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Identification and Weighting of Criteria for Digital Transformation Projects Selection and Prioritization in the Project Portfolio Management Context

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Table of Contents

Introduction 5

1 Literature Review 8

1.1 Project Portfolio Management 8

1.1.1 Definition and Process Structure 8

1.1.2 Strategic Impact 11

1.1.3 Goals and Performance Domains 13

1.1.4 Main Challenges Explored in Literature 15

1.2 Selection and Prioritization Process in Project Portfolio Management 18

1.2.1 Process Overview 18

1.2.2 Critical Success Factors 22

1.2.3 Multi-Criteria Decision-Making Models for Projects Selection and Prioritization 35

1.3 Digital Transformation Projects 38

1.3.1 Digital Transformation Objectives and Project Portfolio Management 38

1.3.2 Critical Success Factors for Digital Transformation Projects Selection 41

2 Methodology 46

2.1 Academic Literature Review and Criteria Identification 46

2.2 Analytical Hierarchy Process (AHP) Method and Criteria Weighting 47

2.3 Practical application of the AHP method 51

3 Application of the AHP method 55

3.1 Criteria identification from Critical Success Factors in academic literature 55

3.2 Success Dimensions and Hierarchy Design 58

3.3 Qualitative priorities identified based on occurrence in academic research 63

3.4 Professionals Identification and Data Collection 66

3.5 Weights assignment and main results 68

4 Discussion of results 76
4.1 Reflections on main findings and comparisons 76
4.2 Limitations and future research 83
Conclusions 85
Bibliography 86
Sitography 93

Table of Figures

Figure 1. Portfolio management ongoing lifecycle (Project Management Institute., 2017) 10
Figure 2. Strategic role of portfolio management (Project Management Institute., 2017) 12
Figure 3. The context's impact on components selection and prioritization (ISO, 2015) 19
Figure 4. Funneling selection process screening with different criteria (Englund & Graham, 1999) 20
Figure 5. Model on the relationship between strategic orientation, Project Portfolio Success and Business Success (Meskendahl, 2010). 23
Figure 6. Objectives and criteria decomposition in AHP method (K H Chua et al., 1999) 38
Figure 7. AHP method characteristics under complex contexts (Vidal et al., 2015)..... 48
Figure 8. AHP method steps (Vargas et al., 1990) 48
Figure 9. Hierarchy structure of the AHP method (Zahedi, 1986) 49
Figure 10. Fundamental scale of AHP method (Saaty, 2004) 50
Figure 11. AHP hierarchy design 59
Figure 12. Industries reached in the data collection 67
Figure 13. Resulted weights of success dimensions 68
Figure 14. Resulted weights for Organization dimension's criteria 69
Figure 15. Resulted weights of People dimension's criteria 70
Figure 16. Resulted weights of the Project dimension's criteria 71
Figure 17. Resulted wieghts of the Uncertainty dimension's criteria 72
Figure 18. Calculation of overall weight in AHP hierarchy 73
Figure 19. Potential application of two-dimensional evaluation 82

Introduction

To transform the business model gaining flexibility and efficiency in business performance, companies in different sectors are implementing digital transformation initiatives (Anisic et al., 2020). The assessment and selection of projects in this area is fundamental due to the complexity and ever-changing landscape that characterize the potential technological development of companies (Tavana et al., 2013).

In this complex context, the are many challenges to face toward the results achievement and balancing what is feasible and what is essential is paramount to the fulfillment of strategic objectives. The Project Portfolio Management becomes then a fundamental tool for organizations to build a structured approach to balance and manage heterogenous initiatives toward the strategy success (Project Management Institute., 2017).

Portfolio Management is a central topic for organizations since it affects many critical areas that are challenging and problematic like strategic alignment, project selection and prioritization and resource allocation among projects. Because of the criticality of all these areas, project portfolio management can be seen as a multifaceted concept in which many challenges can arise (R. G. Cooper et al., 1998). Understanding and measure portfolio management practices performance is in fact a vital question to reach effectiveness and efficiency in results achievement. While assessing its performance among different industries, R. G. Cooper et al. (1998) identifies that the more relevant shortcomings are in the area of selecting the right number of projects given scarce resource and of balancing the portfolio of projects in terms of long-term and short-term objectives, high and low risk and so on.

As a consequence, the projects selection and prioritization problem of project portfolio management is an essential issue that companies need to undertake, since the effective combination of initiatives and their corresponding performance foster strategic alignment and shareholders' value, while balancing resource allocation and risks. The increasing uncertainty of the business environment creates a strong challenge to this activity since managers have to take decisions under non-deterministic conditions. In this volatile context, only through the definition of accurate criteria and selection factors, an organization can achieve its objectives (Costantino et al., 2015).

The criteria and indicators on which the selection and prioritization of projects is subject to ambiguity due to the high number of stakeholders involved and the consequent definition of success and priorities for each actor (Belassi & Tukel, 1996). Furthermore, the project prioritization and selection is affected by the complex interdependencies between initiatives and the multi-factor and conflicting objectives on which the decision-making process should be based (Pajares & López, 2014).

Many project portfolio selection models have been developed in literature trying to identify the best criteria that should be established in organizations to prioritize and implement the suitable project portfolio to address strategic objectives and generate value for shareholders, customers and employees. However, the proposed approaches are not always successful because of poorly selected criteria and overlooking of the complex interdependencies among projects (Bai et al., 2021). Thus, there is still not an agreement on which should be the most effective criteria to select and prioritize projects and the selection guidelines should receive a major attention from academic and professional world (Kaiser et al., 2015).

This research aims at (1) identifying a set of criteria and (2) investigating the corresponding weights to be considered in a multi-criteria decision-making method that can help managers as a support tool in the selection and prioritization projects. Particularly, the analysis is focused on the selection and prioritization of digital transformation projects due to the complexity caused by multiple and conflicting objectives and rapid growth of digital initiatives (Isikli et al., 2018).

In the first chapter, a comprehensive review of the relevant literature is performed. The review explores the project portfolio management definition, goals and field of application while highlighting the major challenges. Consequently, the focus is applied on the selection and prioritization issue in project portfolio management investigating the different solutions proposed in the literature. Finally, this aspect is particularly analyzed for digital transformation projects through the review of the most recent studies.

The second chapter highlights the methodologies used to conduct the research, identify the criteria and assign the corresponding weights. In particular the literature review process is explained for the identification of the criteria. Then the AHP method is introduced for the weight calculation, involving 12 professionals to perform the necessary pairwise comparisons.

The third chapter explains the practical application of the AHP method starting from the design of the hierarchy to the involvement of a panel of experts, concluding with the actual calculation of the corresponding weights thanks to the eigenvalue method application.

In the final chapter, the main results of the study are discussed and compared with the previous findings in academic literature, while limitations and suggestions for future research and implementations of resulted criteria and weights are proposed.

1 Literature Review

1.1 Project Portfolio Management

1.1.1 Definition and Process Structure

A portfolio can be defined as a collection of programs, projects, operations and subsidiary portfolios that are managed together to achieve strategic objectives. These components can present interdependencies or be independent, have related or unrelated objectives, but they compete for the same limited resources. The presence of components and the corresponding assigned resources depend on the organization's strategy and so companies need to analyze their needs and circumstances to effectively balance and optimize their portfolio of initiatives. The project portfolio management is a dynamic activity that allows a centralized management of initiatives to achieve organization's objectives and to align the portfolio and its components to the organizational strategy (Project Management Institute., 2017). The vital importance of Project Portfolio Management lies in fact in its impacts, highlighted by Cooper et al. (2002) in its best practices studies:

- Maximization of value, financial returns and achievement of financial goals
- Maintenance of business competitive position
- Proper and efficient allocation of resources
- Alignment of projects to organization's strategy
- Focus only on relevant projects, given the limits imposed by scarce resources
- Balance of projects to pursue both long-term and short-term objectives
- Communication of priorities both vertically and horizontally to provide clear guidance for projects selection

Given the several paramount areas of impact, project portfolio management has been developed in global standards and frameworks receiving a stable attention from the management research, in order to develop and formalize best practice to help managers prioritize projects and achieve strategic objectives (Martinsuo, 2013).

For clarity purposes, it is important to establish and define the differences and the relationships between a portfolio and its components. The Standard for portfolio management (Project Management Institute, 2017) defines the characteristics of the

different components. While portfolio management focuses on delivering value aligned with strategic objective through the allocation of resources based on organizational capacity and the balance of conflicting demands among components, the aim of its subsidiaries (projects, programs and operations) is different. Program management aims at managing in a coordinated manner a group of subsidiary projects to achieve business benefits and outcomes that could not be reached if managed separately. Project management is instead a temporary endeavor focused on the realization of specific deliverables to the organization within the intended cost and schedule. Finally, operations management is responsible for the planning, coordination and execution of day-to-day activities which can support the projects portfolio and can be linked and aligned itself to the organization's strategy through portfolio management.

Given the complexity of the numerous components, a portfolio needs to be managed in a continuous manner in order to be adaptable and flexible for the constantly changing influences affecting all the components, which can arise internally or externally to the organization. The dynamic nature of the process, following the Standard for portfolio management (Project Management Institute., 2017), can be described as an ongoing lifecycle that focuses on the four main stages, detailed below, that are also adopted in the project management best practices:

1. Initiation: validation of strategic goals; identification of portfolio components in scope; definition of long-term roadmap with financial goals and assessment metrics; stakeholders' definition and role; communication and governance.
2. Planning: identification of priorities and interdependencies among components; budgeting required for successful execution; analysis of resources required; agreement on metrics to measure success; confirmation of stakeholders accountability; identification of risks.
3. Execution: the deliverables of all components; management and resolution of risks; facilitation of components communication; reprioritization and change of components as needed; monitoring of benefits realization; management of portfolio assets and resources.
4. Optimization/Monitoring and Control: ongoing availability of resources; maximization of available conditions and opportunities; appropriation of lesson learned; monitoring and controlling to provide corrective actions if needed.

Despite the impression of the linearity of the process, these phases are not necessarily sequential but are usually characterized by a strong cyclicality. What is particular to portfolio management is the strong link between the initiation phase and the organization's strategic planning that is fundamental and preliminary to fulfill the strategic alignment objectives. However, organizations' priorities are likely to be reviewed and need to be included in the portfolio management activities.

In this way, the iterative characteristic of the process is concentrated also in the planning phase where the portfolio can be "refreshed" with addition, modification and reprioritization of components.

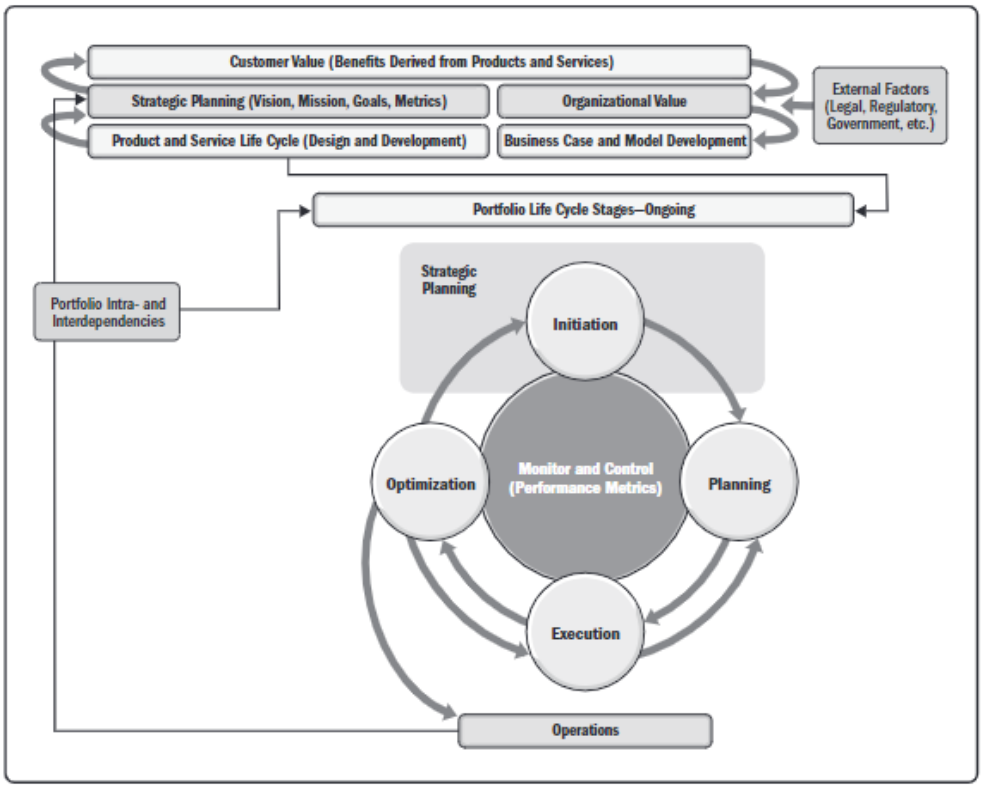

Figure 1. Portfolio management ongoing lifecycle (Project Management Institute., 2017)

A more structured, but always traditional, version of the portfolio management process is proposed by Wideman (2007), dividing the main necessary actions for the successful performance of the practice in ten steps grouped in five principal phases:

1. PREPARE: Portfolio setup and categorization; Identify Needs and Opportunities; Evaluate of Options, Select the work.
2. PLAN: Prioritize the work; Balance and optimize the portfolio.
3. EXECUTE: Authorize the work; Plan and execute.
4. HARVEST: Report on portfolio status, Improve the portfolio.

On the other hand, new untraditional concepts are causing a revolution in the way projects are organized and executed. The main example is the Agile project management method that shows completely different patterns in respect to the standards, since it is mainly focused on recurring activities called organizational routines. The Agile concept embrace the project environment as uncertain and ever-changing and relies on the iterative delivery of intermediate objectives rather than commit to the linear predictability of a sequence of steps from project initiation to finalization (Nerur & Balijepally, 2007). Advantages deriving from this method can be applied outside individual projects and aimed at the broader organizational environment that characterized the project portfolio management (Stettina & Hörz, 2015). From an interviews analysis involving 30 organizations, Stettina & Hörz, (2015) confirm that Agile routines at project level, like iterations reviews, are expanding toward the circumstantial fields of portfolio management. There is in fact more demand for interactions between strategy and operations, since at the moment the particular agile management framework is still not frequently applied at portfolio level. However, because of the high frequency of interactions and self-management of actors and agile teams, the practice of portfolio management will need to undertake several modifications to fit in this new concept and enable agility.

1.1.2 Strategic Impact

The standards underline the role of project portfolio management in the overall strategic direction of organizations. The strategic goals, policies as the specific actions to reach these objectives serve in fact as primary output for portfolio management. The links created between portfolios and strategy are fundamental to maximize the business value and to balance the use of resources in executing projects, program and operational activities. In this way portfolio management is able to enhance the right key business performance indicators to improve the overall societal value giving a holistic view of the company (Project Management Institute., 2017).

The efficient management of projects can be seen as a "powerful strategic weapon" to enhance economic value and competitive advantage. It affects different objectives set by the organization in different timeframes and dimensions that range from short term to long term horizon (Shenhar et al., 2001). Furthermore, the project portfolio management can play a supportive role not only in deliberate strategies but also in emergent ones. Emergent strategies are realized without the explicit organization intention and traditional top-down approach and arise independently, being fundamental business innovation. Portfolio management practice and the strategic control applied in it, not only can provide monitoring and measuring performance tools, but can also foster the impetus and direction of emerging strategies (Kopmann et al., 2017). The importance of portfolios when dealing with emerging strategies arising from routing is also identified by Kaufmann et al. (2020) in its studies on Agile practices.

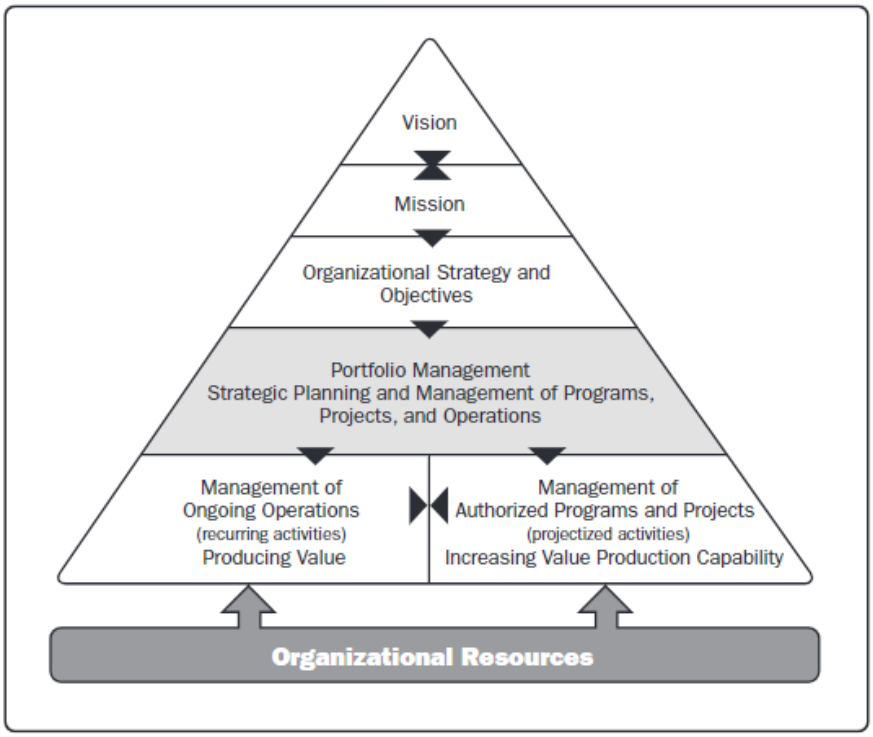

Figure 2. Strategic role of portfolio management (Project Management Institute., 2017)

When using portfolio management for strategic alignment purposes, two main issues can arise. These are the strategic fit of projects (if the initiatives selected are consistent with business' strategy) and the spending breakdown (if the breakdown of organization's

spending reflects priorities). To support these challenging activities, two ways can be pursued to incorporate the strategic alignment goal in the portfolio management practices (R. Cooper et al., 2002):

- Bottom-up: including strategic criteria in project selection and prioritization tool
- Top-down: from setting strategic priorities to allocate funds and resources to relevant projects, viewed as strategic buckets of money

Since the portfolio management functions as a link between the planification of strategic objectives and their implementation, adequate selection and prioritization techniques should be in place to ensure portfolio management strategic success. However, successful portfolio management depends also on the structural alignment of the organization with this practice. From this point of view, the organization structure becomes an antecedent to portfolio management to ensure the right implementation of strategy (Kaiser et al., 2015). It is noticeable that in both perspectives, portfolio management is a paramount element to be carefully integrated in the complex environment of an organization.

1.1.3 Goals and Performance Domains

Understanding the critical role played by the portfolio management in organizations' strategy, it is key to analyze its main goals and purposes.
R. Cooper et al. (2002) higlights four main macrogoals that can be addressed when applying portfolio methods:

- Maximization of value: this goal can be achieved through the selection of projects that ensure the higher commercial worths of the overall portfolio. The right allocation of resources among initiatives will optimize the summed value if projects in pipeline. The indicators applied to measure the selection are multiple (NPV, Expected Commercial Value, Productivity Index etc.) and range from financial to scoring model.
- Balance: this goal relies on different perspective of this definition. The most relevant concepts are the appropriate balance in short-term and long-term objectives or high versus low risk projects. However, it is alwasy more important balancing the portfolio in therms of markets, technologies and type of products.

- Strategic direction: this goal is focused on ensuring that the initaitives selected are in line with the organization's strategy and that the spending and resources allocated reflects correctly the business prioirities.
- Right number of projects: this goal answer to the companies' need of selecting only a limited amount of projects among the available ones because of resouce scarcity.

An organization establish its mission and strategic objectives and move toward is vision through measurable steps for goal achievement. The portfolio management is the primary tool to enable this strategy implementation process and therefore has the fundamental goal to support the organization in benefits realization. To fulfill this purpose, it is important to understand that portfolio components are affected by the whole complexity present in organizations and therefore portfolio management practices should be integrated with organizational enablers creating a framewrok identified as Organization Project Management (Project Management Institute., 2017). The standards indentify the link between strategy and strategic business execution as the ultimate goal for portfolio management and it can be achieved through six performance domains that highlights the strong interaction of this practice with all the dimensions of an organization:

- Portfolio Strategic Management: align each components of the portfolio to a strategic objective and monitor the realization of the related benefits
- Portfolio Governance: ensure open and transparent governance to make processes comprehensible and facilitate the agreement of all the stakeholders involved
- Portfolio Capacity and Capability Management: match the composition of the portfolio with the actual capacity and capability of the organization.
- Portfolio Stakeholder Engagement: ensure active communication and expectation management since high alignment level boost portfolio performance.
- Portfolio Value Management: provide the expected return over the investment as defined by the strategic expectations.
- Portfolio Risk Management: evaluate risk and opportunities that can arise through constant monitoring and plan for consequent actions.

From this perspective, portfolio management requires high performance in different dimensions, which can be extremely complex and affected by idiosyncrasies of internal

and external dynamics (Müller et al., 2008). For this reason, portfolio control factors should be identified to link the controlling practices to the performance of portfolio on different dimension in order to achieve strategic goals. Müller et al. (2008), through a quantitative analysis of best practices among 242 professional responses, identifies thre factors for portfolio control (portfolio selection, portfolio reporting, decision making-style) and two related factors affected in portfolio management success (achievement of pre-established portfolio results, achievement of components purpose). However, the results explained significance but low variance affecting portfolio success, highlighting the continuous need of idetnifying and explaining factors that contribute to portfolio success from both operational and strategic perspective.

1.1.4 Main Challenges Explored in Literature

Given the several fundamental goals impacted by portfolio management, the literature addresses the main performance dimensions identified by the standards outlined in the previous section. Particularly, it focuses on value maximization, strategic alignment and portfolio balance, in terms of risk, resources and projects selection (H. Sanchez et al., 2008).

The value maximization of portfolios has been addressed particularly by a financial perspective (H. Sanchez et al., 2008). Many options and indicators have been identified to define and analyse the value concept in protfolios. Kendall & Rollins (2003) highlights the centrality of the ROI in representing the value concept for projects and prortoflios. In particular, tey link the ability to reduce the cycle time of projects with the optimization of ROI, making the reduction of projects duration the key element for the value maximization mission.

Cooper et al. (2002) introduces a differentiation between financial and scoring models to assess value maximization. Net Present Value (NPV) evaluates the projects exclusively from a financial point of view and should allow to optimize the overall NPV of the portfolio but assumes that only financial objectvies are important. Expected Commercial Value (ECV) introduces the concept of risks and probabilities in the caluclation of value through a decision tree. The probabilities affecting the resulted value depends in fact both on commercial and technical success. The last financial indicator identified is the Productivity Index (PI). It further develops the ECV calculation including a given

resource constraint specifically focused on technical success. Finally, scoring methods are proposed especially for Go/Kill decisions. These methods can be applied to portfolio management since they focus on several criteria which can better represent the complex context of portfolios. On the other hand, other authors have linked the value definition of portfolios to other dimensions like the scientific contribution of projects or the contribution of acoomplishing the organization's strategic goals (H. Sanchez et al., 2008).

The strategic alignment issue of portfolios is frequently addressed by the literature. Shenhar et al. (2001) underline the impact on multiple strategic dimensions of portfolio management and the importance of assessing both the defined short and long-term goals to assess the success of portfolio alignment. Furthermore, Kopmann et al. (2017) enlarge the concept of strategic alignment including the emergent strategy. Project portfolio management impacts the possibility of exploiting the emergent strategy that independently arise in organizations without the traditional top-down imposition of directions.

However, the focus of reserchers has been more on the formulation side, realizing a gap on the execution and implementation. Meskendahl (2010) suggests therefore a framework to link the strategic orientation to portfolio structuring to achieve business success. The framework resulted from the study lies on four proposition: average individual project success; structure and formalization in portfolio structuring; analytical, aggressive and risk-taking posture; relationship between portfolio structuring and portfolio success.

Therefore, the performance domain of risk management should be also aligned with the portfolio management strategy. Even if the literature about risk management applied in portfolios is spare, this area impact on both the strategic alignement and value maximization objectives. To this aim, Sanchez et al. (2008) outlines a framework to identify risk and opportunity to orient managers through six steps. Hofman & Grela (2017) instead identifies three main category to facilitate the selection and identification of risk: component risk, structural risk and overall risk. The model assigned, thanks to the evaluation of experts through a Delphi method, 36 risks specific to the project portfolio. On the other hand, in the contxt of digital transformation, Diaz et al., (2020) divides the risk identification in three major categories called time, control and information uncertainty and build a model to assess cost-benefit tradeoff in portfolio projects.

Guan et al. (2021) focuses instead on the two different applicable strategies in project portfolio management. Particularly, the work studies the impacts on budget allocation of risk prevention used to reduce risk probability and risk protection used to reduced risk loss. The models developed investigates the impact that risk has on costs and resources allocation.

Resource management and balance is a complex activity in project portfolio since it deals with solving the conflicts among projects competing for the limited availability and achieving the optimal allocation (Li et al., 2017). The topic of resources allocation has been more developed in the multi-project context, which focuses on more operational issues that are not always considered in the strategic point of view of project portfolio management. However, portfolio management should include operational issues especially in the selection and alignment of projects. In this way, the interrelations between individual projects can be taken into account already in the initial phase, resulting in a more aligned and positevely interdependent portfolio (Pajares & López, 2014). Following this reasoning, to assist the project selection in presence of resource constraints, Shariatmadari et al. (2017) propose an integrated resource management approach for simultaneous project selection and scheduling.

Finally, the topic with extreme strategic importance for companies regarding portfolio management is the project selection and prioritizaiton problem. This activity helps organizations with all the issues listed above from strategic alignment, to balance of resources to maximization of value for all the stakeholder's. Therefore, companies should focus on the creation of accurate criteria to define their success dimensions, in order to implement these critical success factors into their decision-making process (Costantino et al., 2015).

Analyzing the portfolio management practice with six metrics among 205 businesses of different industries, R. G. Cooper et al. (1998) finds that current project portfolio management practices are able to obtain reasonable strategic alignment, moderately-high-value projects and reflect the business strategy fairly well. However, they identified more relevant shortcomings in the area of selecting the right number of projects given scarce resource and of balancing the portfolio of projects in terms of long-term and short-term objectives, high and low risk and so on. Following the challenges raised by these finding,

the current literature is mostly focusing on the importance of selection and prioritization of projects to sustain the several strategic goals (Meskendahl, 2010).
The identification of criteria is a complex issue since time, cost and quality are not always enough to evaluate a process as successful. Companies have a considerable number of indicators that can be implemented in the selection and prioritization process depending on industry, project type, product characteristics, organizational practices and strategies. Due to the complexity and the fundamental impact, it is well established that projects selection guidelines should have the major attention of practitioners and scholars (Kaiser et al., 2015).

1.2 Selection and Prioritization Process in Project Portfolio Management

1.2.1 Process Overview

Given the attention and suggestion of the literature review to focus on the selection and prioritization problem in portfolio management, it is important to investigate the characteristics of this process.
A portfolio is a set of subsidiary portfolios, programs, projects and operations managed in a coordinated way to ensure the realization of organizational results. These components need to be measured, ranked and prioritized to ensure the effectiveness of portfolio management. The interdependence and the size of the components can vary a lot but it is necessary to maintain a manageable number of components that matches the capabilities of an organization, as well as the risks and opportunities that can arise in the external and internal environment (Project Management Institute., 2017).

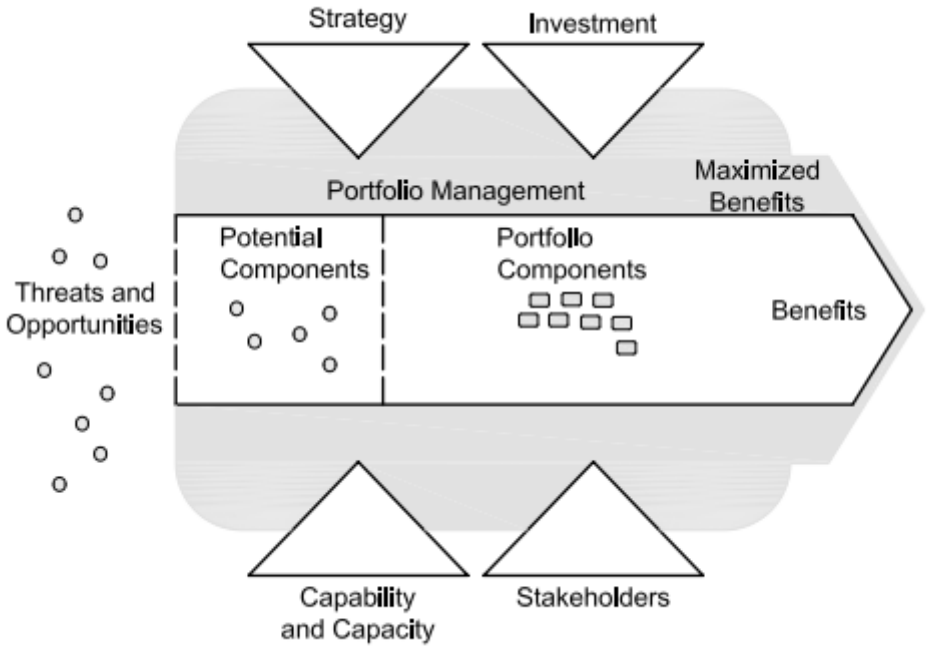

Figure 3. The context's impact on components selection and prioritization (ISO, 2015)

As mentioned before, having the right number of projects is one of the four macro goals of portfolio management highlighted by R. Cooper et al. (2002) and it is meant to avoid a pipeline gridlock: multiple projects wait in queue, delaying their time to market and cutting down key activities because of lack of time and resource resulting in unsuccessful balance and objectives accomplishment.

As a consequence, the proper selecting decisions become a competitive advantage for organizations and require the establishment of several and ongoing processes to ensure prioritize projects evaluating their success. The fundamental steps of the selection and prioritization process in portfolio management are the following (Purnus & Bodea, 2014):

1. Identification of the selection criteria in line with the strategic objectives.
2. Establish the score scale and the scoring method for each criterion developing effective indicators.
3. Calculate the project score for each criterion and the total score.
4. Prioritize projects based on one criterion (single-criteria approach) or by a comprehensive analysis using all the criteria (multi-criteria) approach. The latter

method requires the assignment of weights to each criterion, matching the needs of the organization and the projects characteristics.

These steps are also in line with the phases reported by Rogério Tadeu et al. (2011) which insist on (1) establishment of the evaluation criteria, (2) collection of project information, (3) evaluation and recommendations and (4) monitoring of the portfolio through the allocation of financial and human resources to prioritized components. However, here the attention is focused on the first step as the crucial point to ensure that the following stages are successful. The identification of the criteria is critical for the organizational alignment and should be based on the perceptions and values of the decision makers. This activity is the most important step since it is the moment where the specific needs of the organizations can be met and satisfied taking into considerations both the preferences of decision makers and the structured management techniques for the particular situation. This steps division is based on the work of Englund & Graham (1999). What is also added in their work is the potential funneling process that organizations can undertake when selecting process. Firms can in fact implement different criteria at different stages in order to go from the "trivial many projects" to "The critical Few". In the example studied, they report the first screen based on organizational strategic goals, the second based on market landscape characteristics and the third one based on specific needs and capabilities like technology fit or marketing effort.

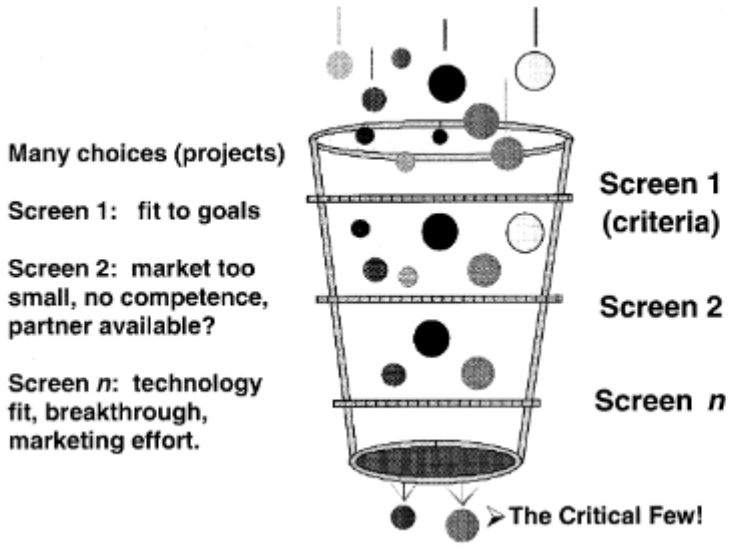

Figure 4. Funneling selection process screening with different criteria (*Englund & Graham, 1999)*

The process to identify the key necessary components is therefore challenging since it is needed to know profoundly the strategic objectives of the firm and the portfolio components' contribution to them at different levels to make effective decisions. Furthermore, this evaluation process is iterative and can happen on a regular basis or usually triggered by the following events (Project Management Institute., 2017):

- Change in organizational strategy
- Gap between expected and actual results
- Major change affecting a key portfolio component
- Validation of a new component
- Possible exploitation of new opportunities

To perform this continuous management and balance of portfolio components the standards (ISO, 2015) propose the following steps to iteratively assess the current status:

1. Collecting the relevant data and information on portfolio components
2. Categorize the components based on the identified criteria
3. Evaluating potential resources constraints and capabilities
4. Identification of interrelations among the components

The complexity of the process is underlined by its recurring problems that companies face during this decision-making process. Despite the multiple models proposed, there is still not agreement in literature for the cause of these issues, which are usually explained as a consequence of undesirable behavior or misapplication of the solutions proposed. The most important recurrent problems can be summarized as (Gutiérrez et al., 2008):

- Components are selected without taking into consideration operational factors as resource requirements, interactions and portfolio balance.
- There are major difficulties in explaining in an organization that ongoing projects need to be stopped or terminated because a new idea have been selected and prioritized, even if the ongoing implementation is no longer justified in the business
- Several behavioral patterns impact the process because of managers forcing the pursuing of projects which are no longer a priority for the organization's strategy

This complex environment is characterized by increasing uncertainty and volatility and managers are forced to take decisions in non-deterministic conditions. It is therefore necessary for each company to establish the right criteria on which to base the selection and prioritization process. The identification of these criteria and corresponding indicators should be based on the Critical Success Factors that are aligned with the strategic objectives and that affect the future implementation of projects (Costantino et al., 2015).

1.2.2 Critical Success Factors

1.2.2.1 Understanding Success in Organizations

The selection and prioritization process is affected by a strong complexity, due to the multi-faceted characteristics and to the high number of stakeholders involved and the corresponding diverse priorities and definition of success (Belassi & Tukel, 1996).
Costantino et al. (2015) report the complexity characteristics that can affect the proper selection KPIs in organizations. These difficulties embrace the different perception of priorities regarding fundamental selection criteria, organizational and functional structure, size of the project, industrial sector, different perspectives among stakeholders, different stages of the life cycle.
For this reason, an agreement has not been reached yet regarding which indicators should be taken under consideration to select and prioritize projects according to the identified critical success factors. A continuous and deeper analysis is therefore needed by researchers and professionals to understand and clarify this issue (Kaiser et al., 2015).
To develop this understanding, the first step is to assess what success means inside the organizations and how it can be linked to projects success. Meskendahl (2010) investigates the linkage between business strategy, project portfolio management and business success. The overall relationship appears strongly complex since there is no complete framework integrating the whole cycle from strategy to success through portfolio management but the outcomes are developed only on single concepts. The studies converge then on how the strategic orientations developed as analytical posture, risk-taking posture and aggressive posture influence the process to obtain success in

organizations. This process is analyzing constructing a framework that undertakes the phases of Project Portfolio Structuring, Project Portfolio Success and Business Success.

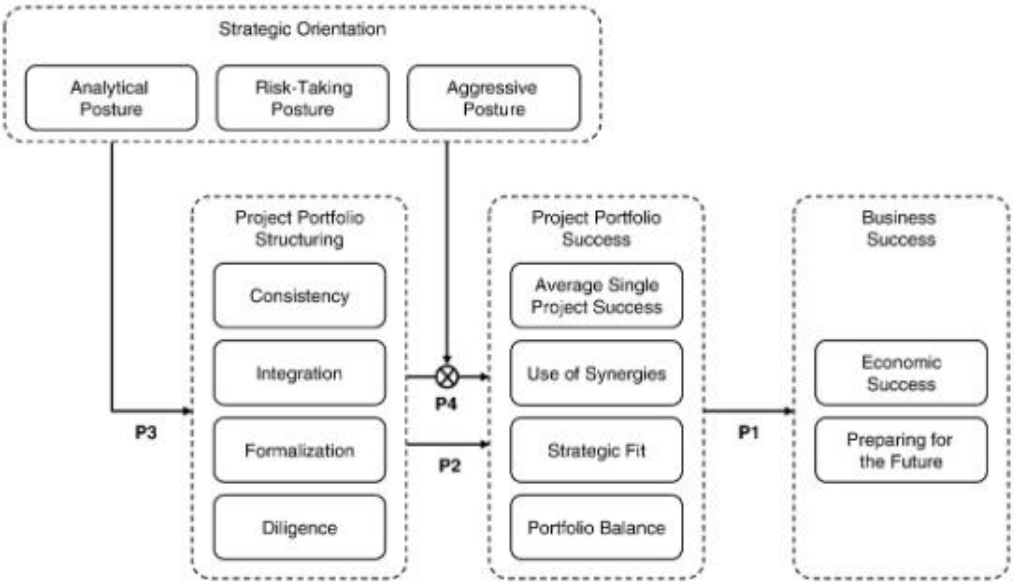

Figure 5. Model on the relationship between strategic orientation, Project Portfolio Success and Business Success (Meskendahl, 2010).

The model (Meskendahl, 2010) integrates particularly the Project Portfolio Structuring phase to link the strategic orientation to the success of portfolio and business. This phase, including the selection, screening and assessment of a set of projects , is detailed in the fundamental elements of (1) consistency in further detailing the organization strategy in the portfolio and projects, (2) integration of all the stakeholders from internal department and external environment, (3) formalization of the portfolio management processes, (4) diligence in actually selecting the right projects that are carefully related to the organizational strategy considering the right balance among resources requirements, short-term and long-term risks and goals.

The project portfolio success part is instead based on the framework proposed by R. Cooper et al. (2002) regarding four dimensions of success. The first is the average single project success, which has been described as a multi-dimensional topic in literature that requires to go beyond the “iron triangle” of time, cost and quality compliance, especially also including customers and stakeholders satisfaction as dimension. Secondly, the use of

synergies concentrates the realization of additional benefits on the exploitation of the complex but useful interdependencies of projects, particularly between the market and technical synergies. The third success dimension is the strategic fit of the portfolio of projects, which should ensure the alignment of components to each other and include only projects that are aligned with the business strategy. The last dimensions is portfolio balance, which enables the firm to achieve its goals without being exposed to unreasonable risk. This can be achieved through the balancing of projects in terms of short-term incremental improvements and long-term realization of benefits, different sizes and durations and diversities in technological advancements.

These dimensions are developed in order to reach the final stage of the model called business success. This area has been in the past linked merely to financial objectives, but many studies have identified these measures as insufficient to represent the complete success required in organizations. The leading idea is that a multidimensional model is required to implement and monitor the successful implementation of strategic objectives of firms as developed in structure techniques like the Balance Scorecard of Kaplan & Norton (2001). The concept is further developed and based on the differentiation highlighted by Shenhar et al. (2001) between the short-term economic success and the long-term "preparing for the future". The economic success is particularly composed by market success, including sales objectives like market share and volumes usually compared to competitors and environment, and the commercial success, focused on financial management criteria usually compared to initially set objectives. The "preparing to the future" is a long-term dimension aims at preparing the organizations in terms of resources and technological infrastructure to address the future needs (Meskendahl, 2010).

Therefore, to achieve the organizational success becomes fundamental the identification of Critical Success Factors that can serve as fundamental criteria to select and prioritize the projects considering strategic needs, managers' experience and competitive environment (Costantino et al., 2015).

1.2.2.2 Proposed Critical Success Factors (CSFs)

A stream of literature has been developed trying to assess the critical success factors, although there is not yet aa shared agreement. In this section, the review focus firstly on

the standards suggestions and then follow a chronological order to show the main results reached in literature.

According to the standards (Project Management Institute., 2017), to define the key components of a portfolio, three categories of factors should be analyzed. Realization factors refer to the specific cost, duration, resources, expected deliverables and complexity. Organization's objective-oriented factors represent the trade-off between positive and negative impacts on the strategic objectives of the firm, as the simplicity and visibility of results and the benefits realization timeline. External factors include the organization's image, contribution and interdependencies with communities, countries and the resistance to change. Furthermore, to proceed with the selection of the components, the suggestion focus on the investigation of these particular areas: alignment with the organizational strategic objectives to provide long-terms visions and guidelines; study of the alignment and interdependencies among projects in the inventory of work of the organization; analysis of the portfolio process assets concerning the portfolio funding and resources requirements; understanding of the enterprise environmental factors and their contributions to the portfolio components.

One of the first models developed in literature is the Project Implementation Profile developed by Pinto (1990). The model has firstly the aim to support managers in assessing the "soft side" of the project management investigating the behavioral and human dimensions in relation to the status of the project. Secondly, the objective is also to focus the attention of managers on the strategic dimension. The model develops the following 10 critical success factors which have been discovered and validated questioning the activities of 54 managers. "Project mission" is fundamental to provide the guidance toward the general strategic objectives and the benefits that projects are expected to achieve. The clear picture and knowledge of the strategi goals is vital for the project stakeholders. "Top management support" is useful to understand the true commitment of the top management toward projects which goes further than simple words and statements. Understanding this point can help managers assessing the support they can expect to receive from top management. "Project schedule/plans" is paramount for the operational side of project management where activities should be detailed, scheduled and supported by the right number of resources. This factor is particularly important also for enabling the controlling phase having a baseline against which managers can monitor.

“Client consultation” has to be performed not only at initiation but through the whole implementation. The project is intended for the client and so must be informed on the status of the project and consulted for any change needed. “Personnel” is a factor that is too often overlooked by companies which assign staff only based on convenience. The project team is instead very important for effective projects implementation. Another factor identified, even more important nowadays, is “Technical tasks” which refers to the right assessment of technologies and infrastructure possessed by the firm to perform the particular activities of the project. This criterion also involves the evaluation of capabilities of the staff present in the organization to manage these technologies. “Client acceptance” is the factor which is concentrated on the final stage of the project but should be considered as equal as the other factors to enable success. The project team should focus not only on the technical activities but also in order to ensure the client acceptance of the results delivered, especially in the broad vision of stakeholders’ satisfaction objectives (Meskendahl, 2010). “Monitoring and feedback” remains fundamental to continuously assess the status of the projects and allow identification of problems and application of corrective measures. “Communication” is more focused on the soft side of projects and is truly relevant for the clear exchange of important information among all the stakeholders involved. The last criterion identified by Pinto (1990) is “trouble shooting” that refers to the presence of contingency plans which are available to continuously deal with unexpected problems arising along the implementation.

Belassi & Tukel (1996) propose instead a new framework to identify critical success factors and the focus is more on the grouping and interactions of these factors. The first group is “factors related to projects” which focus on the specific characteristics of projects. Among them they list six relevant topics to be analyzed as project size, value, uniqueness of activities, density of project network, project lifecycle and urgency of a project outcome. The importance of managing these dimensions simultaneously help managers to understand how to use capabilities and allocate resources to ensure project performance. The second category of CSFs is “factors related to project manager and team members”. Here, it is noticeable again the paramount selection of project managers which are strongly committed and performing in technical and administrative activities. Furthermore, the competence of the project team is found to be fundamental during the implementation phase and the effective communication channels internal and external

can ensure clients and stakeholders satisfaction. “Factors related to the organization” is the third categories and is again focused especially on top management support. The relationship among different type of managers is interestingly detailed in their work. Top management usually ensures the accessibility of resources of the project managers which are however under the control of the functional managers, referring to matrix organizations. The commitment toward projects of top management and functional managers is therefore fundamental to ensure that the project managers can access the adequate resources to complete the projects. The whole organization support is therefore necessary to deploy strategic projects successfully (Belassi & Tukel, 1996). The final category highlighted regards “factors related to external environment”. Environmental, political, social, economic and legal dimensions have of course a strong impact on the project performance. It was found in literature that these factors affect projects especially in planning phase of projects life cycle, but instead these elements can even lead a project to termination during the execution phase. What is noticeable is that even the actors external to the organization are listed in this category. A strong attention to external clients, suppliers, subcontractors is fundamental to ensure clear communication and achieve all stakeholders’ satisfaction. Finally, the most striking feature highlighted in the model by Belassi & Tukel (1996) is that grouping CSFs is not sufficient, but the interdependencies should be analyzed inside the different organizations It is true that these relations among categories of CSFs risk to cause further complex problems if many unexpected outcomes arise simultaneously, but at the same time it is possible to leverage different elements from different categories to solve these issues thanks to a comprehensive organizational effort. It is worth to mention that their work also identifies 6 main CSFs and investigates their relations with different type of industries, organizational forms in order to highlights the different needs required in different organizations. Finally, the 6 CSFs, mentioned as “Top management support”, “Client consultation”, “Preliminary estimates”, “Availability of resources”, “PM performance” and “Others specific” have been related to 4 projects dimension considered to be critical: cost, time, quality and client satisfaction. The most interesting findings is that for each of the 4 dimensions of projects success organizations are more concerned about technical aspects of project management, especially the CSF “Availability of resources”.

Another analysis that relates CSFs to the main projects objectives of time, cost and quality is the work of K H Chua et al. (1999), which also adopts an analytic hierarchy process (AHP) to prioritize the factors. They identify four categories of CSFs which are all related to the three main objectives of budget, schedule and quality performance. The first set of 9 CSFs is grouped under the name of "Project characteristics" and is mainly structured in internal and external criteria. In this category, "economic risks and "adequacy of funding" result most related to budget performance, "efficiency of technical approval authorities" with schedule objective and "site limitation and location" is the most relevant with schedule performance, highlighting the importance of regulatory environment. The second category is "Contractual arrangements" and, composed by 5 CSFs, focus more on the major consideration that support the to the definition of contracts instead of the actual contract type. In this group, adequacy of plans and specifications results as the most influential CSF on all the three project objectives. This can be explained by the fact that these specifications are fundamental for subcontractor tenders, allocation of resources, alignment with client's expectations and so satisfaction of several stakeholders (K H Chua et al., 1999). Other factors related to contractual arrangements are focused on developing motivations and commitment among all stakeholders and are identified as "realistic obligations and clear perspective" and "motivational schemes and incentives". The third category is instead "Project Participants" and, with 32 potential CSFs analyzed, take into consideration the several roles included in the projects' activities with the aim to avoid the extremely harmful conflicts that can arise in organizations. The Project Manager and the Client role result as the most important for all the project objectives, underlying again the importance of client focus for projects success. However, also in this study the relevance of top management support and the competence of the project team is found in order to ensure both adequate resource allocation and technical capabilities. Finally, the category "interactive processes", studying potential 20 CSFs, is based on the suggestion that all stakeholders should collaborate as a team towards the common goals facilitating the communication and coordination throughout the whole project life cycle. These processes are identified subdividing the project management activities between four dimensions as Communication, Planning, Monitoring & Control, Project Organization. What resulted from this last category's analysis is that the monitoring and control phase

is the most related to this category and the CSFs identified are fundamental to quickly identify problems and ensure prompt and effective reactions.
On the other hand, Cooke-Davies (2002) approaches the problem of identifying CSFs in a different way, trying to answer three questions: “What factors are critical to project management success?”, “What factors are critical to success on an individual project?” and “What factors lead to consistently successful projects?”. This differentiation is based on two different distinctions:

- Project success vs Project management success: the former measured against the overall goals of a project while the latter against the traditional triangle of quality, costs and time
- Success criteria vs Success factors: the former used to judge the success or failure of projects while the latter input in the management practices and systems to drive the project success.

Analyzing the projects performed between 1994 and 2000 in 23 European organizations to answer the first question of project management success, 6 CSFs were identified to be related to time performance while only 2 CSFs correlated to cost performance. To investigate the second question, the study analyzes the relations and impacts of the different stakeholders involved in a project with the aim of bridging the differentiation between project success and project management success. For this category, only one CSF is identified and corresponds to “The existence of effective benefits delivery and management process that involves the mutual cooperation of project management and line management functions”. Finally, the third question is more focused on moving toward the overall organizational success. This topic is focused on ensuring that companies are able to translate the strategic objective into concrete projects and operational activities. 3 CSFs are identified in relation to this area, which are mainly focused on strategic alignment, establishment of indicators to link projects success to business success and the importance of learning from experience.

Similarly, to the previous analysis of K H Chua et al. (1999), the framework proposed by Alias et al. (2014) is based on the relation between CSFs and project performance objectives of cost, time, quality and client satisfaction. The main 11 CSFs identified in literature and presented are generally focused on top management support, technical

competencies of project team, strong and detailed plan, communication channels, effective control and monitoring and adequate financial budget. The element added by this study is the identification of five variables that affect the project performance and therefore the needed critical success factors:

- Project Management Actions: focused on communication, planning actions and on creating the structure needed to ensure control, quality and safety processes.
- Project Procedures: focused on the tendering and procurement strategies.
- Human Factors: including all the characteristics of stakeholders and especially clients, to define contributions, roles and decisions ownership.
- Project Related Factors: investigating size, type and complexity of projects.
- External Issues: including all the factors that impact the project from a political, economic, social and legal point of view.

These variables constitute the framework through which further research should investigate specifically the CSFs to be included in each area and that should guide the whole lifecycle of projects from inception to completion (Alias et al., 2014).

Maghareh et al. (2016) studied a more specific hierarchy of management indicators studying the importance of 38 factors. The necessity of understanding different perspectives of criticality and priorities is pursued in this work through the involvement of two different groups of experts: Consultant & Contractors (C&C) and Managers and Experts (M&E). The findings revealed that despite their differences, these groups have the same opinion on 25 indicators out of 38 and that the most complex and critical factors are: "allocation of credits and budgets", "effects of inflation over costs", "repeating changeover of managers", "instability of building materials costs", "delay in completion of projects", and "insufficient skill in executive personnel".

Even in more recent studies focused on new AI technologies to support decision-making in portfolio management, the CSFs are investigated to determine on which criteria the Machine Learning models should be based. Marchinares & Aguilar-Alonso (2020) identifies 18 CSFs based on the analysis of nine literature references. In line with previous described studies, their work highlights that the most criteria repeated in literature are top management support, communication and knowledge sharing, customer satisfaction and characteristics of projects related to the iron triangle.

The identification individual CSFs to use as criteria to select and assess projects based on their predicting success is critical to achieve specific projects and overall business success, but the disagreements and complexity of heterogenous priorities and actors still threaten their effective definition. Going beyond it, it is necessary to explore the interdependencies and complexity that can arise in portfolio management, especially due to the multifaceted characteristics and the different stakeholders involved (Bai et al., 2021b; Belassi & Tukel, 1996; R. Cooper et al., 2002; Pajares & López, 2014).

1.2.2.3 Complexity and interdependencies

Given the increasing complexity in project management, it is necessary to understand how to measure and analyze it especially when assessing several projects in a portfolio Several complexity measures have therefore been proposed in literature (Vidal et al., 2015).:

- Coefficient of Network Complexity: intuitive definition that captures the structural complexity through the analysis of graphs. It applies also to precedence network and PERT (Program Evaluation and Review Technique) where it is equal to the quotient of activities squared divided by events.
- The cyclomatic number: measure of the independent cycles in a graph calculated subtracting the number of nodes (N) from the number of arcs (A) plus one:

$$S = N - A + 1$$

- Static entropic measurement of complexity: traditional indicator which emphasizes how information and disorder are related. It is defined as the summation of the logarithm of the probabilities of receiving a message n_i.

$$Sha = \sum log_2(p(n_i))$$

- Degree of interrelationships between the activities in a schedule: this measure further develops the concept of Coefficient of Network Complexity in order to avoid the indicator to consider redundant arcs on Activity on Node graphs:

$$\mathrm{Cn} = 100 \times \left(\frac{\mathrm{Log}\left(\frac{\mathrm{a}}{\mathrm{n}-1}\right)}{\mathrm{Log}\left[\frac{\mathrm{n2}-1}{4(\mathrm{n}-1)}\right]} \right) \% \text{ if n is odd}$$

$$\mathrm{Cn} = 100 \times (\mathrm{Log}(\mathrm{a}/(\mathrm{n}-1))/\mathrm{Log}[\mathrm{n2}/4(\mathrm{n}-1)])\% \text{ if n is even}$$

However, there are also limitations regarding the ability of these complexity measures especially given the fact that projects with the same network characteristics have shown different easiness in being managed. Furthermore, they are usually difficult to understand for managers during the decision-making process (Vidal et al., 2015). There is in fact no agreement regarding how to define and measure complexity and there is the need then to define the factors that can better describe this characteristic of project. Vidal et al. (2015) propose then to group these factors into four main dimensions which can intuitively represent complexity in projects: project size, project variety, elements of context and project interdependence. This latter dimension of project complexity, seen as the representation of the interactions between the activities undertaken to execute the project, is found by researchers as the main driver of project complexity.

The importance of interactions and interdependencies in project portfolio management is also highlighted by Pajares & López (2014), which presents the criticality of the issue in the projects selection field. The problem is that portfolio management has been too much concerned about selecting the right number of projects to ensure strategic alignment, while also forgetting the evaluation of operational topics. The operative issues are usually only analyzed in the context of multi-project management where different initiatives compete for a limited number of resources and activities like scheduling, resource allocation and risk assessing becomes fundamental. Consequently, there is a gap between the selection of project in portfolio management focused on strategic objectives and the multi-project management focused on scheduling and resource allocation. This missing link risks to cause the overlooking of operational problems that are not anticipated in the selection phase and organizations end up with a set of strategic aligned projects that are on the other hand difficult to manage together. It is therefore necessary to closely relate the portfolio management and multi-project management decisions investigating the dimensions through which different portfolio elements and projects can interact. These dimensions can be the following (Pajares & López, 2014):

- Portfolio and project risks: risk management at portfolio and project level are strongly related. The addition of a project to a portfolio can increase dramatically the portfolio risk or on the contrary reduce the portfolio risk. This latter

mechanism can be identified as “hedging projects” where an additional project is able to increase economic value and reduce risk of a portfolio at the same time.

- Cash flow and capital costs: there are two types of financial interactions among projects and portfolio level. Firstly, a new project can either overload the cashflow needs of a portfolio or could contribute to finance other existing projects. Secondly, in case of strong capital limitations, the interactions among the structure of cash flows of different projects can change the cost of capital and therefore the value of a portfolio. In order to measure this interaction, Hernandez et al. (2011) propose a new metric called Project Value to Portfolio Value (PV2PV) to consider specifically the added value of a new project included in a portfolio. This indicator is computed updating the cost of capital (WACC) at each period of time considering the dynamic inclusion of new projects and termination of existing ones. Then the total cost of capital after taxes is calculated and use to discount the expected value-added flows of the new project.
- Scheduling and resource allocation: The inclusion of a new project affects of course the scheduling and resource allocation in place for the existing projects in a portfolio. For this reason, the selection and prioritization of projects should take into account not only the strategic alignment of the portfolio toward organizational goals or financial properties, but also the interactions with the existing projects in terms of resources scheduling and allocation.

The consideration on interactions among projects is implemented by Bai et al. (2021), which propose a method to perform project portfolio selection taking into consideration not only strategic objectives but also dynamic synergies. The method is composed of thre steps. Firstly, the projects are screened to respect resources constraints and projects that exceed the firms capabilities are eliminated. Secondly, projects are valuated in respect to their functional value derived by the strategic indexes of the model. Finally, a system dynamic approach is applied through a computer simulation using the model created. This model creation and simulation is structured in three phases: definition of portfolio strategy indexes through the use of the Balanced Scorecard methodology; development of causal loops and relationships among strategic indexes; development of a stock-flow diagram for a computer simulation of the model.

Thanks to the Balance Scorecard approach, it is possible to further decompose the strategy of organizations into perspective, objective and function layers, which are interrelated and gradually progressed (Bai et al., 2021). In this way, starting from the five strategic perspectives of Finance, Customer and market, Internal process, Learning and innovation, Sustainability, the author further develops seven dimensions in the objective layer and 21 indexes in the function layer thanks to a systematic literature review and the Balance Scorecard method. The interactions are studied and visualized at functions level through a causal loop diagram that is then translated in a stock-flow diagram to perform the computer simulation and support managers in their decision making regarding the assessment of strategy realization of projects.

The combined effects of projects affecting the portfolio success are also modeled by Bilgin et al. (2017) through the proposition of a dependency map that can support not only the identification of different dependencies but also to evaluate the combined effects of these interdependencies. These interactions are grouped in four main types:

- Financial dependency: the same financial factors affect different projects at the same time.
- Resource dependency: different projects share the same resources and are affected by issues arising from the same resource.
- Learning dependency: similar projects can foster the same knowledge area contributing simultaneously to the learning loop of the organization.
- Outcome dependency: an outcome of a project is needed for the success or simply affects the outcome of other projects.

Each dependency type is further decomposed in attributes, which are then weighted by the user in order to define the overall weight of each general dependency type. After the determination of the importance of each dimension, the dependencies among projects in the portfolio of the user are visualized through a visual network map. The diagram is developed with the aim of easily capturing the most important dependencies, using different sizes for the nodes more interconnected and differentiating between ongoing and potential new projects with different colors. The method results therefore extremely useful for managers to quantify the dependencies among projects and can be used

specifically for risk management, resource allocation and assessment of projects complexity purposes.

1.2.3 Multi-Criteria Decision-Making Models for Projects Selection and Prioritization

As investigated in the previous sections, project portfolio management is a dynamic decision process where projects are constantly reassessed and updated based on changing information, strategic considerations, interdependences among projects, multiple decision makers and locations. Therefore, to select and prioritize projects, considering all the different short-term and long-term factors and their relationship, the Multi-Criteria Decision-Making (MCDM) methods are often used to support organizations in implementing portfolio management more successfully. These methods are extremely useful thanks to their scoring techniques, especially for large projects, and pair-wise comparison methods suitable for small projects. Since there is not only one MCDM method to support portfolio management it is necessary to investigate the different methods proposed in literature for this specific subject and their effectiveness (Danesh et al., 2017).

A first example of taxonomy of selection methods is proposed by Hall & Nauda (1990) and comprehend four main categories. The first example is Mathematical Programming (MP) methods, which have the aim of optimizing an objective function while respecting the given constraints. These methods can be further divided among linear programming, integer, programming and nonlinear programming, which can allow to model more complex type of constraints despite its complexity. These MP methods are particularly attractive because are able to address a specific quantitative objective function. The second category is Benefit Measurement Methods, which aims at developing a quantitative indicator to measure the success of projects and select the ones that deliver the highest benefits. Always respecting the overall budget constraints. This category is subdivided in: (1) comparative approaches, which require to respondent to compare different groups of projects and are usually based on group discussions and iterative revoting; (2) scoring models, which requires respondent to assign value to a list of criteria in order to establish an overall project rank that will be used to prioritize the list of projects; (3) contribution models, which try to perform a cost-benefit analysis and assess

the financial risk of performing a project using specific financial indicators as IRR and NPV. The third category is instead Cognitive Emulation Methods that are focused on actually understanding the dynamic of the decision-making process used by managers to select projects. Many sophisticated computer programs have been developed to simulate the inference process that managers undertake when selectin process but also simpler model as linear regression have been used for this type of analysis. Finally, the fourth category is instead called Ad Hoc methods which are based on providing a top-down direction to select projects, such as allocation of funding to researchers to investigate any project of their choice (Hall & Nauda, 1990).

A more recent taxonomy is proposed by Danesh et al. (2017), which is based on other taxonomies proposed in literature. MCDM methods are in this case split between:

- Multi-attribute Decision-Making (MADM) – Discrete: these methods perform the screening, prioritization, selection and ranking of a limited number of options based on several criteria. The first type is defined as Utility-based techniques that, like the analytic hierarchy process (AHP) and the analytic network process (ANP), have the goals of assigning an overall amount of utility to each alternative. The second type is the Outranking methods which aims to determine whether an alternative is at least effective as another one, with the objectives of ranking all the options since one is able to obtain an effective level of control over the others. The most used examples of these methods are the ELECTRE method and the PROMETHEE method and are usually used when there are several metrics difficult to aggregate and with unique dimensions. The final type can be named as Compromise methods and are based on the concept of sharing ideas to select the best practical option based on mixed factors. All these methods use a finite number of options and very effective for selection and prioritization issues (Danesh et al., 2017).
- Multi-objective Decision-Making (MODM)/Mathematical Programming Methods – Continuous: these methods are useful in situation where multi-criteria decisions are involved and multiple targets need to be addressed, respecting the limitations, but without having a clear direction toward which target is the most important to reach. These methods are attractive because can use an unlimited

number of options and are more suitable for design/search problem looking for an optimal quantity (Danesh et al., 2017).

As explained above the MCDM methods, the MADM subcategory, including models such as AHP and ELECTRE are found in literature to be more suitable for the selection and prioritization process. In fact, it is noticeable that these methods have been many times proposed in literature to solve this multi-faceted issue. Buchanan & Sheppard (1999) use the ELECTRE method to prioritize projects since this method is able to better represent the "fuzzy nature of decision-making" thanks to the inclusion of threshold of indifference. Besides the successful applications in literature and in construction projects, they underline its simplicity if compared to the high number of pairwise comparisons required by other methods like the AHP. Particularly, they focus the prioritization of projects on five main criteria named as (1) financial, (2) solution delivery, (3) strategic contribution, (4) risk management and (5) environmental, implementing a combination of subjective measure and numerical indicators like the NPV.

More recently, also Daneshvar Rouyendegh & Erol (2012) confirm the identification of ELECTRE method as the most used and high-performance policy thanks to the ability of including both quantitative and qualitative criteria. propose a fuzzy ELECTRE method including in the process also the opinion of experts.

On the other hand, based on a list of fundamental characteristics identified in literature, Vidal et al. (2015) identify the AHP as the most satisfying method, because it can be easily understood by decision-makers and is a flexible but systematic repeatable procedure. Furthermore, also for this method a high number of applications can be found in literature (Vidal et al., 2015) The use of AHP method to prioritize construction projects can be found in the work of (Simpson & Cochran, 1987), where they try to identify how to select projects in situations with a limited budget to be allocated. Another example is the AHP application in the ranking of outsourcing projects proposed by Bea & Lloveras Joaquim (2007), which highlights how this method is useful to avoid the partial view during the decision-making process, easily considering different criteria with different weights, improving therefore the overall quality of the decision.

It is worth to notice that MCDM models like the AHP have not been used only to select and prioritize projects, but also to define the ranking and weights among critical success factors of projects. A great example is the analysis of K H Chua et al. (1999), which

propose this method to identify the top CSFs among a set of 67 success-related criteria questioning a panel of experts in order to obtain the pairwise comparison needed by this method.

Figure 6. Objectives and criteria decomposition in AHP method (K H Chua et al., 1999)

The authors highlight the suitability of the method for the clear explanation of the objectives pursued. It is in fact possible to clearly identify CSFs by further decomposing the objectives at different level starting from the primary goal project success, decomposing it directly into budget, schedule and quality performance objectives, until finally specifying the different categories of factors necessary to achieve the primary goal.

1.3 Digital Transformation Projects

1.3.1 Digital Transformation Objectives and Project Portfolio Management

In order to focus the selection and prioritization process of portfolio management specifically on digital transformation projects it is fundamental to understand its definition and intended goals.

A complete definition is provided by Vial (2019) based on the study of 23 definitions from 28 sources in literature and comprehend the concept of target entity, scope, mean and expected outcome of digital transformation. It is defined as “a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies”. What is remarkable is that this definition refers to an entity that goes

beyond the simple idea of organization and insists on the concept of changes and improvements as expected results of digital transformation. Of course, this definition suggests the central role played by technologies that can trigger disruptions and responsive strategies. Therefore, organizations must overcome complex barriers and structural changes that hinder their transformational projects to reach the desired value creation (Vial, 2019).

This transformation initiatives are more complex because do not aim to only digitalize specific resources or assets in organizations, but can potentially include the changes in business model, products and internal processes. The digital transformation is in fact a broader innovation process that goes through the analysis of different phases in organizations as initiating, developing, implementing and exploiting (Barthel et al., 2020).

It is noticeable that digital transformation projects have a strong link with the overall strategy of organizations both from an operational point of view (markets, products, processes) and from functional perspective (Finance, HR, IT). However, beyond these two perspectives it is possible to identify 4 dimensions of digital transformation strategies and objectives (Matt et al., 2015):

- Use of technology: an organization should assess its ambition in terms of new technologies advancement in line with its capabilities to use and fully exploit the benefits deriving from these changes. Setting ambitious technological standards can be a competitive advantage but can at the same time require higher costs and capabilities
- Changes in value creation: different form of process and monetization could require a strong change in business scope or market and customers addressed. It gives the opportunity for new products but arises new risks due to the less experience in the field.
- Structural changes: with the inclusion of new activities in the corporate structure it is needed to reorganize the organizational processes on the basis of new operations. In this case it is important that the firm understand if the digital transformation affects more the products or the processes.
- Financial aspects: financing projects of digital transformation can either boost or hinder the forces that drives these changes. It is important to pursue these kinds

of projects in the right timely manner and put a balanced financial pressure to communicate the right urgency to act.

Osmundsen et al. (2018) further develop which are the main objectives and drivers that push an organization to undertake digital transformation projects. The drivers are identified as the triggers that stimulate these initiatives and are listed as (1) change in customer behavior and expectations, (2) digital shift in the industry, (3) Changing competitive landscape and (4) regulative changes. Understanding the main drivers is really important to understand the purpose of digital transformation implementation in organizations. Osmundsen et al. (2018) also identify 6 main objectives:

- Ensure digital readiness
- Digitally enhance products
- Embrace product innovation
- Develop new business model
- Improve digital channels
- Increase customers satisfaction and dialogue

To pursue these digitalization strategies and corresponding objectives, managing technology projects becomes essential especially from the strategic point of view of portfolio management. De Reyck et al. (2005) found out in fact that portfolio management practices increase the return on the projects and reduce the number of problems faced in technology projects, especially when focused on "choosing the right projects". In particular, organizations can reach the desired benefits' value choosing the right elements to adopt when going through digital transformation.

Finally, in a more recent study Barthel et al. (2020) argue that successful digital transformation can be achieved only through the appropriate selection of solutions that can help choosing and managing simultaneous digital transformation projects. They also highlight the uncertainty concerning the PPM activities in relation to digital transformation projects, because organization desire portfolio management practices to coordinate the multiple digital initiatives but at the same time do not want these methodologies to reduce the creativity and innovativeness of digitalization through excessively structured processes. One specific criticality is that digital transformation projects require a completely new set of measures and criteria that better focus on

strategic fit, customers alignment and financial criteria. Practices developed until now are not developed beyond only initial stages and especially to not consider the level of interdependencies and synergies among projects (Barthel et al., 2020).
Given this underlined need, in the next section the different criteria based on critical success factors for digitalization projects are reviewed as well as some projects selection model proposed in literature.

1.3.2 Critical Success Factors for Digital Transformation Projects Selection

Since many companies in different industries are applying digital transformation initiatives to exploit their benefits it is important for firms to identify strategies and criteria to successfully coordinate, select and implement these projects (Matt et al., 2015). The assessment and selection of projects in this area is even more complex given the everchanging characteristics and continuous innovation that define the digital transformation field (Tavana et al., 2013). Examples of critical success factors to achieve the ensure the success of this kind of projects have been recently analyzed in literature. Particularly, many studies assess the success factors of digital transformation projects investigating the development of Information System technologies since it is an immanent condition for today's transformation (Vogelsang et al., 2018).
Matt et al. (2015) insist on the necessity of (1) previous experience of the person in charge of the operational implementation of projects, (2) top management support along the whole process since these initiatives affect the whole company, (3) involvement of different stakeholders and functions to ensure the complementation of various set of skills and (4) definition of a set of measures to continuously monitor and control and evaluate immediate progress of this fast-changing environment.
O. P. Sanchez et al. (2017) investigate four levels of critical factors that can impact the cost and time success of information systems development projects. Firstly, at portfolio level they propose the factors of Project Network Eigenvector Centrality and project Network Closeness. Secondly at project level the factors of project size, duration, postponement and outsourcing index. Then they propose a level focused on the specific role of project manager with two critical factors of project manager formal power and project manager diversity. Finally, the focus of the last level is on the team, which is

characterized by the factors of team size, team hierarchy diversity and team allocation dispersion.

Vogelsang et al. (2018), focusing on the manufacturing industry, conduct semi-structured interview to define success factors in digital transformation. They identify three main dimensions of success with related success factors. These three dimensions do not correspond to specific technologies or different field of application, but the qualitative research allows to cover broader and richer conclusions:

- Organization: pilot projects, prepare for futures, customer needs, autonomy, employee qualification, culture, big data use, management support, usability, interdisciplinary.
- Environment: connectivity, transparency, collaboration, hybrid value creation, standards.
- Technology: infrastructure, reliability, relevance, adaptability, security, completeness, availability, real-time data.

Morakanyane et al. (2020) identifies instead seven critical success factors and 23 related subfactors. The main factors listed are Determine Digital Trigger, Cultivate Digital Culture, Develop Digital Vision, Determine Digital Drivers, Establish Digital Organization, Determine Transformed Areas and Determine Impact.

An example of these success factors used as criteria for a projects selection process in digital transformation is provided by Dreyer et al. (2020). The author develops the selection indicator on three levels: production entities, digital capabilities and aggregated measures. While some factors are specific for smart factory projects evaluation, the "digital capabilities" category is strongly interesting for general considerations. This group is composed by four factors:

- Real-time ability: measured as the time between the occurrence of an event and the system ability to analyze the corresponding data and respond
- Interoperability: based on the increasing entity that are interconnected and able to communicate information
- Virtualization: calculated as the improvement of correctness and accuracy of the simulation before and after the implementation of the digital transformation

- Decentralization: as the entities that do not need higher level interferences after the digital transformation

Regarding instead a selection and prioritization model proposed for more general digital transformation projects, Isikli et al. (2018) propose an integer programming model. This type of model is proposed because considered as particularly effective to consider the several constraints and interrelationships among projects in a portfolio. The objective function aims at maximizing the profitability of the portfolio, selecting the projects that produce the higher financial benefits. In the context of digital transformation, the following financial criteria proposed to increase profitability: net present value of energy savings, net present value for labor savings, net present value for material savings and investment cost of projects. It is noticeable that due to the high uncertainty related to the definition of savings, these values are considered as stochastic. However, the most striking features are the constraints set for the model since they are fundamental to represent the complex interrelationships among portfolio elements. Firstly, a budget constraint is of course monitored in order to control the cost side of the portfolio. Furthermore, a threshold is set for each type of savings with the aim to ensure that the portfolio match at least a certain amount of savings strategically set by the organization. After these general constraints, the dependencies among projects are managed defining three set of particular projects: mandatory projects, set of projects with either-or relation and the set of projects with mutually exclusiveness relation. Finally, to control the scheduling a set of predecessors for each project is defined in order to set the additional schedule constraint. The model is at the end validate on a set of projects of an automotive manufacturer. This model determines the optimal mix of projects that aims at maximizing profitability for the overall organizations success. The interdependencies of projects are also considered in the model, but the author acknowledge that the further research should develop other criteria and objectives which go beyond the merely financial perspective.
On the other hand, with a particular focus on customer experience, Sahu et al. (2018) highlight through experts interview analysis four dimensions with corresponding CSFs:

- Analytics: Data analytics; Process analytics; Trends analysis.
- Business: Strategic execution; Business model; Value proposition.
- Customer: Process; Collaboration; Services; Engagement.

- Digital: Integration; Capability; Capacity.

Focusing instead on the maritime transport industry, Tijan et al. (2021) analyze from a comprehensive literature review a list of CSFs for digital transformation. The factors concentrating on actively reshaping business model and organization strategies underline again the importance of strategic alignment of digitalization initiatives. They insist in fact on having a clear vision of the scope and results the firms want to obtain in order to effectively implement and select the best initiatives. Furthermore, the attention is point to people and communication insisting on the importance of establishing leadership roles from top management to project manager and investing in team skills training. Particularly, it is useful to involve different organization functions to complete the diversified set of skills required. Fluent communication is also evidenced as paramount to build internal collaboration network and efficient cooperation with external stakeholders and clients. Following this objective, the instauration of knowledge and data sharing channels are again fundamental for successful implementation of digital transformation projects. Finally, the financial readiness is the base to ensure the availability of resources to sustain these initiatives.

Pursuing a more general view, Wolf et al. (2018) identify the major challenges in implementing digitalization initiatives and propose corresponding solutions. The main highlighted obstacles include differentiated expectations of customers and final users, existing structure problematic, monotonous workforce and fragmented knowledge, non-transparency and unavailability of data, dependence on partners and authorities, small resources availability, gap between day-today business operations and strategic innovation. The solutions proposed are based on creating the preconditions to adopt the transformation and ensure the digital value creation. This can be achieved through the implementation of agile methods, diversified workforce, training and fostering knowledge, promotion of data exchange and collection, involvement and networking with external partners.

More recently, Correani et al. (2020) have identified a framework to successfully implement digital transformation projects based on three initiatives implemented by ABB, CNH Industrial and Vodafone. The findings are consistent with the previous literature highlighting first of all the importance of having a clear scope and result of digitalization. This scope establishment can be only reached through a clear definition

and alignment of organization strategic goals with digital transformation initiatives. Secondly, data collection and data platforms are fundamental for value creation and both internal and external sources can be leveraged to establish organization's competitive advantage. Another fundamental factor is people management dimensions: it is paramount to identify the project management role that will lead the initiative for coordination and alignment purposes, but also to prepare an experienced and well-trained team with the full capabilities to pursue the opportunities that digital transformation can create.

This evidenced need of considering more diversified criteria and objectives is in line with the complexity of the selection and prioritization problem previously identified in literature. This is confirmed especially because of the high number of stakeholders involved and the consequent definition of success and priorities for each actor (Belassi & Tukel, 1996) and by the complex interdependencies between initiatives and the multi-factor and conflicting objectives on which the decision-making process should be based (Pajares & López, 2014). For this reason, it is possible to conclude that there is still no agreement in literature regarding the models and the involved critical success factors to be used as criteria to select and prioritize projects (Kaiser et al., 2015). The criticality of the issue becomes even more important when considering the complexity and ever-changing landscape that characterize the potential technological development of companies (Tavana et al., 2013).

The consideration on the selection and prioritization process in project portfolio management in general studies and in analysis focused on digital transformation lead the formulation of the following research questions:

1. *Which factors should be considered in a multi-criteria decision method for digital transformation projects selection and prioritization?*
2. *Which weights should be assigned to these criteria when using them in a multi-criteria decision-making method?*

2 Methodology

This section presents the methodology used to perform the study starting from the initial research, for the criteria identification, until the final analysis and results through the AHP method.

2.1 Academic Literature Review and Criteria Identification

First of all, a comprehensive literature review has been performed concerning project portfolio management characteristics. Particularly, the libraries of Scopus, ASCE and Google Scholar were used to collect the most relevant academic literature regarding project portfolio management practices and optimization, as well as research focused on the selection and prioritization problem. The collection and screening phase resulted in 86 relevant articles for review purposes.

The general review of project management and portfolio management served the fundamental purpose of understanding the main objectives and usefulness of these practices, in order to better support the following analysis concerning critical success factors. Consequently, the review has been focused on the selection and prioritization problem, since selecting the right number of projects and balancing the portfolio was found by R. G. Cooper et al. (1998) as the most relevant challenge in project portfolio management. Several studies try to solve this problem analyzing the most effective criteria to assign priorities to projects and create a successful portfolio and it is paramount to base these criteria on the critical success factors of projects (Costantino et al., 2015).

Therefore, a specific focus was dedicated to the investigation of the criteria and factors proposed in literature. This additional screening phase resulted in 29 articles valuable to analyze the most relevant criteria to select and prioritize project. A particular attention was put on digital transformation projects, reviewing academic literature regarding digitalization at large and specific criteria for digital transformation projects evaluation.

The specific analysis of these articles allowed to identify the most useful criteria to select digital transformation projects, to group them in success dimensions and to create a qualitative hierarchy based on the presence of each criterion in the academic articles. In order to validate and quantitatively weight these criteria, the AHP method described in

the next section was used and a group of experts in digital transformation projects was contacted to collect data.

2.2 Analytical Hierarchy Process (AHP) Method and Criteria Weighting

In order to assign priorities and weights the criteria identified the AHP method was selected as multi-criteria decision methodology.

This method is included in the category of Multi-attribute Decision-Making criteria, which is found to be the most suitable for analyze selection and prioritization problem (Danesh et al., 2017). Furthermore, following the of Vidal et al. (2015), the AHP results to be the best method after a scoring analysis based on the different 12 main characteristics that should define a multi-criteria decision methodology.

The model has been used also in many project management applications since it provides a well-structure, systematic and flexible procedure for business decision and that can be also understood by managers in practice (Vidal et al., 2015). The effectiveness of this method is especially fostered by the possibility of integrating qualitative and quantitative decision-making, which perfectly satisfy the need of managing the complex aspects of project portfolio management.

The AHP methods allows in fact the relative comparison of different alternatives and involves seven characteristics that explain the strength of the method (Vidal et al., 2015):

- Possibility to compromise different objectives
- Effective approach to complex systems
- Analysis of interdependences among elements
- Possibility to build a hierarchical structure
- Measure of both tangible and non-tangible aspects
- Solid coherence and consistency in judgements
- Synthesis capabilities

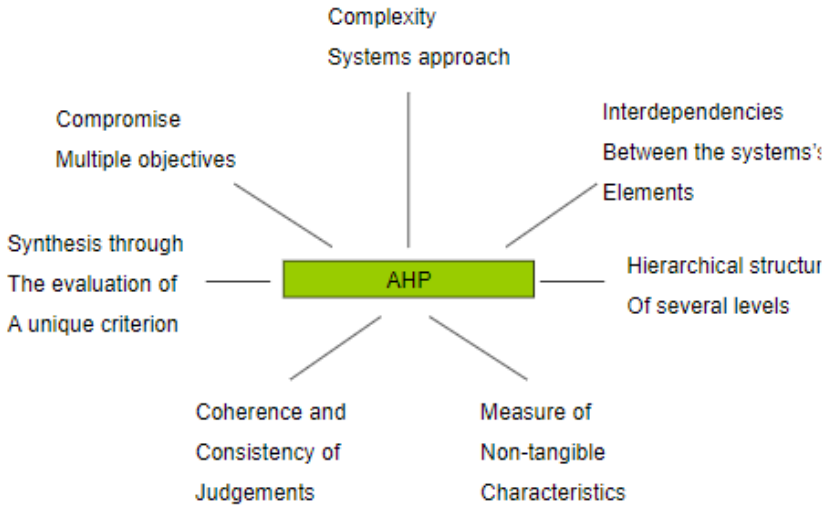

Figure 7. AHP method characteristics under complex contexts (Vidal et al., 2015)

The AHP method can be generally structured in two main phases which comprehend the design and evaluation. The design phase has the aim of creating a hierarchy and requires a comprehensive understanding of the subject of interest. In any case, hierarchies designed can vary among decision makers and even preferences about the specific elements can be very diversified. This step can be seen as a combination of three simultaneous actions defined as identification of levels and elements, concept definition and question formulation (Vargas et al., 1990). Particularly, the levels of the hierarchy are identified and as a consequence the element corresponding to each level. If during the questions formulation phase and evaluation the respondents find difficulties in answering the hierarchy should be revised. As suggested by Vargas et al. (1990), the design phase is an iterative process where the main questions posed when evaluating the hierarchy determine the levels and elements of the structure.

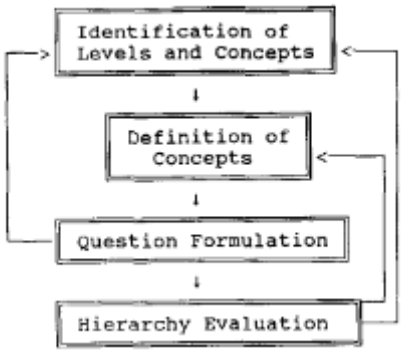

Figure 8. AHP method steps (Vargas et al., 1990)

Following the design phase, the next step concerns the hierarchy evaluation. For each criterion, the decision maker confirms, through a pairwise comparison, which element contribute more to the element in the level above. This practice is iterated with all the elements in the hierarchy at all levels. The paired comparisons result in a matrix of comparisons. The exact steps to perform during the AHP methods are listed by Zahedi, (1986):

1. Creation of the hierarchy by breaking down the problem into decision elements
2. Collection of data through pairwise comparisons
3. Perform the "eigenvalue method" to calculate the weights of hierarchy elements
4. Aggregation of the relative weights resulted for each element to define the priorities for the alternatives

The first step generally results in the following schema:

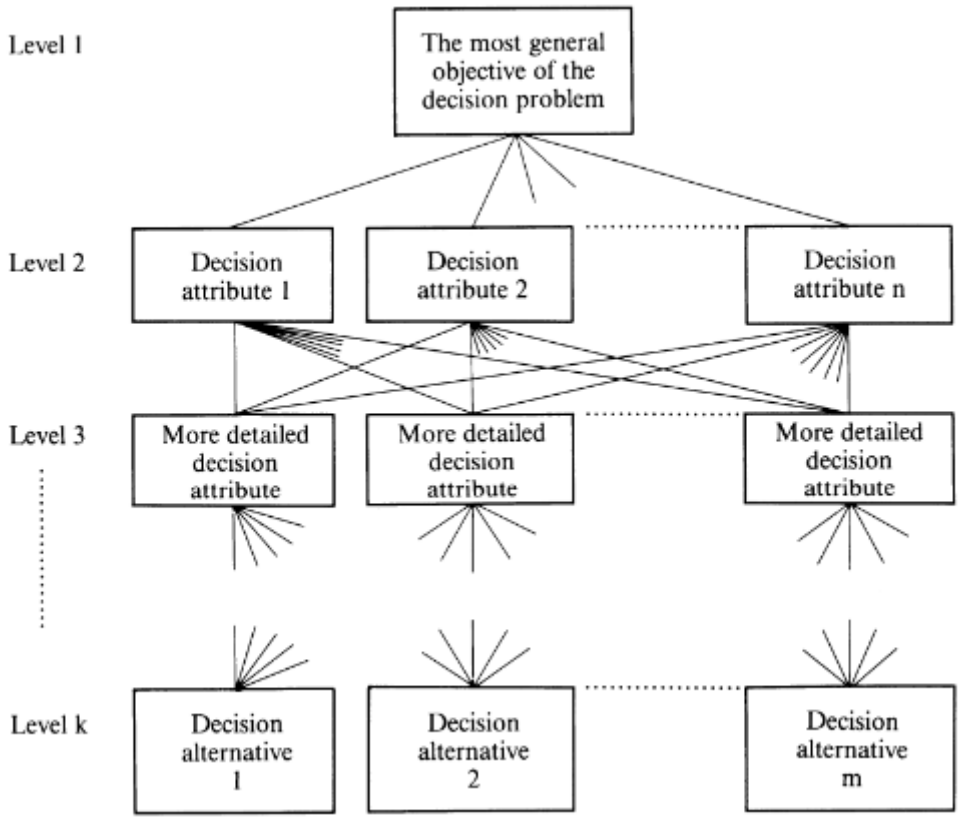

Figure 9. Hierarchy structure of the AHP method (Zahedi, 1986)

Thanks to this schema it is possible to perform the second step through a pairwise evaluation of the different elements in order to confirm which contribute more to element in the level immediately above. The decision-maker adopt the following fundamental scale of absolute numbers to express its judgements (Saaty, 2004):

Intensity of Importance	*Definition*	*Explanation*
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining *n* numerical values to span the matrix

Figure 10. Fundamental scale of AHP method (Saaty, 2004)

Thanks to the data collected from decision-makers it is then possible to create the reciprocal matrix A of comparisons and apply the eigenvalue method (Saaty, 2004):

$$\begin{array}{c} \\ \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & \cdots & A_n \\ w_1 & w_2 & \cdots & w_n \end{array} \\ \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ & & \vdots & \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix} \end{array}$$

It is noticeable that in order to obtain the vector $w = (w_1, \ldots, w_n)$ it is necessary to solve the system of equation $AW=nw$.

The solution's existence is defined by the fact whether n is or not an eigenvalue of the characteristic equation of A. However, the matrix has rank 1 and all the eigenvalues are equal to zero except for one. Therefore, n result as the principal eigenvalue of the matrix and of course w is the corresponding eigenvector. Thanks to this process it is possible to identify the weights associated to the elements of the hierarchy through the vector w (Saaty, 2004). Of course, as a result of the decision makers judgements, the pairwise comparison matrix A can result as inaccurate. However, a consistency ration can be implemented to assess the solution of the eigenvalue problem and it is generally assumed the value of 0.1 as acceptable. This characteristic of the AHP method make the procedure even more appealing to solve subjective and complex problems (K H Chua et al., 1999).
Finally, the fourth and final step fundamental to calculate the overall weights of the elements of the hierarchy. If more than 2 levels are obtained in the initial design phase, the overall weight of each factor is obtained through the successive multiplication of the weights obtained at each level. Thanks to this process, the priority of factor in the lower level reflects its contribution to the overall goals stated at the top of the hierarchy (K H Chua et al., 1999).
The success of the AHP method is generated by the robustness and simplicity of the procedure. The theory is based on the following axioms (Vargas et al., 1990):

1. Reciprocal comparison: the decision maker states his preferences and must specify the intensity of them following the reciprocal condition that if factor X is a times more preferred than Y, than Y is $1/a$ times more preferred than X.
2. Homogeneity: since the scale is bounded the judgements expressed are homogeneous.
3. Independence: when the decision makers express preferences the criteria are assumed to be independent of the alternative elements
4. Expectations: the hierarchy is assumed to be complete to ensure taking effective decision and comparisons.

2.3 Practical application of the AHP method

In this work, the method has been applied following exactly the four steps listed by Zahedi (1986). Of course, the aim of the analysis is to identify a hierarchy of criteria to select and

prioritize digital transformation projects and assign weights to the elements identified. This hierarchy can be useful for managers to evaluate digital transformation projects when trying to build a successful portfolio.

As a first step, the hierarchy was created through the analysis of the literature addressing the critical success factors to select and prioritize projects. Then 29 articles were selected to investigate the most effective criteria and success dimensions following the general approach reported in the same articles.

Secondly, the data collection through pairwise comparison was performed thanks to a group of professionals from different industries, but with a role strongly focused on digital transformation. Particularly, the following criteria have been adopted to select the professionals that could participate in the pairwise comparison:

- Professional role as Head of department, Project Manager or Consultant in the digital transformation department of organizations
- Professionals involved in international projects in large organizations
- Located in the European Economic Area
- More than 5 years of experience in digital-related role
- Leadership and decisional position in digital department and projects

Then a survey on Google Form enabling the pairwise comparison and following the AHP scale suggested by Saaty (2004) was submitted to the participants in order to express their weighted preference at the first level of success dimensions and the second level composed by the criteria.

Once all data have been collected, the results were calculated following the method and the model on Excel created by Goepel (2013). The model allows to insert for each participant, his/her answers regarding the preferences for each criterion. A summary sheet displays the final results and other final sheets solve the eigenvalue problem through the eigenvalue method mentioned above. Particularly, the model was set and used with the linear 1 to 9 AHP scale and priorities p_i in each participant's sheet are calculated using the row geometric mean method (RGMM), with the pairwise comparison through the matrix $A = a_{ij}$:

$$r_i = \exp\left[\frac{1}{N}\sum_{j=1}^{N}\ln(a_{ij})\right] = \left(\prod_{i=1}^{N} a_{ij}\right)^{1/N}$$

$$p_i = r_i ./ \sum_{i=1}^{N} r_i$$

For each of the participant it is possible also to check the inconsistencies in their preferences and weighted judgements. The strongest inconsistencies are found investigating the pair i,j with:

$$\max(\varepsilon_{ij} = a_{ij} * \frac{p_j}{p_i})$$

Then, the consistency indices calculate in each participant's sheet and in the summary sheet are based on the principal eigenvalue λ_{max} (obtained from the priority eigenvector from RGMM in each participant's sheet or from the eigenvalue method in the summary sheet). The consistency index CI and the consistency ratio CR are given by:

$$CI = \frac{\lambda_{max} - N}{N - 1}$$

$$CR = \frac{CI}{RI}$$

For the consistency ratio it is used the Alonson/Lamata linear fit (Goepel, 2013):

$$CR = \frac{\lambda_{max} - N}{2.7699N - 4.3513 - N}$$

Thanks to this procedure the geometric consistency ratio is also displayed by the model using:

$$CGI = \frac{2\sum_{i<j} \ln a_{ij} - \ln \frac{p_i}{p_j}}{(N-1)(N-2)}$$

The model finally aggregates the priorities obtained in the different participants' sheet in the summary sheet. The k participants inputs are aggregated through the weighted geometric mean of the matrices elements $a_{ij(k)}$. The weight of each decision maker was set equal to 1. The elements of the consolidated matrix C are calculated as (Goepel, 2013):

$$c_{ij} = \exp \frac{\sum_{k=1}^{N} w_k \ln a_{ij(k)}}{\sum_{k=1}^{N} w_k}$$

Finally, a useful indicator is calculated in order to understand the consensus among the participants' preferences. The consensus indicator, using Shannon alpha and beta entropy (Goepel, 2013) are reported below:

$$S^* = \left[M - \exp(H_{\alpha \min})/\exp(H_{\gamma \max})\right]/\left[1 - \exp(H_{\alpha \min})/\exp(H_{\gamma \max})\right]$$

$$M = 1/\exp(H_{\beta}).$$

This model allows not only to identify the main results, but also to check the potential inconsistencies and consensus in the participants answers. Furthermore, for each priority resulted for the criteria analyzed, the errors are displayed in order to validate if the difference between the alternatives is significant. It is in fact possible that, even if the consistency ratio is below the set threshold (10% as suggested by Saaty (2004)), errors are significantly high and the weights overlaps in the displayed ranges.

The methodology described in this section is applied in practice to identify and weight the criteria to select and prioritize digital transformation project. The results of this analysis aimed at facilitating the creation of a successful project portfolio are reported in the next chapter.

3 Application of the AHP method

3.1 Criteria identification from Critical Success Factors in academic literature

The first objective of this work is to identify the criteria to select and prioritize digital transformation projects. In fact, there is still no agreement on the topic despite numerous research and a great effort should be applied in this direction given the strategic importance of the subject (Kaiser et al., 2015). Particularly, the attention in this phase is focused on digital transformation projects given the growing number of initiatives in different industries and the high uncertainty in the objectives characterizing different industries (Isikli et al., 2018).

As stated in the methodology section, this analysis aims at identifying the criteria and organize them in a hierarchy to support the AHP method. This procedure allows to also assign weights and priorities to the elements identified and prepare a solid basis for future decision-making processes and projects evaluation. While in the next chapter the attention is put on the data collection and calculation associate with the AHP method and professionals support, this section is focused instead on the first step of the procedure through the identification of criteria and design of the hierarchy (Zahedi, 1986).

This first step for criteria identification was performed through the review of academic literature focused on critical success factor identification in different industries and also with a focus on digitalization initiatives, since the criteria to select and prioritize projects in a portfolio should be based on the critical success factors to ensure the organizational success (Costantino et al., 2015).

The identification of criteria was based on 29 screened articles, which addresses the selection and prioritization problem in project portfolio management covering different years, industries and actors perspective. Firstly, for each article, the critical success factors suggested have been investigated as a base for the subsequent aggregation. Secondly, the elements suggested have been merged and compared to identify the shared critical success factors can act as criteria in the projects selection. Finally, the criteria shared by at least 5 sources in academic literature (more than 15% of the total 29 sources used) have been included in the final list used for the hierarchy of the AHP method.

As a result, 16 criteria resulted from this analysis covering different aspects of projects. In the table below, it is possible to notice the different criteria identified with the corresponding sources that suggest and validate them based on experts judgements and other previous literature analysis:

Criteria identified	Source from academic literature
Alignment to strategic objectives	(Tijan et al., 2021), (Bai et al., 2021b), (Morakanyane et al., 2020), (Barthel et al., 2020), (Correani et al., 2020), (Wolf et al., 2018), (Sahu et al., 2018), (Project Management Institute., 2017) (de Reyck et al., 2005), (Cooke-Davies, 2002), (Buchanan & Sheppard, 1999)
Top Management Support	(Tijan et al., 2021) , (Marchinares & Aguilar-Alonso, 2020b), (Vogelsang et al., 2018), (Matt et al., 2015), (Alias et al., 2014), (K H Chua et al., 1999), (Belassi & Tukel, 1996), (Pinto, 1990)
Organization's functions involved	(Tijan et al., 2021), (Dreyer et al., 2020), (Vogelsang et al., 2018), (O. P. Sanchez et al., 2017), (Maghareh et al., 2016), (Matt et al., 2015), (Cooke-Davies, 2002), (K H Chua et al., 1999), (Belassi & Tukel, 1996)
Readiness of required technology	(Dreyer et al., 2020), (Morakanyane et al., 2020), (Marchinares & Aguilar-Alonso, 2020b), (Vogelsang et al., 2018), (Sahu et al., 2018), (Osmundsen et al., 2018), (O. P. Sanchez et al., 2017), (Alias et al., 2014), (Cooke-Davies, 2002), (, K H Chua et al., 1999)
Project Manager expertise and experience	(Tijan et al., 2021), (Correani et al., 2020), (O. P. Sanchez et al., 2017), (Matt et al., 2015), (Alias et al., 2014), (Cooke-Davies, 2002), (K H Chua et al., 1999), (Belassi & Tukel, 1996), (Pinto, 1990)
Team skills and experience	(Tijan et al., 2021), (Correani et al., 2020), (Marchinares & Aguilar-Alonso, 2020b), (Vogelsang et al., 2018), (Wolf et al., 2018), (O. P. Sanchez et al., 2017), (Maghareh et al., 2016), (Matt et al., 2015), (Alias et al., 2014), (K H Chua et al., 1999), (Belassi & Tukel, 1996), (Pinto, 1990)
Stakeholders involvement and motivation	(Tijan et al., 2021), (Morakanyane et al., 2020), (Correani et al., 2020), (Wolf et al., 2018), (Vogelsang et al., 2018), (Alias et al., 2014), (K H Chua et al., 1999)

Client involvement and satisfaction	(Tijan et al., 2021), (Marchinares & Aguilar-Alonso, 2020b), (Vogelsang et al., 2018), (Sahu et al., 2018), (Osmundsen et al., 2018), (K H Chua et al., 1999), (Belassi & Tukel, 1996), (Pinto, 1990)
Financing requirements	(Tijan et al., 2021), (Morakanyane et al., 2020), (Isikli et al., 2018), (Alias et al., 2014), Tijani (2021), Morakanyane (2020), Isikili (2018), (Project Management Institute., 2017), (Pajares & López, 2014), (Rogério Tadeu et al., 2011), (R. Cooper et al., 2002), (K H Chua et al., 1999), (Belassi & Tukel, 1996)
Value creation	(Barthel et al., 2020), (Isikli et al., 2018), (Bilgin et al., 2017) , (Matt et al., 2015), (Hernandez et al., 2011), (Rogério Tadeu et al., 2011), (R. Cooper et al., 2002), (Buchanan & Sheppard, 1999)
Size and complexity	(Marchinares & Aguilar-Alonso, 2020b), (O. P. Sanchez et al., 2017), (Project Management Institute., 2017), (Maghareh et al., 2016), (Vidal et al., 2015), (Alias et al., 2014), (Cooke-Davies, 2002), (K H Chua et al., 1999), (Belassi & Tukel, 1996), (Pinto, 1990)
Interdependencies with other projects	(Bai et al., 2021b), (Barthel et al., 2020), (Isikli et al., 2018), (Bilgin et al., 2017), (Project Management Institute., 2017), (Pajares & López, 2014), (Hernandez et al., 2011), (R. Cooper et al., 2002)
Urgency and timings	(Dreyer et al., 2020), (Marchinares & Aguilar-Alonso, 2020b), (Vogelsang et al., 2018), (Project Management Institute., 2017), (Matt et al., 2015), (Belassi & Tukel, 1996), (Pinto, 1990)
Dependency on external factors	(Vogelsang et al., 2018), (Project Management Institute., 2017), (Maghareh et al., 2016), (K H Chua et al., 1999), (Belassi & Tukel, 1996)
Adequacy of initial risk assessment	(Marchinares & Aguilar-Alonso, 2020b), (Vogelsang et al., 2018), (Wolf et al., 2018), (Matt et al., 2015), (Pajares & López, 2014), (Meskendahl, 2010), (Cooke-Davies, 2002), (K H Chua et al., 1999), (Buchanan & Sheppard, 1999)
Capability of monitoring and controlling the project	(Dreyer et al., 2020), (Morakanyane et al., 2020), (Marchinares & Aguilar-Alonso, 2020b), (Sahu et al., 2018), (Vogelsang et al., 2018), ,(Project Management Institute., 2017), (Matt et al., 2015), (Cooke-Davies, 2002), (, K H Chua et al., 1999), (Pinto, 1990)

3.2 Success Dimensions and Hierarchy Design

These criteria have been identified for the main objective of creating a successful portfolio of digital transformation projects. The 16 criteria affect different aspect of the portfolio management success and therefore it is possible to create a hierarchy where the criteria constitute the elements of the hierarchy which are grouped in four different dimensions that contribute to the portfolio success. It is worth noticing that reasoning in terms of portfolio success, the dimensions do not cover only aspects that are specific for individual projects evaluation but consider also dimension impacting strategic objectives and organization benefit at large. In this way, it is possible to identify four different "success dimensions":

1. Organization success dimension: this aspect includes the factors related to organizational characteristics, structure and capabilities.
2. People success dimension: this aspect includes the factors impacting people management, from skills point of view to stakeholders and client management.
3. Project success dimension: this aspect includes the factors that describe the project-specific characteristics, in order to evaluate not only the overall impact at portfolio level, but also the effectiveness of each project
4. Uncertainty success dimension: this aspect deals with the factor investigating the risk management side of portfolio and project management, taking into consideration the external impact and the internal capabilities of monitoring and controlling the project.

These four success dimensions contribute directly to the digital transformation portfolio success and constitute the first level of the hierarchy. Continuing with the design of the second level of the hierarchy to support the first step of the AHP method, it is important to group the 16 identified criteria according to the corresponding success dimensions creating the second level. In this structure, the 4 criteria contribute directly to the Organization dimension, 4 criteria to the People dimension, 4 criteria to the Project dimension, 3 criteria to the Uncertainty dimension. In the next chapter, by calculating the contribution of each criterion to the corresponding dimension and the contribution of the dimension to the overall portfolio success, it will be possible to investigate also the direct contribution of the second level composed by the criteria to the overall objective of digital

transformation portfolio success. It is therefore possible to identify the following hierarchy resulted from the academic literature investigation and that realize the first design step of the AHP method (Zahedi, 1986):

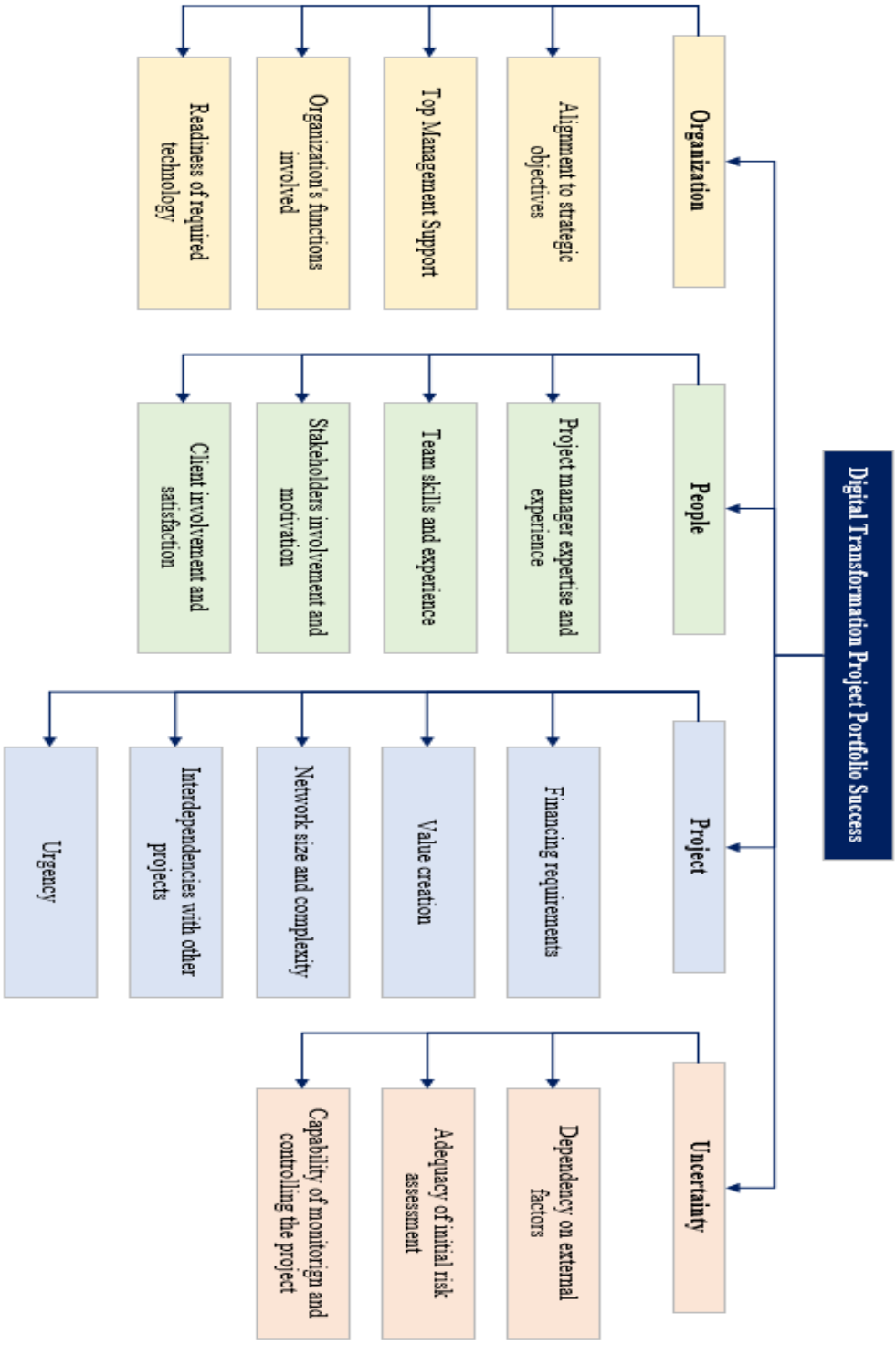

Figure 11. AHP hierarchy design

Furthermore, it is fundamental to describe the meaning of each criterion to clarify which aspect of project and portfolio management they are addressing. The description of each criterion summarizes the aligned views from different authors analyzed during the academic literature review. The clarification of the criteria's meaning is fundamental for the next phase in which the professionals express their judgements regarding the criteria contribution to the success dimensions.

For each criterion, it is also possible to propose an ordinal scale to better link each element to its usefulness in practice. Once the AHP method is completed, each criterion will have an assigned weight that signal their direct contribution to the overall portfolio success. In this way, decision-makers could evaluate the pipeline of projects with ordinal scales for each criterion and multiply the assigned values to the weights found through the application of the AHP method in this analysis.

In the following table, it is possible to read the description for each specific criteria and an ordinal scale from 1 to 5 is proposed to evaluate projects in future once the weights of each criterion are found thanks to the AHP method. Of course, the meaning of each value in the ordinal scale can be changed by managers and decision makers during their decision-making process according to the best needs of the organization:

Success factors	Description	Proposed indicator and scale (from 1 to 5)
Alignment to strategic objectives	Alignment of the project deliverables and benefits to the strategic objectives of the organization	1: Not aligned 3: Aligned with 50% of strategic objectives 5: Covering all strategic objectives
Top Management Support	Level and number of top management roles sponsoring and following the project	1: Not followed by top management actors 3: Sponsored by components of the top management 5: Sponsored and periodically monitored by a top management steering committee
Organization's functions involved	Number of departments and corresponding managers involved and consulted in the project	1: Internal to one function 3: Collaboration between 2 functions 5: Cross-functional project impacting >2 functions

Readiness of required technology	Organization's level of development, implementation and practice of the technology required by the project	1: Technology to adopt from scratch 3: Technology developed and readiness to launch the pilot 5: Technology well implemented and integrated in current practices
Project Manager expertise and experience	Cumulated experience of the role leading the digital transformation initiative	1: First digital transformation project as PM 3: 1-3 years of experience as PM in digital transformation projects 5: >5 years of experience in digital transformation projects
Team skills and experience	Team experience in digital transformation initiatives and level of technology skills	1: First experience in digital transformation projects and necessary trainings on new technology 3: Cumulated experience in digital transformation projects but necessary trainings new technology 5: Solid experience in digital transformation projects and with the required technology
Stakeholders involvement and motivation	Level of communication and motivation in the actors involved in the project	1: Unclear final benefits and absence of incentives 3: Final benefits are clear and shared but lack of inventives schemes 5: Final benefits are clear and shared and inventives schemes are established
Client involvement and satisfaction	Level of communication and inclusion of the client/final user of the project to ensure deliverables satisfaction	1: Client is consulted only at initiation and final delivery of the project 3: Periodical consultation with the client is scheduled for project review 5: The client is continuously involved in project review and development
Financing requirements	Level of organization's resources required by the project	1: <5% of budget allocated to overall digital transformation project portfolio 3: 10-30% of budget allocated to overall digital transformation project portfolio 5: >40% of budget allocated to overall digital transformation project portfolio

Value creation	Value created by the project to quickly recover from the initial investment	1: Payback Period < 6 months 3: Payback Period < 2 years 5: Payback Period > 3 years
Size and complexity	Measure of the complexity in managing the project network of activities	1: Project structured in sequential phases (low Coefficient of Network Complexity) 3: Project structured with simultaneous and overlapping phases (medium Coefficient of Network Complexity) 5: Project structure with simultaneous and overlapping phases and multiple end-to-start relationships (high Coefficient of Network Complexity)
Interdependencies with other projects	Number of resources that need to be shared with other digital transformation projects	1: <10% of resources are shared with other projects 3: 50% of resources are shared with other projects 5: 100% of resources are shared with other projects
Urgency and timings	Expected time required to complete the project	1: <3 months 3: <1 year 5: >2 years
Dependency on external factors	Potential exposure to external risks and PESTEL factors	1: Low exposure 3: Medium exposure 5: High exposure
Adequacy of initial risk assessment	Level of risk analysis already performed on the project	1: Risk register not clearly defined or uncomplete 3: Qualitative risk analysis completed 5: Qualitative and quantitative risk analysis completed
Capability of monitoring and controlling the project	Monitoring the ongoing project thanks to established KPIs in line with organization objectives and capability of implementing controlling actions	1: Uncomplete KPIs/dashboard and low feasibility preparation of controlling actions 3: Complete KPIs/dashboard but low feasibility preparation of controlling actions 5: Complete KPIs/dashboard and feasibility preparation of controlling actions

3.3 Qualitative priorities identified based on occurrence in academic research

Based on the investigation of 29 articles from the academic literature it was possible to identify the 16 criteria, describe their characteristics and propose a potential scale to evaluate potential projects by decision-makers. The weights assigned to each criterion are calculated in the next chapter thanks to professionals' judgement and AHP procedures.
On the other hand, it is also possible to establish already qualitative priorities to be assigned to each criterion based on the number of articles that suggest the particular critical success factor. The identified criteria are covered minimum by 15% of the academic sources used to perform the design hierarchy phase, but it is noticeable that some success dimensions and corresponding sub-elements are more highlighted in literature than others. Therefore, here be low it is reported the qualitative ranking for the success dimensions, which is of course not yet supported by quantitative data collection and calculation:

Total academic articles used	29			
Total criteria identified	16			
Success Dimensions	**Number of criteria**	**% included criteria**	**Number of academic articles**	**% included articles**
Project	5	31%	25	86%
Organization	4	25%	20	69%
Uncertainty	3	19%	17	59%
People	4	25%	16	55%

It is noticeable that the highest portion of sources mention critical success factors that are focused on project-specific characteristics and in fact the highest number of criteria is also included in the Project success dimensions. On the contrary, Uncertainty success dimension include the lowest number of criteria but the number of academic articles highlighting the criteria assigned to this aspect is not so far from the other dimension and even higher than People success dimension.
Focusing on the People dimension, it seems that, although it has the same number of included criteria compared to the Organization dimension, the lowest number of academic

sources insist on this aspect. This point of view could lead to the misleading conclusion that after this preliminary analysis the People dimension results as the less important. However, it is possible to realize that the criteria corresponding to its sub-elements are highlighted and shared by a substantial number of articles and in particular the criterion "Team skills and experience" is the critical success factor most cited in terms of number of research.

In order to ensure a complete view of the qualitative priorities that can be assigned to the different criteria based on the occurrence of articles that highlight the importance of this particular critical success factors, the table below shows the insights for the sub-elements of each success dimension:

Total number of articles		29	
Dimension	Criteria	Number of articles	% of articles
Organization	Alignment to strategic objectives	11	38%
	Top Management Support	8	28%
	Organization's functions involved	9	31%
	Readiness of required technology	10	34%
People	Project Manager expertise and experience	9	31%
	Team skills and experience	12	41%
	Stakeholders involvement and motivation	7	24%
	Client involvement and satisfaction	8	28%
Project	Financing requirements	10	34%
	Value creation	8	28%
	Size and complexity	10	34%
	Interdependencies with other projects	8	28%
	Urgency and timings	7	24%

Uncertainty	Dependency on external factors	5	17%
	Adequacy of initial risk assessment	9	31%
	Capability of monitoring and controlling the project	11	38%

This preliminary view of the priority of the criteria assigned through the investigation of the literature review offers a quite homogenous importance through the different dimensions' elements. As previously explained, the criteria selected are highlighted in at least 15% of the 29 articles use and specifically the "Dependency on external factors" is the CSFs less mentioned with its inclusion in only 5 academic articles.

It is clearer now that the People dimension, even if mentioned in the lowest number of articles, includes criteria which are strongly shared and suggested by the academic literature especially with the "Team skills and experience" criterion which is cited in 12 different research.

Finally, it is possible to identify the most important criteria for each dimension thanks to this preliminary investigation and overview of the academic literature status:

- "Alignment to strategic objectives" for the Organization success dimension, mentioned in 11 academic research.
- "Team skills and experience" for the People success dimension, mentioned in 12 academic research.
- "Financing requirements" and "Network size and complexity" for the Project success dimension, mentioned in 10 academic research.
- "Capability of monitoring and controlling the project" for the Uncertainty success dimension, mentioned in 11 academic research.

The most relevant results from the quantitative calculation provided by the data collection through experts' judgments and the calculation expected in the final steps of the AHP method are presented in the next chapter. Of course, the findings described in the next section have a more solid quantitative base and are supported by current professional preferences covering major role in the digital transformation department of organization in different sectors.

3.4 Professionals Identification and Data Collection

In order to perform the data collection step of the AHP method, professionals were involved to express judgements regarding the pairwise comparisons needed by this procedure.

Specifically, a survey created to the platform Google Form was designed in order to facilitate the judgements. First of all, a description of the general work was explained in order to communicate the overall understanding of the analysis and the purpose of their answers. Secondly, a description of the success dimensions was reported in order to clarify the hierarchy structure and the grouping of the different criteria. In this way, professionals were able to express judgements in the pairwise comparisons between the main four dimensions, using the 1 to 9 scale proposed by Saaty (2004).

Then, within each dimension, the proposed criteria were defined to ensure the clarity of their meaning for the experts and again the pairwise comparison was enabled to express consistent and clear judgements.

To screen the potential experts, the criteria listed in the methodology chapter were applied in order to select experienced professionals focused on the digital transformation areas of organizations. With the objective of selecting managers that actually have a decision-making role in digitalization projects, professional with the role of "Head of digitalization", "Digital Project Manager" and "Consultant in Digital Transformation" were prioritized in the screening. Furthermore, to guarantee a more solid level of experience, only professionals with more than 5 years in digital transformation roles were contacted, but with of course more general experience in their industry. Finally, it was ensured that the involved experts were part of a company having international projects in order to include the globalized complexity of large organizations. Following this procedure, 56 experts were contacted and 12 answers have been received with complete information to enable the AHP method calculations, resulting in a response rate of 21%.

The important objective of collecting answers from diversified industries was reached. Since digitalization is affecting several industries with great dynamism (Isikli et al., 2018), it is paramount to collect judgements from different perspective that reflect the different needs and pace of change that characterize different industries. Particularly, it was possible to collect answers from Automotive, Banking & Finance, Chemicals &

Pharmaceuticals, Management Consulting, Manufacturing and Marketing& Advertising industries. To communicate the specific percentages of industries reached during the survey the following graph is reported:

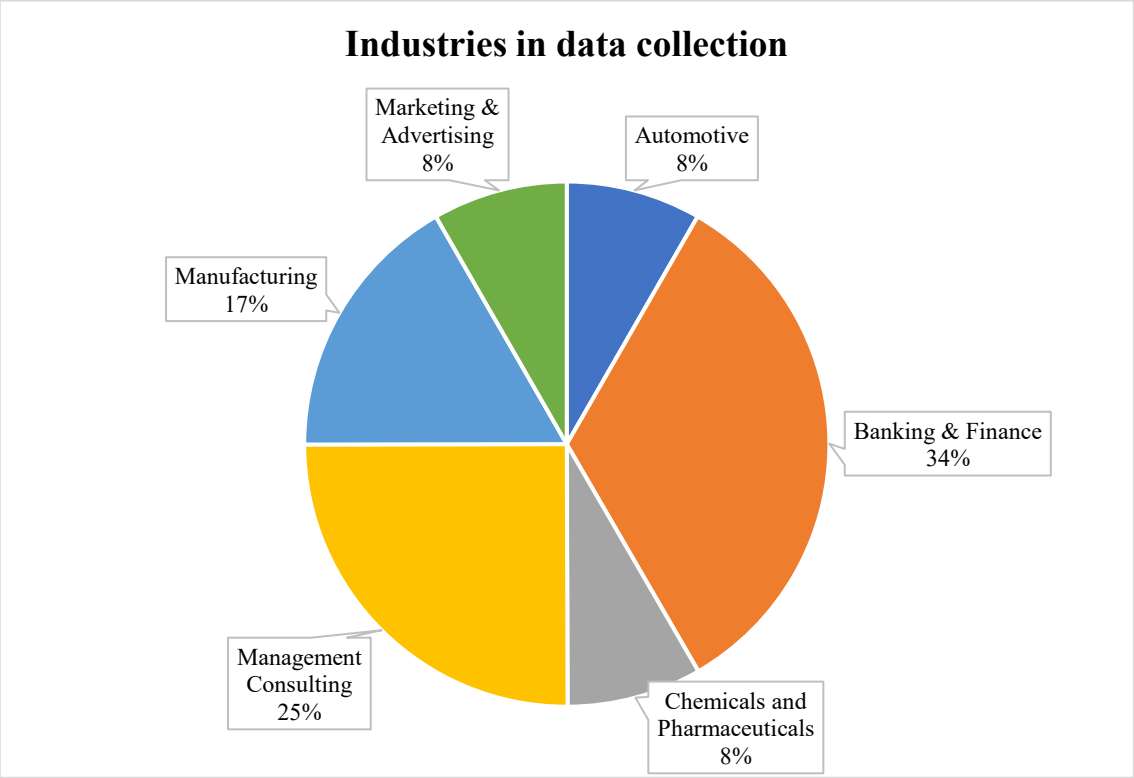

Figure 12. Industries reached in the data collection

It is worth noticing that 25% of answers obtained are from consultants role which is really important to include the different perspective of these type of roles compared to professional directly involved in specific organizations. This differentiation and the corresponding investigation were particularly pointed out by K H Chua et al. (1999) in their critical success factors analysis in the construction industries.

Each of the 12 experts working in the 6 different industries listed above, performed the complete pairwise comparison of both the first level of success dimensions and second level of criteria within each success dimension. In this way it was possible to proceed with the creation of the comparison matrix, calculation of local weights through the eigenvalue method and the aggregation of the overall weights to define the final priorities to answer the second main posed research question. The detailed results are presented in the next section as well as the relevant consistency indexes to validate the analysis.

3.5 Weights assignment and main results

The data collected from professionals' judgement have been inserted in the Excel model reproducing the AHP method following the approach of Goepel (2013). Five different worksheets were used to insert data and perform the eigenvalue method proper of the AHP method in particular for the success dimension and for the four subgroups of organization factors, people factors, project factors and uncertainty factors.

Starting from the first level of the hierarchy analyzing the four success dimensions, the results showed an overall consistency ratio of 5,4% respecting the threshold of 10% generally admitted in theory. The consensus indicator was moderate and particularly at a level of 52,7%. The following table and graph report the final results for the first level of the hierarchy:

Success dimensions	Weights	+/-	Ranking
People	0,578	0,234	1
Organization	0,185	0,065	2
Project	0,152	0,043	2
Uncertainty	0,084	0,014	4

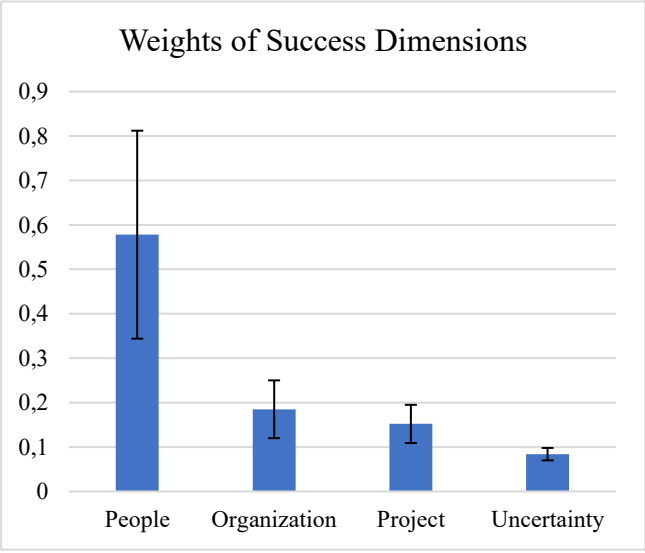

Figure 13. Resulted weights of success dimensions

It is noticeable that the People dimension resulted as the most impactful dimension (weight of 57,8%) following the experts opinion. The error interval is the highest but is not overlapping the other dimensions. Organization and Project dimensions have slightly

different weights but the errors intervals are overlapping nd it is not possible to define a real priority between them. Finally, the least dimension is Uncertainty with 8,4% of assigned weight.

Investigating instead the factors for each success dimension, it was possible to obtain within the Organization dimension's criteria a Consistency ratio of 1,2%, confirming the reliability of results. However, the Consensus indicator is lower about 34,9%. The lower consensus is reflected in the results shown here below:

Organization dimension	Weights	+/-	Ranking
Top Management Support	0,439	0,079	1
Alignment to strategic objectives	0,202	0,032	2
Organization's functions involved	0,183	0,033	2
Readiness of required technology	0,176	0,008	2

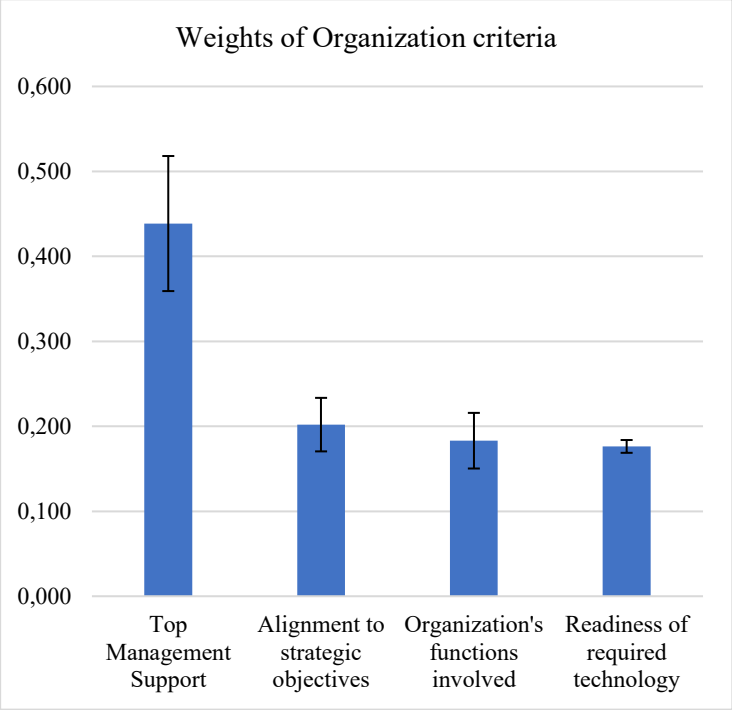

Figure 14. Resulted weights for Organization dimension's criteria

The Top Management Support criteria is undoubtably the most impactful for experts' judgement. The assigned weight is strongly above the other at a percentage of 43,9%. On the other hand, it is not possible to assign a strong ranking among the other three criteria since the not only the weights are similar, but the errors are overlapping.

Following with the second dimensions, the People related criteria showed a very low consistency ratio of 2%, but also a consensus lower than moderate at 44,1%.

People dimension	Weights	+/-	Ranking
Client involvement and satisfaction	0,412	0,045	1
Team skills and experience	0,232	0,057	2
Stakeholders involvement and motivation	0,205	0,041	2
Project Manager expertise and experience	0,151	0,028	4

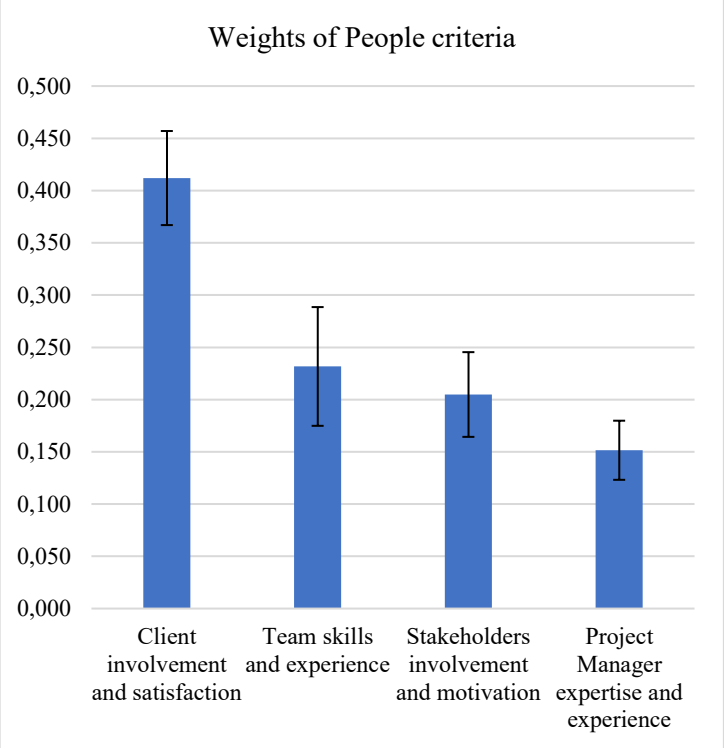

Figure 15. Resulted weights of People dimension's criteria

The Client Involvement and Satisfaction criteria is found as the most important with a weight of 41,2%. The other criteria are overlapping the error intervals, but it is possible to identify more impactful weights for the criteria of Team skills experience and Stakeholders involvement and motivation, respect to the least weight of 15,1% assigned to the Project Manager expertise and experience.

The third success dimension is the Project-specific criteria, which resulted ina consistency ration of 4%, below the acceptance threshold as desired, and a stronger Consensus indicator of 57,5%.

Project dimension	Weights	+/-	Ranking
Value creation	0,479	0,151	1
Financing requirements	0,172	0,052	2
Interdependencies with other projects	0,127	0,021	3
Urgency	0,116	0,046	3
Network size and complexity	0,106	0,029	3

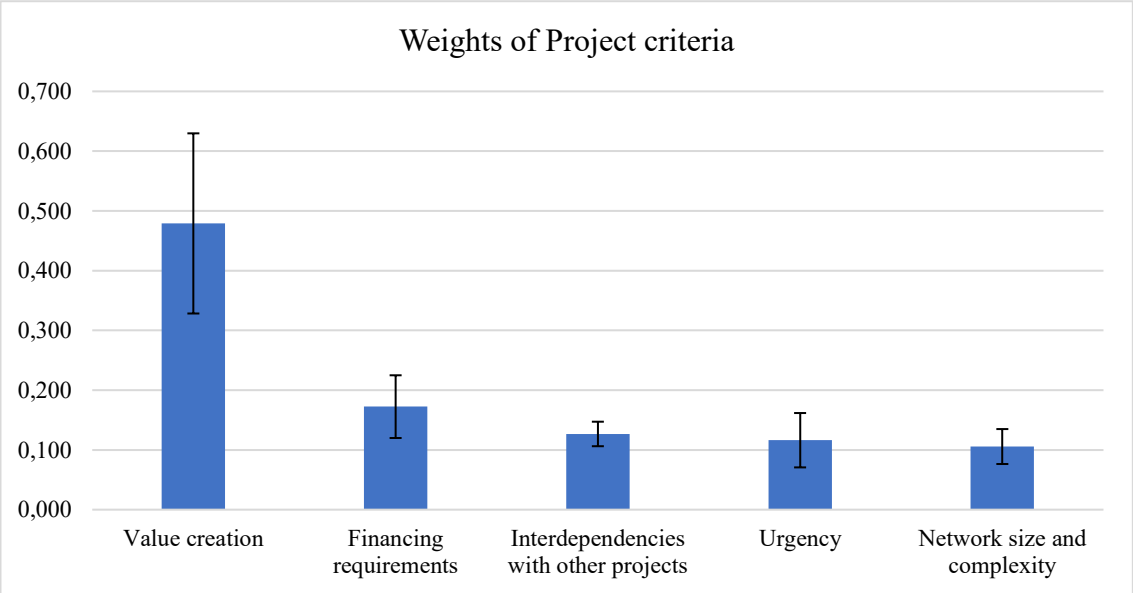

Figure 16. Resulted weights of the Project dimension's criteria

The Value creation criteria resulted as the most impactful, with a weight of 47,9%, very different from the others, The other criteria show similar weights in the graph with some overlapping error intervals. However, the Financing requirements is evidently the second with the highest weight reaching 17,2%. The other three criteria report similar weights with the lowest, Network size and complexity, about 10,6%.

Finally, the last success dimension is related to the criteria corresponding to manage the Uncertainty. The resulted consistency ratio is very low and approaching 0%, but also the consensus indicator is the lowest around 29,5% highlighting some strong different opinion among the 12 participants. However, the ranking among the three criteria of this dimension is quite defined:

Uncertainty dimension	Weights	+/-	Ranking
Capability of monitoring and controlling the project	0,401	0,003	1
Adequacy of initial risk assessment	0,305	0,002	2
Dependency on external factors	0,294	0,002	3

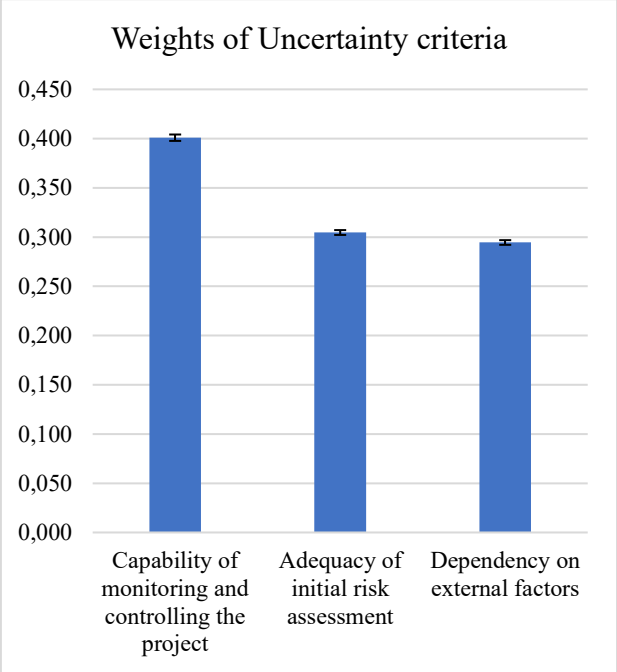

Figure 17. Resulted wieghts of the Uncertainty dimension's criteria

The capability of monitoring and controlling the project is the most impactful criteria with 40,1% of weight. Then, the second position is the ranking is assigned to the Adequacy of initial risk assessment with a weight of 30,5%. Finally, the lowest weight of 29,4% is assigned to Dependency on external factors. It is possible to define clear priorities thanks to the lower and not overlapping error intervals.

Thanks to these detailed figures, it is possible to identify the specific weights and ranking within each success dimension. However, the final step of calculating the overall weights is paramount for the final objective of supporting the decision-making process when selecting and prioritizing projects for the portfolio success. The specific weights of each criterion are further weighted with the priority assigned their corresponding success dimension, in order to obtain the final overall weights. The results obtained are reported below:

Goal	Digital Transformation Project Portfolio Success											
Success dimensions	**Organization**	0,185		**People**	0,578		**Project**	0,152		**Uncertainty**	0,084	
CR 5,4%												
Consensus 52,7%												
Factors		Specific	Overall		Specific	Overall		Specific	Overall		Specific	Overall
	Top Management Support	0,439	0,081	Client involvement and satisfaction	0,412	0,238	Value creation	0,479	0,073	Capability of monitoring and controlling the project	0,401	0,034
	Alignment to strategic objectives	0,202	0,037	Team skills and experience	0,232	0,134	Financing requirements	0,172	0,026	Adequacy of initial risk assessment	0,305	0,026
	Organization's functions involved	0,183	0,034	Stakeholders involvement and motivation	0,205	0,118	Interdependencies with other projects	0,127	0,019	Dependency on external factors	0,294	0,025
	Readiness of required technology	0,176	0,033	Project Manager expertise and experience	0,151	0,088	Urgency	0,116	0,018			
							Network size and complexity	0,106	0,016			
CR index	1,2%			2,0%			4,0%			0,0%		
Consensus	34,9%			44,1%			57,5%			29,5%		

Figure 18. Calculation of overall weight in AHP hierarchy

From the figures reported above it is possible to finally identify the assigned overall weight to each criterion and establish priorities among dimensions and corresponding specific criteria.

The strong weight of the "People" success dimension strongly influences the overall weights of the corresponding criteria, assigning to them the top priority in the overall ranking. Particularly, the "Client involvement and satisfaction" criteria result as the most important factor, followed by the criteria focused on the project's team and other stakeholders, leaving the "Project Manager expertise and experience" fourth in the raking. Then, the "Organization" dimension appears to have the corresponding criteria as priority after the People-related ones. It is worth noticing that the " Top Management Support" has a weight very neat to the first criteria, highlighting its importance.
Only the "Value creation" (Project dimension) and the "Capability of monitoring and controlling the project" (Uncertainty dimension) criteria obtain weights that are higher than some Organization-related factors. It is important to notice that "Value creation" has a particularly higher weights than the other factors included in its dimension.
The other elements of the Uncertainty dimension compose the lowest positions of the ranking followed by the Project dimension criteria. Specifically, "Interdependencies with other Projects", "Urgency" and "Network Size and Complexity" close the ranking with similar weights, respectively of 0.019, 0,018 and 0,016.

The interesting results of the study can be seen in some important differences calculated in the overall weights. The first ranked criterion quite doubles the second one in weight with a value of 0,238. Furthermore, there is an important difference even between the first three ranked criteria and the fourth "Project Manager expertise and experience", which appears more similar to the weights reported for the Organization-related criteria. The differences are even more noticeable when looking at the lowest weights corresponding to the "Uncertainty" and the "Project" dimension. In fact, it is possible to say that the overall weights range from 0,238 to 0,016, strongly caused by the huge difference in experts' judgements regarding the importance of the four different success dimensions.

The following table clarifies the overall ranking and weights assigned to the identified criteria as a final result of this study:

Dimension	Criteria	Overall Weight	Ranking
People	Client involvement and satisfaction	0,238	1
People	Team skills and experience	0,134	2
People	Stakeholders involvement and motivation	0,118	3
People	Project Manager expertise and experience	0,088	4
Organization	Top Management Support	0,081	5
Project	Value creation	0,073	6
Organization	Alignment to strategic objectives	0,037	7
Organization	Organization's functions involved	0,034	8
Uncertainty	Capability of monitoring and controlling the project	0,034	9
Organization	Readiness of required technology	0,033	10
Project	Financing requirements	0,026	11
Uncertainty	Adequacy of initial risk assessment	0,026	12
Uncertainty	Dependency on external factors	0,025	13
Project	Interdependencies with other projects	0,019	14
Project	Urgency	0,018	15
Project	Network size and complexity	0,016	16

4 Discussion of results

4.1 Reflections on main findings and comparisons

The results displayed in the previous section are the outcome of an investigation performed through the collection of 12 experts' judgements. These professionals play decisional roles in the digital transformation departments and projects of important organization. In this way, the figures obtained are the result of a specific focus on digital transformation projects and at the same time include the more general findings of portfolio management literature at large. In fact, different industries were involved to gain a diversified opinion among experts. Particularly, 25% of professionals were from the consulting industry, a field where people can have a different perspective on best practices and procedures to manage projects and also different results can be obtained when focusing on criteria to select projects (K H Chua et al., 1999).

The fact that professionals are involved in international organizations allows to include in their judgements the experience and expertise in complex environment, a characteristic that is always relevant in the project portfolio management context especially concerning digital transformation (Isikli et al., 2018).

In the following, sections the results obtained for each success dimensions are analyzed and compared with previous research in order to highlight differences and confirm important insights of portfolio management practices in the digital transformation context. The success dimensions are listed by decrescent order of assigned weight resulted from the AHP method.

People success dimension

The success dimensions that resulted as the most impactful to the digital transformation portfolio success was the one related to People. In particular, the "Client involvement and satisfaction" criterion resulted as the most important, highlighting the importance of collaborating with the final client in digital transformation projects. The importance of this factor is remarked by Sahu et al. (2018), which dedicates one of the 4 important categories of success factors for digital projects entirely to customers, with great attention on their engagement and collaboration. Also (Marchinares & Aguilar-Alonso (2020b)

includes the customer satisfaction factors as one of the criteria used to select projects through machine learning algorithm. Referring to the more general literature studying the selection of projects, the relevance of customers can be found also in the Project Implementation Profile developed by Pinto (1990) who suggest that the customer involvement must be performed not only at the beginning but through the whole project life. The project is intended for the final user and therefore this criterion should be considered as fundamental.

Furthermore, even client consultation and client satisfaction are included in the most important critical success factors identified by Belassi & Tukel, 1996). The other criteria related to people management results in any case in the first position of the overall ranking and are more focused on the internal stakeholders involved in the process, like Project Manager and the team expertise, skills and experience. These criteria are also highlighted both in the more general portfolio management literature and in the recent research focused on digital transformation as explained in the previous sections.

The higher assigned weights of this dimension compared to all the other criteria insist on the importance of people management in digital transformation projects. The attention to people interactions through collaborative iteration is a strong characteristic of the Agile project management model (Stettina & Hörz, 2015). This new approach to project management has been found to be often suitable to manage the uncertainty of project management and to better involve the final user in the development process (Nerur & Balijepally, 2007). In fact, also Wolf et al. (2018) propose the Agile Project Management as a solution to foster digital transformation in organizations, supporting at the same time both the internal routines between employees and the collaboration with the external client.

In conclusion, it is possible to notice that the obtained results concerning the People dimension and its corresponding criteria suggest the importance of focusing also on the professional involved in projects and not only on the technical data describing the iron triangle factors. A deeper observation also reflects the suggestion of Agile method as an important tool to manage projects at single and portfolio level to address both the client involvement needs and the uncertainty affecting digital transformation projects.

Organization success dimension

This dimension appears to be overall the second most important category of criteria in the overall ranking. Particularly, the "Top Management Support" criterion is strongly more weighted by experts since it is considered to have a strong impact on the success of project and portfolio management. This factor has been selected as one of the most important also in research focusing on general portfolio management or other industries (Belassi & Tukel, 1996; K H Chua et al., 1999; Pinto, 1990). More recently, also Alias et al. (2014) in research with similar objectives to this study, identify this criterion as one of the 11 most important critical success factors to select projects in the portfolio creation through a comprehensive literature review. It seems therefore fundamental to have the first top line of managers convinced and involved in supporting digital transformation projects to give the right amount of attention and initial resource to achieve the desired results.

The other critical factors identified has a similar assigned weights and were not very differentiated by experts in terms of importance. However, these factors, as alignment to strategic objectives and involvement of different functions are often identified as paramount criteria to ensure the efficiency of the portfolio management practices. In fact, portfolio management is identified as a strong "strategic weapon" by Shenhar et al. (2001) and also the model of Meskendahl (2010) which links portfolio results to business success if based in the link to strategy. Therefore, the presence of this criterion is aligned with the role of portfolio in organizational strategy explained by the academic literature, but it remains less important the Top Management Support following the expressed preferences of professionals. The surprising result is that the criterion "Readiness of required technology" is not strongly differentiated in importance internally to the Organization success dimension. In the most recent literature focused particularly on the digital transformation projects this criterion is often highlighted (Dreyer et al., 2020; Marchinares & Aguilar-Alonso, 2020b; Morakanyane et al., 2020; Vogelsang et al., 2018), but the results of this study rank this criterion with the lowest average weight in the Organization success dimension.

Overall, the strong importance given also to this dimension is in line with the claimed importance of efficiently integrating portfolio management in the organization structure and business routines in order to achieve strategy success. The project portfolio

management must be strongly matched and included in the organizational activities, especially to ensure the strategic transformation required for business sustainability (R. Cooper et al., 2002; Project Management Institute., 2017).

Project success dimension

This dimension was assigned a slightly less weight than Organization dimension by professionals. This reflect that the project-specific characteristics remain in any case important also when evaluating projects at broader strategic level. Of course, these criteria lose importance when they have to be weighted and compared with other factors which better represent the complexity faced at portfolio level. These criteria are fundamental indicators when discussed at project management level but in this study are ranked in lower positions since the other success dimensions are also very impactful.

When looking at the specific results of each criterion in this success dimension, it is very noticeable that the element "Value creation" remains very high ranked and differently weighted compared to the others. This result is in line with one of the four main goals of project portfolio management identified by R. Cooper et al. (2002) and named "Maximization of value". Even when focusing on the recent literature focused on selection and prioritization of digital transformation projects, it is possible to identify the concept of value creation as the main driver for decision making. Isikli et al. (2018) build their selection model for digital transformation projects particularly on profitability, analyzing for each project the created value out of all the cost savings and additional resource requirements that can come out of this kind of projects. Also Barthel et al. (2020) describe the needs to develop financial criteria and monitoring practices for digital transformation projects since the value creation and profitability creation remains fundamental for projects.

On the other hand, the professionals' judgements do not consider complexity and interactions of projects as very impactful for the portfolio success. This result is opposite to the stream of studies that highlights the importance of analyzing complexity and interdependencies between projects to anticipate at the strategic and selective level the potential difficulties that can be faced at operational level. In fact, Pajares & López (2014) insist that the project prioritization and selection is affected by the complex interdependencies between initiatives and the multi-factor and conflicting objectives on

which the decision-making process should be based and the used approaches are not always successful because of poorly selected criteria and overlooking of the complex interdependencies among projects (Bai et al., 2021). The professionals' judgement does not follow this indication of recent academic literature and highlight more the financial side of project management.

Generally, it is possible to notice that the results show the constant importance of the financial evaluation and value creation of digital transformation projects, while the other project-specific characteristics as complexity and timings have lower importance when analyzing the assigned weights.

Uncertainty success dimension

The dimension focused on uncertainty and risk factors is a fundamental category because of the complexity and ever-changing landscape that characterize the potential technological development of companies (Tavana et al., 2013). In this study, the dimension was assigned with the lower weight revealing that professionals were not convinced of the impact of uncertainty management capabilities on the portfolio success. The risk management activities in portfolio management remains a paramount component to ensure the effective achievement of result (Project Management Institute., 2017). However, investigating the obtained results, it is possible to notice that the criteria related to the initial assessment of risks, internal and external, is perceived as less important than the capability of monitoring and controlling the ongoing project. Having the right set of KPIs to monitor activities, to identify deviation to promptly implement controlling action and to clearly link strategic objectives to its operational implementation is fundamental at portfolio and organizational level (Kaplan & Norton, 2001). When focusing on digitalization, this topic becomes even more important and challenging because digital transformation projects require a completely new set of measures and criteria to efficiently monitor the ever-changing environment in all its aspects (Barthel et al., 2020). In conclusion, it is noticeable that risk management activities are fundamental for this type of projects due to the complexity caused by multiple and conflicting objectives and rapid growth of digital initiatives in organization nowadays (Isikli et al., 2018). Even if these criteria result to have lower assigned weights, it is therefore important to dedicate a success dimension to uncertainty management. Particularly, decision makers should

foster their focus on develop strong monitoring and controlling capabilities in their organization and standardize the inclusion of these best practices in their activities.

General considerations and potential managerial application

Thanks to the criteria identified and the corresponding weights assigned through the AHP method, it is possible to create a solid set of criteria to select and prioritize digital transformation projects. IN recent years the increasing uncertainty of the business environment force managers to take decisions under non-deterministic conditions. In this volatile context, it is useful to define an accurate criteria and selection factors to achieve organizational objectives (Costantino et al., 2015).

In fact, many methods have been proposed in recent studies in order to provide a supportive tool for managers' decision making, exploiting consolidated mathematical models or even new AI technologies. Referring to the implementation of new technologies for the selection problem in portfolio management, Marchinares & Aguilar-Alonso (2020b) recently suggest 18 success factors to be used as criteria to select projects throgh a machine learning model exploiting Artificial Neural Network. Isikli et al. (2018) propose instead and integer programming model with a strong focus on digital transformation projects and corresponding criteria.

However, the category of Multi-attribute Decision-Making methods, which include the AHP method, is identified by Danesh et al. (2017) as the most suitable for the selection and prioritization problem in project portfolio management. Also, Vidal et al. (2015) suggest the effectiveness of the AHP method to select projects because of its understandability for managers and for the possibility to easily include qualitative and quantitative criteria that can better represent the complexity of projects. An example of the AHP method used to assign weights to selection criteria can be found in the study of (K H Chua et al., 1999).

Following these reasons, the hierarchy and the weights identified can be a decision-making support tool for managers when evaluating the projects for selection and creation of a successful digital transformation portfolio. Decision makers can exploit the designed structure and the resulted data, to analyze project from each criterion perspective. Projects can be assigned points using ordinal scales for each criterion (as proposed during the identification of criteria). Then the point assigned should be multiplied by the weight of

the corresponding criterion in order to obtain a set of weighted points for each project. Finally, the sum of the weighted point for each project will determine the importance of the project itself. This process is also suggested by Goepel (2013), the author of the Excel model used in this study.

Following another option proposed by Goepel (2013), decision makers and managers can also decide to not use all the criteria proposed according to the specific situation or needs of the organization. In this study, it is possible to notice that the project-specific criteria included in the "Project" success dimension have a lower assigned weight when evaluated at portfolio level. A possible application that can be useful to differentiate these criteria from the other is to exclude them from the general prioritization process when using the AHP method. Decision makers can use in the AHP model only the other three success dimensions (Organization, People, Uncertainty) to evaluate the benefit caused by each specific project to the organization. After this phase, each project can be investigated and plotted in a two-dimensional analysis, comparing the benefit to one project-specific characteristic, like costs, timings or complexity. A graphical example of this application is reported below.

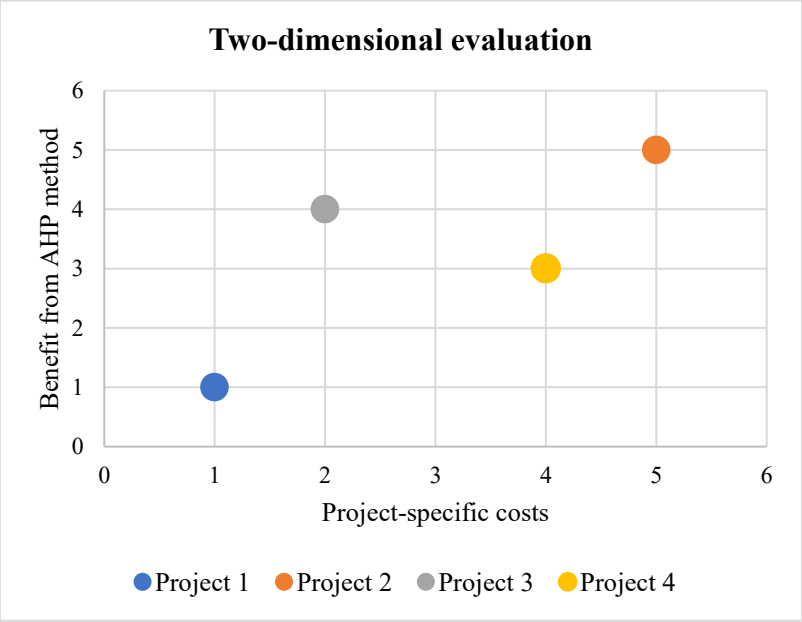

Figure 19. Potential application of two-dimensional evaluation

Thanks to a similar representation, it is easy for decision makers to assess which projects should be selected according to the level of benefits, but evaluating potential resources or timings constraints, which is the crucial challenge of project portfolio management.

In conclusion, it is noticeable that the model proposed can be applied in different ways to support the decision-making process to select and prioritize digital transformation projects in order to create a successful portfolio. It is important to notice that this model allows to include qualitative and quantitative criteria that stimulate the objective and subjective judgement of experts. This is very important to better represent and assess the complexity that characterize the portfolio environment.
It is remarkable that the necessity of going beyond the classic project-specific measures of the "iron triangle" is fundamental at portfolio level and it highlighted not only by the results of this study but especially by the academic literature analyzing the subject in the last decades. Decision-makers in leading position should always keep in mind that project portfolio management and the related activities and practices are included in a broad environment which is strongly impacted by internal and external uncertainty, the structure of the organization and the people involved in the projects.

4.2 Limitations and future research

Despite the usefulness of the model and the potential application explained in the previous section, it is important to highlight some limitations affecting this study.
The literature review highlights the multi-objective characteristics of project portfolio management and the difficulty of establishing a shared set of criteria to select projects given the high number of stakeholders involved and the corresponding different priorities. In this ever-changing and uncertain business environment there is still no agreement on the most useful critical success factors to prioritize initiatives. Therefore, the identified list of criteria presented in this study can vary according to the modalities of the literature review research and investigation and can evolve in time according to the new needs of the general business environment.
Furthermore, referring to the phase of weights assignment to the identified criteria, it is worth noticing that a limited number of professionals were selected and found available. Since the AHP method is based on judgements and perceptions of experts during the pairwise comparison, the restricted number of participants could give more weight to

opinions caused by specific organizational environment and personal experiences which could not completely generate the desired generically applicable results.
In fact, each organization and even each department within have different needs according to their specific situation and can even evolve in time. As a consequence, it is not possible to claim that the list proposed in this study can be the most effective group of criteria to select and prioritize digital transformation projects in each case. Decision makers can of course implement the suggestions proposed by this work and adapt the set of criteria or the corresponding weights according to the tailored company strategy. This is especially true in the digital transformation area which is constantly evolving toward new changes and tools.

In addition, the work can be of course extended with additional and more specific studies. First of all, more organizations and experts can be involved in the pairwise comparison phase of the AHP method. This would generate more widely accepted results and could investigate if the consensus can be higher in a larger panel of experts where personal and too specific experience offset each other.
On the other hand, it would be valuable to narrow the focus of digital transformation projects in a specific industry. In this way, more specific criteria could be identified in order to achieve a higher level of agreement regarding the selection and prioritization process. Focusing on the specific needs of a sector, also the weights and the consistency indicators in the AHP method application can be more accurate.
Finally, this study can be seen as a first step for a broader development of an automated tool to select and prioritized digital transformation projects. A digitalized and automated process which is able to support managers in the decision-making process to select, evaluate and monitor can be an incredible source of added value. With the globalized and complex business environment impacted by a large number of diversified projects, an automated and easily understandable tool to manage the pipeline of projects is a solution often studied and proposed in literature as explained in the previous chapters. Many researchers propose in fact machine-learning-based model that exploit critical success factors of projects for the selection phase. From this perspective, this study can provide the set of criteria and the corresponding initial weights assignment to build the model that can be further developed and tested according to organizational strategic needs.

Conclusions

This study focuses on the selection and prioritization problem in project portfolio management, since it is one of the most crucial phases that can impact the organizational strategic success. Particularly, the field of digital transformation offer a strongly dynamic and ever-changing environment where the decision-making process of management really needs to be supported by model that can help the creation of a successful portfolio.

The literature review performed in this work aims at describing the strategic role played by the project portfolio management in order to understand its goals and challenges. By clearly defining its objectives, it is possible to correctly focus on the critical success factors that can serve as a basis to generate a set of criteria for projects selection.
Following this perspective, the research investigates the solutions proposed in literature in terms of critical success factors and models to better face the selection and prioritization problem. Thanks to this analysis it was possible to identify a set of effective criteria that represent all the characteristics affecting digital transformation portfolio management. The AHP method's procedures have been followed to create a hierarchy of the elements and assign weights to the different criteria. The complete process resulted in a model in line with several aspects highlighted in previous literature and useful for managerial practical application.

Despite the limitations highlighted in the previous section, it is possible to notice that this study provides the insights for the implementation of a model that can support managers in their decision-making process when evaluating and creating a portfolio of projects. The main findings can in fact be used as a basis for an automated system able to prioritize the pipeline of projects.
Finally, it is worth noticing that this study further highlights the strategic importance of the project portfolio management topic at large for business success. Also, the complexity of the topic needs to be further investigated, since it is noticeable that broad attention needs to be dedicated to diversified topic affecting the subject, which space from traditional projects indicators to risks, people management and organizational structure.

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