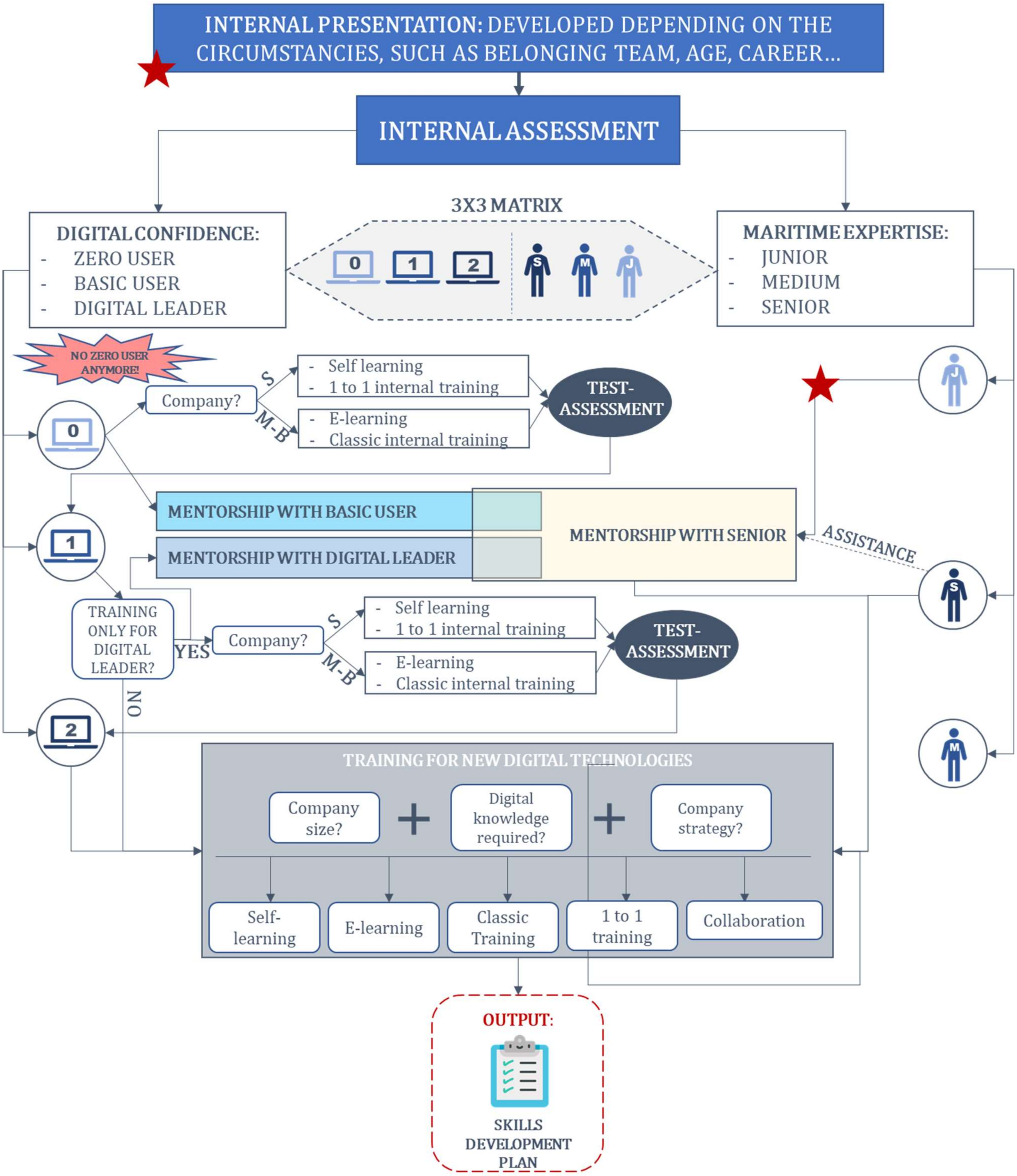


Figure 62. Employees Development Map after validation review

As last part, a further ex-post validation has been conducted, thanks to the collaboration of Subject B. Indeed, he sent to the authors a real training program which Company B deployed for its employees (*Table 16)*. This program basically consisted in a substantial subdivision of skills into two major clusters: maritime competences and digital competences development. It is not properly a plan because it is not showing a checklist of steps to follow, but it is more an internal digital training guide. The aim of this program is the one to associate for each maritime competence the related digital one, in order to fasten the training period of a junior employee.

<table>
<tr><th>Maritime competencies</th><th>Digital competencies development</th></tr>
<tr><td>Concept design</td><td>1 to 1 training with digital expert employee on the use of the basic digital tools (Office suite).</td></tr>
<tr><td>Sizing of the ship (studies), General arrangement studies, compartiments</td><td>E-learning/Classical training and 1-to1 training with internal expert about design SW: CAD programs</td></tr>
<tr><td>Stability, weight control, Capacity calculation, tonnage calculation, power-specifications</td><td>E-learning/Classical training, 1-to-1 training with internal expert about specific SW: i.e. Foran,</td></tr>
<tr><td>Towing tanks test development plan</td><td>1-to-1 training and participation to collaboration projects about innovative SW: LincoSIM (the LINCOLN virtual towing tank), Ansys SW</td></tr>
<tr><td>Technical specifications and reports, technical reports</td><td rowspan="2">Participation to ollaboration projects and E-learning and classical training about innovative SW platform able to integrate several 4.0 technologies: i.e. Siemes SW, LINCOLN IoT platform etc.</td></tr>
<tr><td>Regulations (classifications societies, SOLAS, IMO, National etc)</td></tr>
</table>

Table 16. Example of skills development plan in Company B

The main takeaway of this training program was that it confirmed the subdivision into two spheres of skills proposed by the authors into the Employees Development Map model. It is dutiful to highlight that this training guide has been developed by Company B before the model proposed in the thesis.

At the end of this research process, it is possible to state that the models have been validated by two maritime experts belonging to two relevant blocks of the maritime cluster as Shipbuilding companies and Design Studios. Even if the models lack in terms of practical implementation, it has been greeted with enthusiasm by the validating interviewees in all its parts.

All the adjustments executed in this chapter are slight modifications which do not affect the sense of the overall set of models.

7. CONCLUSIONS

At the end of this research, it came the moment to come to term by drawing up some consistent conclusions.

7.1 DISCUSSION

The file rouge of the thesis, from the introduction until the validation, has been the scheme of research composed of three research fields: maritime sector, skills development domain and digital technologies. By analysing their connections, the authors firstly generated a comprehensive overview into the introduction, to successively focus on the literature review.

The systematic literature search method applied has been considered the most reliable and suitable methodology to not neglect any relevant information. Despite the reduced manoeuvrability on the generated database of articles and the time-consuming activity of qualitatively restricting the articles sample, thanks to this method it was possible to create a solid knowledge base from which starting. Within the literature review, the most fruitful content has been the "digital maritime" one, while the thematic of the skills development process connected to the maritime sphere is more lacking. Concerning the "core" area (*Area 4*) connecting all the three research fields the number of articles was quite poor and sometimes not strictly correlated to the proposed research goals of this thesis. In fact, the research objective of the thesis consisted in creating a model able to facilitate the digital skills development process of the maritime entities.
The literature review was the starting point to allow the accomplishment of this academic enrichment objective.

Despite the completeness of the literature review, it was necessary to complement this purely academic knowledge with a more practical one, and it was possible thanks to the participation to the WMF 2019 in which the authors collected many witnesses of relevant industrial actors about the topic of the digital skills development.

At the end of these two research steps, the authors drew up four research questions to be answered from an empirical research conducted through semi-structured interviews: the case studies. These ones enormously helped the authors to validate the knowledge and the perceptions built during the literature review, and to increase the possibility to identify solutions adherent with the real needs of maritime companies.

At the end of the case studies, it came the moment to elaborate some trustable findings which, assembled together, would have been the basis to develop an overall applicative model. The model consists in three sub-models.

The Skills Development Matrix is a stand-alone model which aims to directly guide each kind of company to the most effective method to perform skills development depending on the company size and the specificity of the tasks to execute. At this point only one research field was considered: the skills development one.

The S.A.I.L. Model attempts instead to connect the digital technologies with the skills development methods previously analysed, identifying four distinct stages of technological implementation. Here the considered research fields were the skills development and the digital one.

The Employees Development Map instead is a process considering also the peculiarities of the maritime sector. This model, receiving in input the outputs produced by the previous two models, tries to address a specific skills development plan tailored on the specific maritime employee's profile. Finally, here all the three research fields are combined, to conclude a three-steps gradual process.

At the end of this elaboration, the authors tried to validate their outcome through other semi-structured interviews with two of the already interviewed experts. The models met their enthusiasm, with the exceptions of some aspects that brought to slight modifications of the models.

It can be concluded that this thesis provided three co-operating models which are both theoretical and practical. The first two tries to theoretically and immediately define the company digital skills development. The third one instead, aided by the knowledge coming from the previous, is able to provide an effective skills development plan which would facilitate the enhancement of the skills in the maritime realities. The expected benefits of addressing a specific skills development plan are the time savings to create a training program for each employee, and the effectiveness to identify the most suitable one, reducing the possibility to make mistakes.

7.2 CONTRIBUTIONS & LIMITATIONS

This thesis aims to fulfil the current inspected academic gap found about the specific research ensemble: *Area 4* (digital skills development of the maritime sector).

The general idea behind this thesis was the one to identify the knowledge present in the less central areas of research (*Area 0, Area 1, Area 2, Area 3*) that was suitable to be inserted within the "core" area. The scheme which reflects this approach is summarized by *Figure 63*.

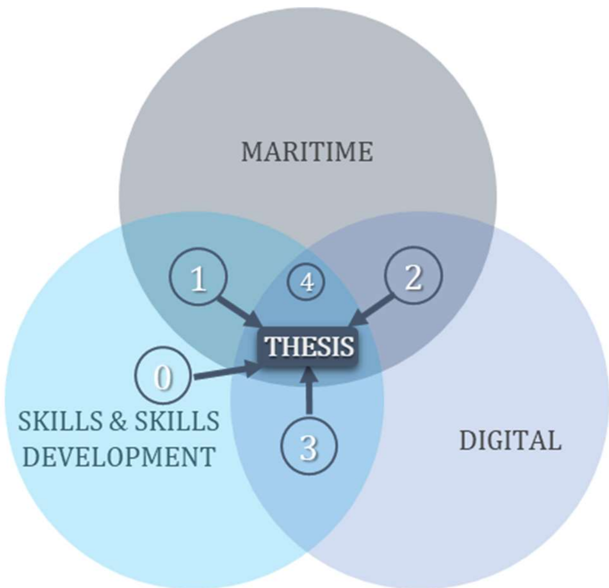


Figure 63. Authors' contributions area

The authors hope to have enriched the current academic material about the digital skills development in the maritime sector. What can be found in this thesis are: a consistent literature review on the specific research field, the presence of relevant maritime case studies and the proposition of three validated and coordinated models.

After having summarized the thesis itself and the benefits provided by the models, it became necessary to identify some limitations through a critical thinking.

First, the analysis, consisting in a literature review and case studies, has been conducted in a qualitative rather than quantitative way. The lack of data could leave some doubts about the models' generation.

Secondly, the models' validation consisted in other interviews, but it is lacking in terms of practical validation into a real working environment.

Third and last constraint, despite the attempt to direct any kind of scenario, the Employees Development Map is not able to manage very specific and particular situations, considering only nine employees' profiles.

These limitations are a normal legacy for this kind of research. Being the authors' contribution directed to a very specific and relatively new research field, an initial lack of practical assessment was forecasted from the beginning.

7.3 FUTURE RESEARCH

After having assessed what has been given to the academic environment, it is dutiful to understand what is going to be added to this research. This thesis aims to provide one of the first building blocks of the maritime digital skills development field. The proposed models need to find practical validation to be fully compatible with actual maritime realities, but it can be flexibly tailored on other comparable industrial contexts. Despite this, the maritime sector needs a deeper academic relevance in this direction, in order to help small and medium maritime realities to take advantage from the digital era, instead of being jeopardized by it.

8. APPENDIX

8.1 COMBINATIONS TABLES

8.1.1 Web of Science

AREA	COMBINATION	TOPIC	DOCUMENT TYPE: ARTICLE	SUBJECT AREA FILTER	LANGUAGE: ENGLISH	YEAR
0	Skills development	84746	60016	16351	14602	1047
0	skills enhancement	3786	2721	676	652	29
0	Competence development	37223	27507	7100	5870	476
0	Skills training	778902	57807	14876	13498	561
1	maritime industry skills	73	38	38	38	13
1	shipbuilding skills	38	18	9	8	4
1	naval industry skills	15	4	2	2	2
1	maritime industry competences	39	9	9	9	8
1	shipbuilding competences	14	14	14	14	3
1	naval industry competences	5	3	3	3	3
1	maritime skills development	132	68	53	51	51
1	maritime training	1098	564	336	313	146
1	shipbuilding skills development	9	9	9	9	9
1	shipbuilding training	75	51	45	39	38
2	digital maritime industry	334	167	72	61	25
2	digital shipbuilding	69	38	24	19	16
2	digital naval industry	311	121	32	30	30
2	industry 4.0 maritime	14	9	9	9	9
2	industry 4.0 shipbuilding	11	11	11	11	11
2	industry 4.0 naval	6	6	6	6	6
2	internet of things maritime	44	31	31	29	16
2	internet of things shipbuilding	9	9	9	9	9
2	internet of things naval	1	1	1	1	1
2	virtual reality maritime	40	42	42	42	9
2	virtual reality shipbuilding	25	25	25	25	25
2	virtual reality naval	56	36	8	7	6
2	augmented reality maritime	21	22	22	22	6
2	augmented reality shipbuilding	11	11	11	11	11
2	augmented reality naval	17	6	6	6	3
2	big data maritime	278	214	41	35	35
2	big data shipbuilding	14	14	14	14	14
2	big data naval	158	78	17	16	16
2	cloud computing maritime	1054	917	143	143	16
2	cloud shipbuilding	19	19	19	19	19

2	cloud computing naval	130	91	14	14	14
2	real time maritime	1037	484	185	181	90
2	real time shipbuilding	79	72	23	23	18
2	real time naval	648	267	45	43	21
2	simulation maritime	2489	1585	451	445	155
2	simulation shipbuilding	334	202	67	64	51
2	simulation naval	1582	891	236	232	146
2	simulation maritime sector	63	57	49	45	38
2	simulation naval sector	23	23	23	23	23
2	simulation marine sector	193	161	80	78	36
2	vr maritime	10	5	5	5	4
2	vr naval	1	1	1	1	1
2	vr shipbuilding	16	14	9	6	2
2	ar maritime	51	46	39	34	29
2	ar naval	9	9	9	9	9
2	ar shipbuilding	58	36	8	7	7
2	iot maritime	28	25	17	14	8
2	iot naval	4	4	4	4	4
2	iot shipbuilding	1	1	1	1	1
2	Additive manufacturing shipbuilding	8	8	8	8	8
2	additive manufacturing maritime	5	5	5	5	5
2	additive manufacturing naval	23	23	23	23	23
2	artificial intelligence shipbuilding	11	11	11	11	11
2	artificial intelligence maritime	62	54	47	33	28
2	artificial intelligence naval	26	26	26	26	26
2	Shipbuilding 4.0	13	13	13	13	13
2	Shipyard 4.0	22	22	22	22	22
2	Shipping 4.0	252	209	65	64	64
2	Naval 4.0	37	37	37	37	37
2	Maritime 4.0	80	49	28	28	23
2	Smart Yards	42	42	42	42	42
2	Smart shipbuilding	13	13	13	13	13
3	Digital skills development	3095	1612	752	593	466
3	digital skills enhancement	108	45	45	45	28
3	digital competences development	1098	548	303	161	30
3	digital skills training	1855	1030	445	327	55
3	industry 4.0 skills development	108	87	67	56	45
3	industry 4.0 skills enhancement	5	5	5	5	5
3	industry 4.0 competences development	53	15	15	15	15
3	industry 4.0 skills training	53	19	19	19	17
3	internet of things skills development	128	42	42	42	42
3	Internet of things training	55	35	33	24	19
3	Virtual reality skills development	1051	577	188	178	66
3	Virtual reality training	3016	2064	507	491	50
3	Augmented reality skills development	246	92	53	49	49
3	Augmented reality training	367	183	62	58	12

3	Big data skills development	2072	1360	504	474	272
3	big data training	1413	918	322	301	13
3	cloud computing skills development	321	172	62	56	56
3	cloud computing training	171	89	39	36	36
3	real time skills development	1731	908	281	265	113
3	real time training	1911	1201	373	355	36
3	simulation skills development	3873	2579	806	761	269
3	simulation training	8159	6061	1873	1797	70
3	ar skills development	147	70	24	24	24
3	vr skills development	282	165	61	59	59
3	iot skills development	56	13	12	12	12
3	ar training	139	69	29	29	29
3	vr training	904	641	155	151	16
3	iot training	29	19	19	19	7
3	Additive manufacturing skills development	28	24	24	23	19
3	Additive manufacturing training	2016	1940	234	133	80
3	Artificial intelligence skills development	277	254	124	90	16
3	Artificial intelligence training	4950	2654	2434	1457	1243
4	digital skills development maritime	1	1	1	1	1
4	digital skills maritime	6	6	6	6	3
4	digital training maritime	24	17	17	17	9
4	digital competences maritime	1	1	1	1	0
4	digital skills development shipbuilding	0	0	0	0	0
4	digital skills shipbuilding	1	1	1	1	1
4	digital training shipbuilding	1	1	1	1	1
4	digital competences shipbuilding	2	2	2	2	2
4	digital skills naval	5	5	5	5	2
4	digital skills development naval	2	2	2	2	1
4	digital training naval	17	6	6	6	6
4	digital competences naval	4	4	4	4	4
4	digital capabilities maritime	35	35	35	35	35

8.1.2 Emerald

AREA	COMBINATION	ABSTRACT, TITLE, KEYWORDS	DOCUMENT TYPE: ARTICLE	YEAR
0	Skills development	114000	98134	5579
0	skills enhancement	13000	11005	890
0	Competence development	43000	36931	2521
0	Skills training	86000	75176	3927
1	maritime industry skills	1000	928	87
1	shipbuilding skills	873	388	30
1	naval industry skills	1000	56	35

1	maritime industry competences	466	147	45
1	shipbuilding competences	304	256	17
1	naval industry competences	356	199	14
1	maritime skills development	1000	996	109
1	maritime training	1000	456	127
1	shipbuilding skills development	814	89	28
1	shipbuilding training	1000	731	29
2	digital maritime industry	596	503	55
2	digital shipbuilding	251	145	15
2	digital naval industry	624	547	28
2	industry 4.0 maritime	1000	261	166
2	industry 4.0 shipbuilding	821	490	54
2	industry 4.0 naval	1000	77	69
2	internet of things maritime	289	146	37
2	internet of things shipbuilding	85	45	8
2	internet of things naval	249	178	38
2	virtual reality maritime	199	145	18
2	virtual reality shipbuilding	93	27	7
2	virtual reality naval	174	65	21
2	augmented reality maritime	84	36	6
2	augmented reality shipbuilding	58	35	11
2	augmented reality naval	100	67	15
2	big data maritime	1000	888	201
2	big data shipbuilding	721	577	59
2	big data naval	2000	1718	112
2	cloud computing maritime	199	156	30
2	cloud shipbuilding	83	64	18
2	cloud computing naval	215	181	19
2	real time maritime	2000	1633	158
2	real time shipbuilding	1000	456	44
2	real time naval	2000	1235	95
2	simulation maritime	634	527	77
2	simulation shipbuilding	248	226	25
2	simulation naval	865	754	64
2	simulation maritime sector	378	111	53
2	simulation naval sector	261	178	29
2	simulation marine sector	456	367	32
2	vr maritime	31	26	17
2	vr naval	17	11	0
2	vr shipbuilding	14	11	1
2	ar maritime	168	77	14
2	ar naval	226	77	10
2	ar shipbuilding	89	65	10
2	iot maritime	41	25	10
2	iot naval	16	11	7
2	iot shipbuilding	7	6	3

2	Additive manufacturing shipbuilding	68	68	64
2	additive manufacturing maritime	102	67	53
2	additive manufacturing naval	140	33	29
2	artificial intelligence shipbuilding	99	49	32
2	artificial intelligence maritime	203	135	34
2	artificial intelligence naval	265	187	23
2	Shipbuilding 4.0	908	618	54
2	Shipyard 4.0	343	222	14
2	Shipping 4.0	12000	11329	535
2	Naval 4.0	2000	773	122
2	Maritime 4.0	1000	687	209
2	Smart Yards	292	212	16
2	Smart shipbuilding	139	57	10
3	Digital skills development	19000	15935	1717
3	digital skills enhancement	2000	578	257
3	digital competences development	6000	5365	1185
3	digital skills training	13000	10934	1023
3	industry 4.0 skills development	34000	7155	3029
3	industry 4.0 skills enhancement	4000	2940	527
3	industry 4.0 competences development	14000	12667	1989
3	industry 4.0 skills training	2300	2278	1886
3	internet of things skills development	13000	10433	988
3	Internet of things training	9000	986	552
3	Virtual reality skills development	7000	6043	486
3	Virtual reality training	5000	4227	281
3	Augmented reality skills development	3000	2713	315
3	Augmented reality training	2000	1966	179
3	Big data skills development	64000	53986	5152
3	big data training	45000	38431	3319
3	cloud computing skills development	4000	3368	466
3	cloud computing training	3000	2375	311
3	real time skills development	73000	61321	4044
3	real time training	54000	46254	2602
3	simulation skills development	10000	8878	758
3	simulation training	7000	6652	483
3	ar skills development	3000	2730	230
3	vr skills development	482	363	116
3	iot skills development	448	167	131
3	ar training	2000	205	104
3	vr training	338	252	22
3	iot training	254	114	59
3	Additive manufacturing skills development	1000	568	311
3	Additive manufacturing training	1000	564	335
3	Artificial intelligence skills development	4000	2678	870
3	Artificial intelligence training	5000	3457	1271

4	digital skills development maritime	243	130	81
4	digital skills maritime	248	127	81
4	digital training maritime	341	167	85
4	digital competences maritime	93	57	45
4	digital skills development shipbuilding	141	137	26
4	digital skills shipbuilding	141	77	26
4	digital training shipbuilding	160	126	26
4	digital competences shipbuilding	54	45	14
4	digital skills naval	238	99	46
4	digital skills development naval	230	48	46
4	digital training naval	367	66	56
4	digital competences naval	78	48	21
4	digital capabilities maritime	359	278	43

8.1.3 Scopus

AREA	COMBINATION	ABSTRACT, TITLE, KEYWORDS	KEYWORDS FILTER	DOCUMENT TYPE: ARTICLE	ENGLISH	SUBJECT AREA FILTER	YEAR
0	Skills development	132384	1459	738	702	517	219
0	skills enhancement	5190	29	18	17	11	7
0	Competence development	61065	543	237	199	162	64
0	Skills training	109784	2396	1680	1556	586	225
1	maritime industry skills	168	99	24	23	22	13
1	shipbuilding skills	157	119	61	57	57	13
1	naval industry skills	85	NO	24	20	18	6
1	maritime industry competences	58	NO	24	23	22	17
1	shipbuilding competences	33	NO	15	13	13	5
1	naval industry competences	21	NO	3	2	2	1
1	maritime skills development	218	18	7	7	6	5
1	maritime training	1752	767	240	240	191	75
1	shipbuilding skills development	47	1	0	0	0	0
1	shipbuilding training	329	249	116	106	102	15
2	digital maritime industry	102	44	13	12	10	9
2	digital shipbuilding	237	193	75	63	63	16
2	digital naval industry	85	36	4	4	4	2
2	industry 4.0 maritime	9	NO	3	1	NO	1
2	industry 4.0 shipbuilding	18	16	4	3	3	3
2	industry 4.0 naval	11	11	1	0	0	0
2	internet of things maritime	81	NO	22	20	19	18
2	internet of things shipbuilding	19	NO	3	3	3	3
2	internet of things naval	15	NO	2	2	2	2
2	virtual reality maritime	121	NO	29	27	26	12

2	virtual reality shipbuilding	88	NO	40	39	39	9
2	virtual reality naval	191	NO	55	52	45	9
2	augmented reality maritime	40	NO	6	6	6	6
2	augmented reality shipbuilding	20	NO	7	7	6	6
2	augmented reality naval	41	NO	2	2	2	2
2	big data maritime	131	NO	40	37	36	36
2	big data shipbuilding	16	NO	2	2	2	2
2	big data naval	47	NO	5	4	4	4
2	cloud computing maritime	53	38	16	15	12	12
2	cloud shipbuilding	50	NO	18	16	16	9
2	cloud computing naval	11	NO	2	2	2	2
2	real time maritime	1176	440	118	114	80	59
2	real time shipbuilding	125	NO	46	39	36	16
2	real time naval	1227	625	164	153	129	30
2	simulation maritime	3597	91	33	32	28	22
2	simulation shipbuilding	1052	876	404	373	365	164
2	simulation naval	3891	14	5	5	5	3
2	simulation maritime sector	23	23	9	8	7	6
2	simulation naval sector	6	6	4	4	4	4
2	simulation marine sector	21	21	14	14	3	3
2	vr maritime	26	26	13	12	10	6
2	vr naval	41	41	10	10	8	3
2	vr shipbuilding	19	19	7	7	7	2
2	ar maritime	53	53	29	23	11	8
2	ar naval	84	84	41	33	8	3
2	ar shipbuilding	24	24	15	11	9	6
2	iot maritime	66	66	14	13	12	12
2	iot naval	19	19	2	2	2	1
2	iot shipbuilding	13	13	3	2	2	2
2	Additive manufacturing shipb.	20	20	7	4	4	3
2	additive manufacturing maritime	7	7	3	3	3	1
2	additive manufacturing naval	35	35	8	8	8	8
2	artificial intelligence shipbuilding	67	67	24	24	24	3
2	artificial intelligence maritime	446	89	22	22	19	15
2	artificial intelligence naval	251	79	17	16	13	5
2	Shipping 4.0	5	5	1	1	1	0
2	Shipbuilding 4.0	3	3	1	1	1	1
2	Shipyard 4.0	10	10	4	3	3	3
2	Naval 4.0	0	0	0	0	0	0
2	Maritime 4.0	1	1	0	0	0	0
2	Smart Yards	6	6	1	1	1	1
2	Smart shipbuilding	2	2	1	0	0	0
3	Digital skills development	3969	132	57	53	46	32
3	digital skills enhancement	200	23	11	11	5	5
3	digital competences development	1209	39	16	12	11	8
3	digital skills training	2216	566	223	204	135	81

3	industry 4.0 skills development	106	10	2	2	2	2
3	industry 4.0 skills enhancement	6	NO	2	2	2	2
3	industry 4.0 competences dev.	57	51	16	9	8	8
3	industry 4.0 skills training	63	49	16	15	14	14
3	internet of things skills dev.	145	6	2	2	2	2
3	Internet of things training	885	749	238	220	209	183
3	Virtual reality skills development	1664	138	63	60	33	16
3	Virtual reality training	13849	12711	4981	4647	2352	556
3	Augmented reality skills dev.	299	32	10	9	8	8
3	Augmented reality training	1913	475	87	85	65	20
3	Big data skills development	248	19	9	9	8	8
3	big data training	2819	1335	388	348	291	218
3	cloud computing skills dev.	177	7	1	1	1	1
3	cloud computing training	1181	362	85	80	77	48
3	real time skills development	1315	74	38	37	22	9
3	real time training	20720	5056	2038	1882	1357	390
3	simulation skills development	5482	413	261	253	131	50
3	simulation training	66327	19155	10852	10113	4465	1161
3	ar skills development	19	19	8	6	4	4
3	vr skills development	39	39	21	21	12	11
3	iot skills development	2	2	0	0	0	0
3	ar training	2191	584	144	135	118	88
3	vr training	708	567	297	284	110	44
3	iot training	5	5	2	2	2	2
3	Additive manufacturing skills dev.	50	50	23	22	19	8
3	Additive manufacturing training	217	156	65	59	45	33
3	Artificial intelligence skills dev.	62	62	16	15	10	4
3	Artificial intelligence training	22460	20114	7031	6688	4831	849
4	digital skills dev. maritime	4	4	2	2	2	2
4	digital skills maritime	11	11	5	4	3	3
4	digital training maritime	40	40	10	8	6	4
4	digital competences maritime	5	5	1	1	1	1
4	digital skills dev. shipbuilding	2	2	2	2	2	2
4	digital skills shipbuilding	4	4	4	3	3	3
4	digital training shipbuilding	6	6	4	3	3	2
4	digital competences shipbuilding	1	1	0	0	0	0
4	digital skills naval	15	15	4	4	3	3
4	digital skills development naval	8	8	2	2	2	1
4	digital training naval	40	40	17	16	15	5
4	digital competences naval	4	4	1	0	0	
4	digital capabilities maritime	71	71	21	21	17	8

8.1.4 ScienceDirect

AREA	COMBINATION	ABSTRACT, TITLE, KEYWORDS	DOCUMENT TYPE: ARTICLE	YEAR
0	Skills development	193	160	40
0	skills enhancement	96	81	23
0	Competence development	63	56	14
0	Skills training	349	294	80
1	maritime industry skills	19	14	6
1	shipbuilding skills	11	9	5
1	naval industry skills	5	4	1
1	maritime industry competences	5	5	4
1	shipbuilding competences	1	0	0
1	naval industry competences	1	1	1
1	maritime skills development	20	17	10
1	maritime training	40	29	14
1	shipbuilding skills development	0	0	0
1	shipbuilding training	5	5	2
2	digital maritime industry	8	6	6
2	digital shipbuilding	17	17	10
2	digital naval industry	4	2	1
2	industry 4.0 maritime	1	1	1
2	industry 4.0 shipbuilding	1	0	0
2	industry 4.0 naval	2	2	2
2	internet of things maritime	2	2	1
2	internet of things shipbuilding	0	0	0
2	internet of things naval	0	0	0
2	virtual reality maritime	5	4	1
2	virtual reality shipbuilding	4	3	1
2	virtual reality naval	3	2	0
2	augmented reality maritime	5	5	2
2	augmented reality shipbuilding	0	0	0
2	augmented reality naval	1	1	1
2	big data maritime	21	17	12
2	big data shipbuilding	1	1	1
2	big data naval	4	4	2
2	cloud computing maritime	2	2	1
2	cloud shipbuilding	0	0	0
2	cloud computing naval	2	2	0
2	real time maritime	168	156	73
2	real time shipbuilding	23	22	10
2	real time naval	64	60	16
2	simulation maritime	437	409	164
2	simulation shipbuilding	64	62	29
2	simulation naval	198	186	58

2	simulation maritime sector	10	10	8
2	simulation naval sector	4	3	3
2	simulation marine sector	46	40	20
2	vr maritime	2	1	0
2	vr naval	1	1	1
2	vr shipbuilding	1	1	1
2	ar maritime	4	3	1
2	ar naval	12	12	4
2	ar shipbuilding	0	0	0
2	iot maritime	1	1	1
2	iot naval	0	0	0
2	iot shipbuilding	1	1	0
2	Additive manufacturing shipbuilding	3	3	3
2	additive manufacturing maritime	1	1	1
2	additive manufacturing naval	5	5	4
2	artificial intelligence shipbuilding	3	3	0
2	artificial intelligence maritime	8	7	3
2	artificial intelligence naval	6	4	1
2	Shipbuilding 4.0	3	3	2
2	Shipyard 4.0	3	3	3
2	Shipping 4.0	8	7	4
2	Naval 4.0	7	7	3
2	Maritime 4.0	12	9	1
2	Smart Yards	5	4	2
2	Smart shipbuilding	2	2	2
3	Digital skills development	324	261	89
3	digital skills enhancement	159	136	45
3	digital competences development	82	77	33
3	digital skills training	89	63	56
3	industry 4.0 skills development	26	25	19
3	industry 4.0 skills enhancement	13	12	10
3	industry 4.0 competences development	9	9	8
3	industry 4.0 skills training	17	17	16
3	internet of things skills development	13	11	7
3	Internet of things training	73	65	56
3	Virtual reality skills development	136	103	42
3	Virtual reality training	1215	892	261
3	Augmented reality skills development	30	26	9
3	Augmented reality training	187	151	50
3	Big data skills development	47	38	21
3	big data training	430	344	213
3	cloud computing skills development	12	9	5
3	cloud computing training	95	89	59
3	real time skills development	291	232	80
3	real time training	3723	3528	1046
3	simulation skills development	847	670	197

3	simulation training	130	115	43
3	ar skills development	21	17	9
3	vr skills development	39	34	11
3	iot skills development	5	2	2
3	ar training	302	270	79
3	vr training	433	360	128
3	iot training	61	57	46
3	Additive manufacturing skills development	7	4	3
3	Additive manufacturing training	39	29	20
3	Artificial intelligence skills development	47	39	14
3	Artificial intelligence training	797	702	283
4	digital skills development maritime	0	0	0
4	digital skills maritime	0	0	0
4	digital training maritime	0	0	0
4	digital competences maritime	0	0	0
4	digital skills development shipbuilding	0	0	0
4	digital skills shipbuilding	1	1	0
4	digital training shipbuilding	0	0	0
4	digital competences shipbuilding	1	1	1
4	digital skills naval	0	0	0
4	digital skills development naval	0	0	0
4	digital training naval	1	1	1
4	digital competences naval	0	0	0
4	digital capabilities maritime	1	1	0

8.2 CASE STUDIES INTERVIEW

Q1) GENERAL INFORMATION

- Role and functional area;
- 2018 company turnover;
- Nr of employees, roles distribution and background;
- How long have you been in this company?
- How long have you been in this sector?

Q2) TECHNOLOGY INVESTIGATION

- Cloud Computing;
- Database Management/BI;
- IoT;
- AI;
- AR;
- VR;
- Simulators;
- Additive Manufacturing;
- Others.

Can you give us a **prioritization** of these technologies? Which are the most important for your Company?

For each technology:

- If it was used:
  - Since when?
  - Why did you opt for it?
  - Did you meet the expectations? Which benefits did you had?
  - Did you reach the objectives? Which criticalities did you meet, if you met?
  - Do you have any Cost data? Which is the ROI?

- If it was not used:
  - Which benefits do you think it can bring?
  - Why did you discard it?
  - Room for the usage in the future?

Q3) SKILLS DEVELOPMENT

- How did you enable skills development? (e.g. training)

- Can you provide us the specification of the methods applied?
- Why did you opt for this method?
- Did you meet the expectations? Benefits reached? Criticalities met?
- Why did you discard the other methods?
- If you opted for more than one, in which sequence and why?

Q4. MARITIME SECTOR

- How do you perceive these trends in this sector? Is there a gap in your opinion?
- How did the project Lincoln impact on your embedded skills?

8.3 VALIDATION INTERVIEW

8.3.1 Skills Development Matrix Validation

1) Basing on the first interview, we noticed that Companies develop the skills through CLASSIC TRAINING + E-LEARNING and COLLABORATION with partners and providers. Considering all the possible other ways, depending on which criteria a company should choose one rather than the other?

Here is all the ways to develop skills that we extrapolated:

- Classic Training;
- One-To-One Training;
- E-Learning;
- Knowledge Sharing Platform;
- Self-Learning;
- Collaboration;
- New Employments;
- Outsourcing.

2) These are the criteria we found, which ones are more impacting for you? (choose 5 of them and give them a prioritization) and especially why?

Criteria:

- Company size/number of employees;
- Time available to embed the skills;
- Skill specificity (standard or specific task);
- Tool maturity;
- Time necessary to acquire the skill;
- Employees digital readiness;
- Digital benefits awareness;
- Employees workload;
- Employees resistance;
- Employees awareness (perceived benefits of the skills).

3) From that roster, basing on the interviews, we identified the nr of employees and the specificity of the skill to train as more correlated. Could you please fulfil this matrix with the methods?

	STANDARD TASK	SPECIFIC TASK	VERY SPECIFIC AND COMPLEX TASK
SMALL COMPANY			
MEDIUM COMPANY			
BIG COMPANY			

Methods that have to be inserted:

- Classic Training;
- One-To-One Training;
- E-Learning;
- Mixed Solution (half digital, half classic training);
- Knowledge Sharing Platform;
- Self-Learning;
- Collaboration;
- New Employments;
- Outsourcing.

4) Can you explain us the difference between a standard and very specific skill/task?

5) Do you think E-Learning will completely substitute Classic Training in the future?

8.3.2 S.A.I.L. Model Validation

From the interviews, we identified 4 stages of a technology implementation within a company, and we defined the **S.A.I.L.** model

6) Imagine that you are a traditional company, and you wake up knowing about industry 4.0, that you never heard before. How would you approach a single technology until the full implementation?

Do you agree with this model? (The S.A.I.L. Model was shown)

7) Considering these methods of skills development (in which we insert EXHIBITION CENTRES and FREE PROJECTS as way to develop for free) how would

you use them? Which ones would you apply before, and which one later? Can you provide us an order of application depending on the stage you are?

METHODS:

- Free projects;
- Exhibition Centres,
- Outsourcing;
- Open Sources;
- New Recruitments;
- One-to-one training
- Classic Training;
- Collaboration;
- E-Learning;
- Knowledge Platforms.

8.3.3 Employees Development Map Validation

8) Imagine you are a company and you want to implement a new solution: you have to develop a specific skill. How would you treat the different employees? How would you distinguish them in terms of skills development before starting the industry 4.0 training?

9) Would you differentiate them in terms of digital capabilities? If yes, do you think is reasonable to divide them in 3 standard users? (Zero User, Basic User, Independent User).

10) Would you differentiate them in terms of experience in the maritime sector? If yes how would you divide them creating 3 classes?

11) Before starting a technology implementation (e.g. Simulation), would you consider useful to make a presentation regarding the benefits introduced by the technology to all the employees? It would increase the motivation and their belief on the new tool?

12) Do you think is better to wait that an employee is digitally independent and with a good maritime experience before training him or her on an industry 4.0 technology? (e.g. before teaching how to use artificial intelligence the employee has to attend a course and learn how to use pc and how maritime sector works).

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10. ACKNOWLEDGMENTS

We would like to thank Monica Rossi and Lucia Ramundo for the great opportunity of take part to a very interesting project in cooperation with maritime companies. The chance to meet maritime industry experts, participate at the WMF 2019 was very exciting and fruitful for the thesis and for ourselves. We also have to thank them for supporting and guiding us through this project. Their help in apply the right methodology to the thesis development was very important to approach problems in an effective and structured manner.

We would like to thank also all the interviewees; the importance and the contribution that they gave to this project was fundamental.
A special thanks to the interviewees of the first two companies, who dedicated us a further interview to validate our models. Without your precious collaboration this thesis would have been surely less meaningful.

Last but absolutely not least, we would like to thank Politecnico di Milano for having taught us that sacrifices are always paid off. Even if our university path is going to conclusion, we will always keep with us part of this experience during our working life. Thank you all.

Andrea and Alessio

Ringrazio la mia famiglia e tutti i miei amici per essermi stati vicini ed avermi supportato in questo percorso, Grazie.

Andrea

È anzitutto doveroso, da parte mia, ringraziare il mio compagno di tesi Andrea, con cui ho condiviso questo lungo e tormentato viaggio chiamato tesi. Un collega, un amico, ma prima di tutto un uomo vero che sa assumersi le proprie responsabilità.

Ringrazio la mia famiglia. Grazie mamma e papà per avermi reso l'uomo "non più studente" che sono oggi. I valori da voi trasmetti sono impossibili da contare. Grazie a mio fratello Mattia per lo smisurato e incontenibile affetto che mi trasmette. Per merito tuo vivo con la costante consapevolezza di avere qualcuno sempre al mio fianco in qualunque difficoltà; sappi che dietro questa mia parvenza fredda si cela un sentimento di fratellanza uguale e inverso. Grazie a Simona, sempre più parte di questa cerchia, per aver reso mio fratello una persona più felice.

Ringrazio poi tutta la mia famiglia estesa, mia nonna Anna e i miei nonni non più presenti, i miei zii e "cuginetti" (ormai più alti di me per distacco). Grazie a tutti per avermi accompagnato nella mia crescita ed avermi concesso la fortuna di avere una famiglia vera e completa; mi avete lasciato innumerevoli ricordi indelebili legati alla mia città natìa. Un grazie particolare sulla mia tesi la merita mio nonno Gianni, per avermi instillato, in maniera forse anche troppo insistente, l'interesse per il sapere.

Amici, non mi sono dimenticato di voi, tranquilli. Ringrazio le mie prime vere amicizie Francesco, Filippo, Alessandro, Luca e Lorenzo per avermi fatto conoscere il sentimento dell'amicizia. Un grazie particolare a Riccardo per la sua concretezza. Ringrazio anche i miei amici del liceo Mattia e Giuseppe per avermi fatto trascorrere momenti scolastici difficili da dimenticare e certo poco consoni ad una sfera prettamente scolastica. Grazie anche a Micol per la sua presenza costante. Ringrazio tutti i miei più cari amici attuali con cui ho condiviso e continuo a condividere grandi momenti di amicizia. Lorenzo, Andrea, Luca, Giambattista vi garantisco che su di me potrete sempre contare. Discorso analogo e certo non meno sentito va alla crew di Tibaldi: Nicolò, Giovanni, Stefano e Francesco. Grazie a voi ho provato la sensazione di avere un secondo luogo in cui sentirmi a casa. Doveroso ringraziare Giovanni per la sua generosità sempre (o quasi) mostrata nei miei confronti. Ringrazio infine i miei compagni di università Luca, Francesca, Marwa, Chiara, Serena, Davide e Claudio. Siete persone eccezionali.
Avete tutti contribuito, seppur in diversa misura, al raggiungimento di questo traguardo rendendo questi 24 anni di percorso certamente più gradevoli. Grazie!

Ultima per ordine ma non per importanza, ringrazio la mia fedele compagna di sofferenze a tinte nerazzurre, per avermi trasmesso la virtù della pazienza e della fedeltà ed avermi insegnato che ciò che conta veramente non sono i risultati, quanto la passione con cui si vive per raggiungerli. Amala.

Alessio