Managing Knowledge Exchange and Supplier Selection in a Product Technology Transfer

An innovative manual to guide practitioners in the early phases of product technology transfers

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Summary

In an ever more interconnected and integrated world, supply chains are undergoing continuous radical redesigns triggering in turn transfers of products and technologies between suppliers across the globe. This multi-year, cross-functional process, referred to as *product technology transfer* is determinant for the success or failure of a supply chain redesign and involves three stakeholders: the focal company, the sending site and the receiving site. The focal company is the initiator and leader of the process and owns the products to be transferred. The sending site is the current manufacturer, knowledgeable about products, technologies and processes. Finally, the receiving site is the future manufacturer of the object of the transfer.

The product technology transfer successful completion depends on the outcome of three subsequent phases: pre-transfer, implementation and launch. The first one includes the processes for knowledge exchange and supplier selection. The sending site shares with the focal company the knowledge on the products in the scope of the transfer. Moreover, the focal company selects the receiving site among a set of candidate suppliers and distributes to this new manufacturing plant the acquired knowledge. During the second phase, the receiving site implements the transfer in a process supported by the focal company. Finally, in the third phase, the receiving site ramps-up the production and starts distributing the products to the market: the transfer is complete.

This thesis project intent is to *deliver a manual aimed at supporting practitioners in handling the pre-transfer phase of product technology transfers*. The manual tackles the procedures for both knowledge exchange and supplier selection, the two intertwined groups of activities which precede the implementation of the transfer. Overall, the recommendations, guidelines and tools provided answer the following research question:

"How can companies effectively design the pre-transfer of a portfolio of products and their technologies?"

The manual has been developed through participation in several product technology transfers within a single company at different stages in their lifecycle. Crucial have been observations, brainstorming sessions, workshops, and prototypes development and testing. The early stages of this thesis project have focused on the situation analysis, including the processes of ideation, objectives discovery, stakeholder analysis and requirements identification. Subsequently, the process entered the design phase, which has been divided into three steps: conceptual design, preliminary design and detailed design. Throughout, the approach has changed from

descriptive to prescriptive and from simplified to elaborated. Finally, the manual has been validated.

It has been discovered that knowledge exchange is exceptionally challenging because the market for knowledge is imperfect. Indeed, knowledge is partly tacit and often perceived as complex and new. Furthermore, organisational, physical, cultural and normative distances between the parties involved in the transfer pose a real challenge to an adequate knowledge flow, especially for international transfers. Acknowledging these factors, the manual provides recommendations to improve the effectiveness of the knowledge exchange. Practitioners need to focus on experience, expertise and absorptive capacity when designing the team for the product technology transfer project. Furthermore, they ought to maximise the quality of the multi-party interactions which occur throughout the process by leveraging on communication, cooperation and coordination. Enhancing these relational levers requires considering both direct and indirect forms of interconnections. The former group includes online and face to face meetings, training and workshops. Indirect interconnection refers instead to the shared platforms over which knowledge flows between sites in the form of documentation. These platforms should be user-friendly, easily accessible, and logically organised, reducing redundancies and ensuring comprehensiveness. They should also be easy to maintain and standardise to be re-used in new projects.

When thought as a process, supplier selection is the procedure through which a company contacts several short-listed suppliers, ask them to prepare a bid for the object of the transfer, analyse and negotiate the proposals, and finally select the best candidate. The process involves both commercial and technical functions, the latter providing fundamental inputs throughout the procedures. It has been discovered that these inputs form a dense network of interconnections between knowledge exchange and supplier selection to the point that the two processes need to evolve together. In this context, this thesis project delivers a comprehensive tool and recommendations to structure the supplier selection process, by focusing on the factors which have proven to be most important: standardisation, automation, maintainability, time-reductions, resiliency, complexity management and cross-functional cooperation.

This project contributes to the literature in several ways. Firstly, by addressing in a single study both knowledge exchange and supplier selection, it brought light to the impacts interconnections and dependencies between the two processes have on a product technology transfer. Secondly, this study enriches the body of literature on knowledge exchange: researches on the topic have mostly concerned early-lifecycle technologies transfers from universities to the industry. In contrast, this study addresses exchanges of knowledge for mature products and technologies between suppliers (the sending site and the receiving site), initiated and led by the company owning them (the focal company). Thirdly, studies on supplier selection procedures are scarce and mostly concern transfers of software. This study contributes to the topic by developing a management tool for transfers of product and technologies. This tool satisfies a uniquely wide range of requirements including some related to cross-functionality, an aspect of supplier selection procedures which has been largely neglected so far.

In terms of practical contributions, this thesis project addresses the lack of a structured and re-usable approach to handle the pre-transfer processes. Particularly, the manual has been designed to cope well with large-sized transfers of different nature, while still performing at its best in small-scaled ones. Moreover, practitioners are provided with greater visibility on the range of dynamics and interconnections occurring during a product technology transfer. Developed in the context of the pharmaceutical industry, this thesis project is a first attempt at framing into a unified picture the processes of knowledge exchange and supplier selection, by recognising their complementary nature. The manual provides tools, recommendations and guidelines on the pre-transfer that go beyond the boundaries of this sector. On the one hand, practitioners can and are encouraged to apply the manual to industries different from the pharmaceutical. On the other, researchers are invited to enrich it by re-validating, refining and enhancing it in different contexts.

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1. A Globalised World Economy

In the last decades, globalisation has drastically reshaped the world economy, supplying companies with incredible opportunities to grow and risks to fail. New disruptive information, communication and transport technologies, and business-wide trends such as outsourcing and mechanisation are requiring companies around the globe to take drastic actions and redesign their business models. The result is a smaller world where economies are interconnected, and boundaries blurred: the world is now one global market. As this global market evolves under the weight of growing interdependences, so are the companies' supply chains, becoming more and more worldwide-spread ecosystems. A globalised supply chain can contribute reaching new customers, outsource non-core business activities, diversify, save costs and increase profits. Contemporarily, supply chains have never been so complex, and risks and competition have never been higher (Flow Space, 2019). In this context, supply chain managers must act swiftly and embrace change to help their companies gain a sustained competitive advantage on the market.

Once considered relatively stable over time, supply chains around the world are now undergoing continuous redesigns to keep up with the ever-evolving context in which companies operate. When redesigned, the supply networks can change extensively. As old suppliers leave the system, the products they are manufacturing need to be transferred to new ones. Object of this thesis project, this process is referred to as *product technology transfer* and is a crucial step in a supply chain redesign. Product technology transfers are risky, multi-stakeholder, cross-functional processes often spanning over several years. Managed as projects, they not only are expensive to execute and unpredictable, but they will impact the bottom line of the company implementing them for many years to come.

1.1 The Study Context

Product technology transfers have so far received little attention in the literature on technology transfers as they are extremely rare to witness and study. Particularly, pursuing sound research requires highly peculiar settings, allowing the researcher to contemporarily observe several transfers of different nature and at different stages in the project lifecycle. An ideal context for researching on this topic is represented by mergers and acquisitions, which often set in motion extensive supply chain redesigns, triggering product technology transfers in turn. It is in these unique settings that this thesis project was conceived.

Recently, a big acquisition has occurred in the pharmaceutical industry, reshaping the industry landscape. In business-as-usual settings, a company generally carries out only a few product technology transfers per time point. By contrast, the acquisition just completed required the acquiring company to redesign its supply chain drastically, triggering in turn tens of transfers, many of which unusually big. Transferring hundreds of stock-keeping units (SKUs) has dramatically challenged the existing practices and procedures, posing a real threat to the successful completion of the supply chain redesign. For this reason, the acquirer has embarked on an urgent restructuring process led by the technology transfer team. Carried out in this team, this thesis project has focused on redesigning the first stages of the transferring process.

1.2 The Product Technology Transfer

The product technology transfer is a process involving three stakeholders, from now on referred to as *focal company*, *sending site* and *receiving site*. The focal company is the initiator and leader of the transfer and is the owner of the products and technologies in the scope. If the products are currently outsourced, the sending site is the supplier manufacturing them and knowledgeable about the related technologies. Otherwise, it is the internal production plant manufacturing the products. Finally, the receiving site is the beneficiary of the products to be transferred and can be an internal or an external production plant. The transfer is mono-directional, as the sending site shares the knowledge on products and technologies to the receiving site, in a tortuous process mediated by the focal company.

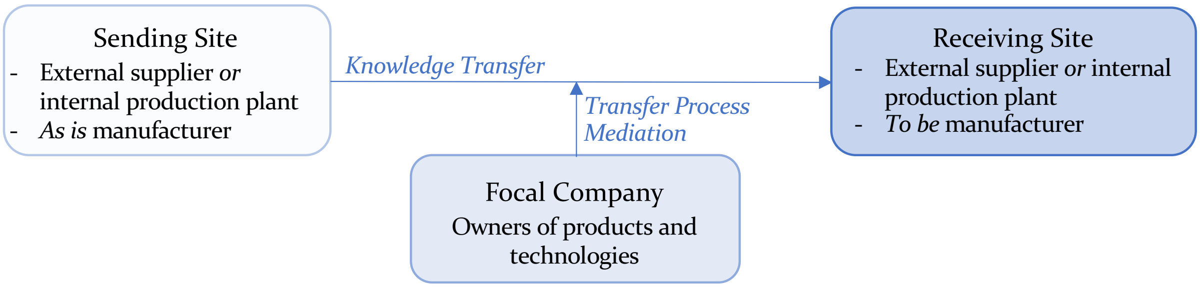

Figure 1 — Stakeholders in the product technology transfer

1.2.1 The Three Phases of the Process

The multidisciplinary of the product technology transfer is reflected in the variety of tasks to be accomplished during the process. These tasks can be grouped into three phases (pre-transfer, implementation and launch), and the process follows a stage-gate approach. The first stage is the *pre-transfer*, which starts following the emergence of a need to realise a transfer and can be further divided into two groups of activities: *knowledge exchange* and *supplier selection*. Knowledge exchange includes the procedures for *knowledge acquisition*, *knowledge package* *development* and *knowledge distribution*. The first term refers to the process the focal company carries out to acquire from the sending site all the knowledge relevant to the transfer. This knowledge needs then to be captured into a knowledge package which will ultimately be distributed to the newly selected receiving site. The development of the knowledge package is a long-lasting process characterised by a fundamental intermediate deliverable: the demand profiles. These documents contain the most relevant knowledge on the products to be transferred, hence serving as an essential input to the supplier selection process. Indeed, candidate suppliers will need to be provided with sufficient technical information to develop their proposals, and the demand profiles are designed for this purpose.

The term supplier selection refers to the process through which the focal company selects the receiving site for the transfer. Firstly, the company needs to prepare the request for proposal (RfP), a set of documents specifying the requirements of the transfer: functionalities, technical characteristics, expected performance, quality and costs of the products or services object of the proposal (Andrea, 2003). Secondly, the candidate suppliers assess the requirements and develop a bid, primarily focusing on costs and eventually proposing new solutions or suggesting modifications to the specifications (Paech et al., 2012). Once the focal company receives the proposals, they are evaluated, eventually negotiated and compared between each other. Finally, the focal company selects the supplier considered to be the best and shares with it an in-depth knowledge package including everything that will be needed in the implementation phase of the process through the process of knowledge distribution.

Within the *implementation phase*, a distinction is generally made between pre-execution and execution. During the former, the focal company discusses the shared knowledge package with the newly selected receiving site and plans the way ahead. These plans include cost, timeline and logistics projections, as well as risk assessments. This information is collected in the technical transfer protocols, documents explaining in detail how the transfer process will be carried out. Once these documents are signed, the execution of the transfer unfolds by implementing manufacturing processes, executing tests and training, and validating procedures. Finally, processes and procedures need to be qualified and approved by the regulatory authorities to achieve operational readiness. (ISPE, 2018).

The *launch* is the last phase of the process. It firstly includes a step generally referred to as performance or process review, during which the focal company evaluates the successfulness of the transfer and the lessons learned. Secondly, the performance of the receiving site is monitored, and the focal company provides support where needed. Finally, accountabilities and responsibilities are transferred from the focal company to the receiving site: the phase-out. In the meantime, as the first commercial batches are shipped to the first countries, the product technology transfer process can be considered concluded (ISPE, 2018). Figure 2 provides an overview of the product technology transfer highlighting its three phases: pre-transfer, implementation and launch. Moreover, the figure presents in dashed boxes the main groups of activities characterising each phase. Finally, the fundamental milestones of the process are provided at the bottom of the picture in blue writing.

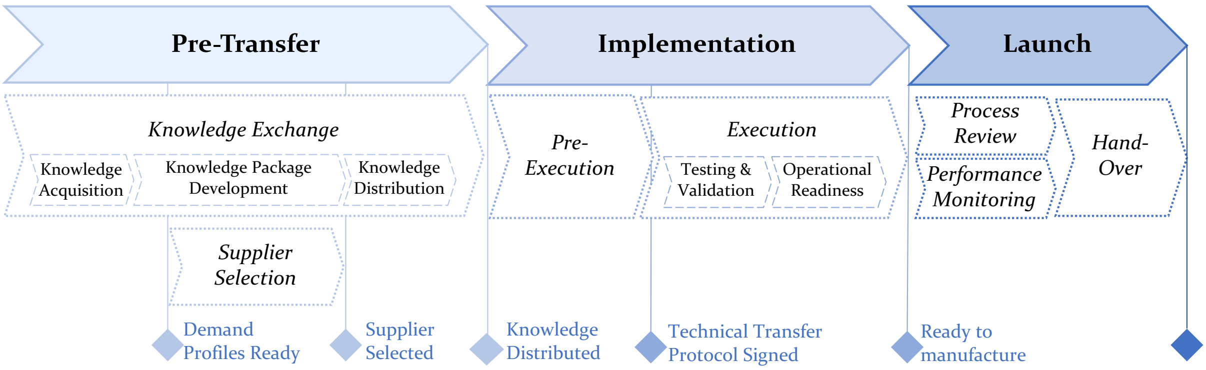

Figure 2 — Milestones in the product technology transfer process

1.2.2 Research Gaps

The implementation and launch phases' structures and components strongly depend on the industry where the transfer is taking place and for many a comprehensive manual for handling these phases is already available (see for example ISPE, 2018). By contrast, the pre-transfer is less formalised and standardised and often managed in an ad-hoc way (Tatikonda & Stock, 2003). While this type of management approach is acceptable when dealing with a few small transfers, it is inadequate for numerous large ones. Indeed, the network of interconnections between stakeholders and functions is still manageable for small-scale and rare transfers but explodes in size as the number of transfers and their magnitude increases. Flexible, user-friendly and standardised approaches are urgently required and the starting point to develop them is a robust system-wide understanding of product technology transfers which is currently lacking.

An in-depth exploration of the topic has exposed several gaps which this research aims at addressing. First of all, the product technology transfer combines the process of knowledge exchange with supplier selection, and the two topics have never been adequately addressed together to the knowledge of the author, even if they are part of the same project. Therefore, underlying synergies and interconnections between the two groups of activities may have so far been overlooked. Furthermore, the literature on technology transfers mostly includes studies on the valorisation process, the process of transferring technologies from a university to the industry. By contrast, transfers of products and the related technologies between suppliers mediated by a focal company have been largely neglected. The two processes share similarities but are distinct in terms of both the object of the transfer and the parties involved. For this reason, the topic of product technology transfer deserves greater attention, especially considering how these processes are becoming more and more common as the world evolves faster and is ever more interconnected. Finally, since it focuses on the valorisation process, the literature on technology transfers concerns studies of technologies at the beginning of their lifecycle, while not mature ones. Consequently, the impact of the product life cycle on technology transfers is not yet fully understood. This research addresses transfers of mature technologies, thus opening the way to a greater understanding of the impact of the product life cycle on a technology transfer.

This project addresses research gaps concerning the topic of supplier selection as well. The body of literature has been enriched by an impressive variety of studies about criteria and methods for supplier selection. However, far less research has been devoted to the perspective of supplier selection as a procedure, for which the previous topic represents only the concluding part of the process. Furthermore, the studies on the subject have mostly focused on supplier selection for software transfers, while this one concerns products and technologies. This thesis project addresses the outlined gaps by taking a process perspective on the topic and by focusing on transfers of products and technologies, enriching the literature with several new insights.

1.3 A Manual for Pre-Transfer Management

To provide a structured and reproducible approach to handle product technology pre-transfers, the deliverable of this thesis project is a manual answering the question:

"How can companies effectively design the pre-transfer of a portfolio of products and their technologies?"

To answer the question, this thesis project investigates knowledge exchange and supplier selection procedures, the two groups of activities composing the pre-transfer phase, and brings to light the factors inhibiting their effective completion. Furthermore, this study explores the functions involved in the process, analysing roles, responsibilities, accountabilities, interests and importance. Subsequently, recommendations, guidelines and tools to handle the hindering factors are provided, establishing a best practice to manage product technology pre-transfers. The manual is addressed to companies redesigning their supply chain and particularly to their project team's leaders who have the responsibility to accomplish the transfer in the broader scope of a supply chain redesign.

This exploratory study has been developed in the context of the pharmaceutical industry, and while generalisability has always been considered a top priority, practitioners are advised to proactively interpret the manual so to adapt it to the requirements of their industry. In particular, the sector possesses several unique characteristics: firstly, the pharmaceutical is an extremely research-intensive industry, characterised by an intricate network of connections between enterprises and research bodies. Intellectual property is exceptionally important as it is fundamental to achieve a sustained competitive advantage over the competition and its management is a great challenge in the context of technology transfers (Scherer, 2000). Furthermore, quality and safety are strictly regulated, adding a layer of complexity which is rarely witnessed in other industries. To add up, established regulations and quality protocols are widely diverse around the world, and approvals are often years-long processes (Scherer, 2000). The result is a puzzling scenario, requiring technology managers to deal with high uncertainty driven by ever-changing regulations, quality risks and unpredictable costs as well as the threat of intellectual property losses. Acknowledging these characteristics is essential to frame the manual developed in this thesis project correctly and to understand when a provided recommendation or guideline might need to be adapted to the context of a different industry. The steps in the manual which are believed to be more industry-dependent have been highlighted.

1.4 Outline of the Thesis

This thesis is structured into six chapters. Following the introduction, the next chapter is devoted to the methodology, and its content has been divided into two main sections: the first one presents the product technology transfer projects representing the most significant source of information for this work, while the second one introduces the design methodology. Chapter 3 concerns the situation analysis. It presents the objectives of the pre-transfer process, the three stakeholders and the focal company's project team's functions. Chapter 4 is dedicated to the literature review, firstly addressing the state of the art on technology transfers and then developing the foundations of the theoretical framework for this thesis project, focusing on both knowledge exchange and supplier selection.

The fifth chapter is devoted to the presentation of the manual for managing the pre-transfer phase of product technology transfers. The chapter unfolds by subsequently addressing the topics of knowledge exchange and supplier selection. The first section builds on a purposely designed theoretical framework. It emphasises the barriers to an effective knowledge flow between the stakeholders and the factors which can improve it. With regards to the factors, the manual presents recommendations and guidelines. The second section of the chapter concerns supplier selection procedures. In that respect, the manual proposes an extensive tool and several guidelines which cover the entirety of the process. The output of this section both support practitioners in handling the procedures for supplier selection and enrich the body of literature on the topic. The sixth chapter concludes the thesis by discussing the main points of the project, reflecting on the results and highlighting the theoretical and practical relevance of the presented manual. Moreover, the chapter presents the limitations of this study and outlines the way forward.

2. Designing the Thesis Project

Chapter 2 of this thesis project is divided into two sections. The first one briefly presents the technology transfer projects which were unfolding in the company where this research took place. The second part of the chapter delineates the design methodology used to develop the manual. The methodology is firstly presented in general and then in-depth through an analysis of its phases: *situation analysis*, *design* and *design communication*. For each, sources of information, methods and means use are explained.

2.1 The Product Technology Transfer Projects

Several projects ongoing at the company object of this study in the period of this research have played a crucial role in the development of this thesis project. Among them, four have been particularly insightful has they differed in terms of technology and products to be transferred, stakeholder system, size, geographical locations and the related challenges. Furthermore, each of this project was in a different stage of the product technology transfer at the time of this study. Figure 3 shows the stage in the pre-transfer process of each of the four projects mentioned. At the time of this study, the first project was in the supplier selection and knowledge package development phase. The second one was in the knowledge distribution phase, while the third one progressed from the firsts two to the latter during the study. Finally, at the beginning of this study, the fourth project was in the knowledge acquisition phase, and it later advanced to the knowledge package development and supplier selection phases. The first three projects have supported the situation analysis process, and the development of the thesis project's manual. In contrast, the last project has allowed to put into practice the manual and validate it as the project started at a later stage in the research.

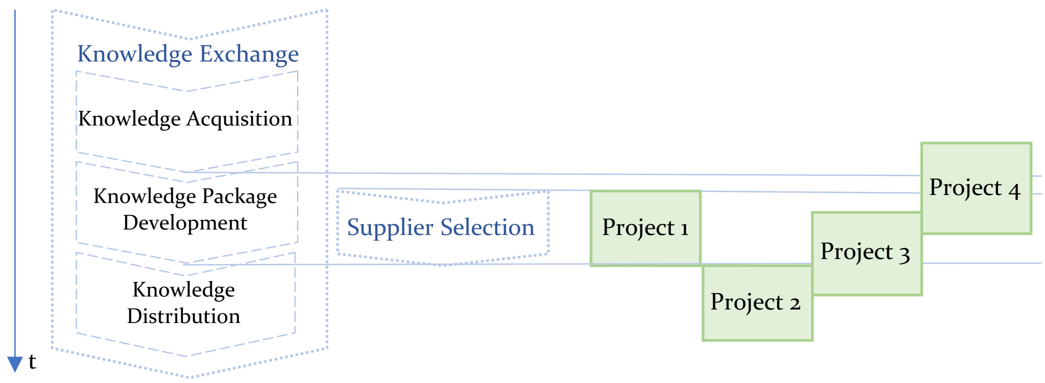

Figure 3 — Projects' stages

2.2 Design Methodology

This thesis project's design methodology has been developed starting from the prescriptive approach proposed by Dym and Little in "*Engineering Design: A Project-Based Introduction*" (1999). In their opinion, this approach is to be preferred to a descriptive one because the latter only attempts at describing the elements of the design process and tends to be abstract. By contrast, a prescriptive approach aims at suggesting what should be done (Dym and Little 1999). Dym & Little (1999) propose a five phases design including problem analysis, conceptual, preliminary and detailed design, and design communication. In this project, the first phase has been strengthened and redefined as situation analysis. It includes the steps of ideation, objective discovery, stakeholder analysis and requirements identification.

The outlined engineering design has been coupled with a system thinking approach. System thinking can be defined as "a set of synergistic analytical skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications [...] to produce desired effects" (Arnold & Wade, 2015). This definition is compelling and is worth analysing its components. Firstly, "synergistic analytical skills" emphasizes how in a system the whole is more than the sum of the single parts. This characteristic has been recognised as essential to discover relations and interconnections between functions and activities in the product technology transfer. Secondly, "identifying and understanding systems" calls for the need to experiment on several different perspectives to uncover what makes a system structure unique and to get familiar with it. This concept has been applied in this thesis project by looking at the problem from different angles and through several means. Thirdly, "predicting their behaviours" is a reference to the dynamism of complex systems, a characteristic which has been pivotal in the modelling process. As suggested by Van Gich (2013), system thinking inspires the researcher in looking at forms of organisation outside of the typical vertical or horizontal integration schemes to uncover the true relationships between the parties involved and the ever-evolving dynamics between them. Finally, system thinking is meant to "devise modifications" which is the fundamental goal the manual is built for.

Figure 4 graphically represents the design methodology used in this thesis project. The initial stages have been devoted to the situation analysis during which this project has been ideated, the problem analysed in its objectives and stakeholders, and the requirements identified. Subsequently, the project has entered the design phase and has finally been validated and concluded. The system thinking approach has permeated the design process. During the situation analysis, it has been key to understand the nature and context of the studied system, as well as detecting the system components' behaviour. In the subsequent design phases, system thinking has been applied to develop the guidelines and recommendations which have become part of the manual. The next sections deep-dive into each of the design phases.

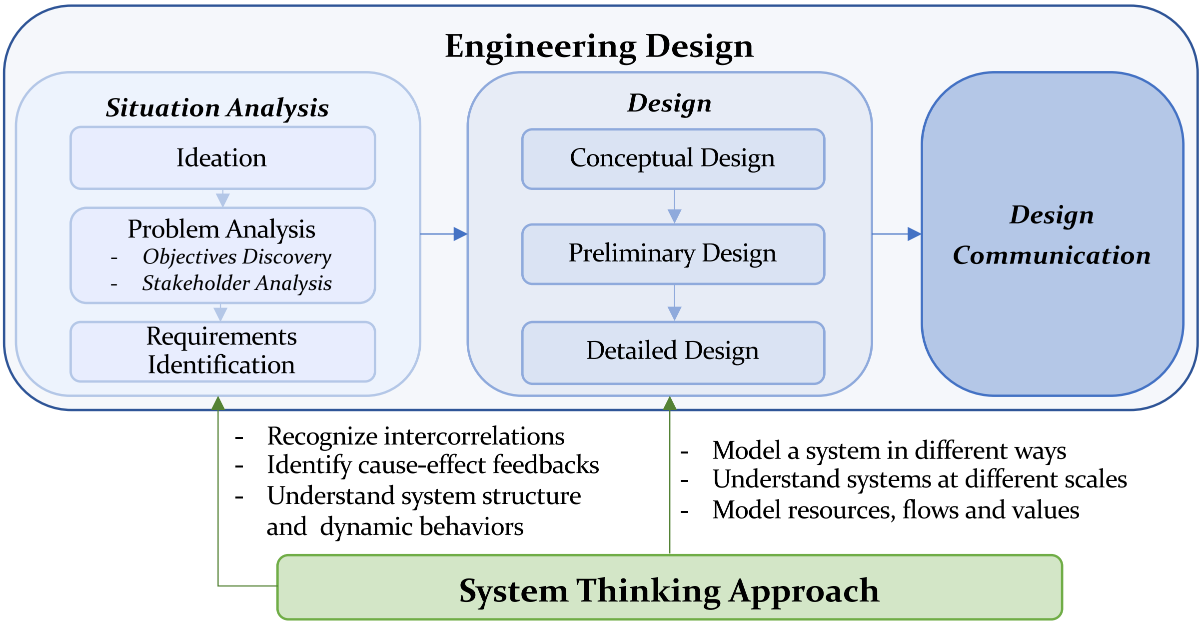

Figure 4 — Design Methodology

2.2.1 Situation Analysis

A process as complex and convoluted as the product technology transfer is not easy to comprehend in its entirety. Therefore, during this study, an extended time has been dedicated to the situation analysis. Active participation in several projects in the company object of this study, data scraping from past projects, brainstorming sessions and informal interviews allowed to understand what product technology transfer are, why they arise and what their critical success factors are. The process has been further supported by a literature review from the technology, innovation, knowledge, project and supply chain management disciplines. The review allowed to identify better the challenges threatening the completion of the process and the research gaps. It has been necessary to address a wide range of bodies of literature because of the multi-disciplinary nature of the topic, which has been tackled from a variety of perspectives. In the next paragraphs, the processes of objective discovery, stakeholder analysis and requirements identification will be described.

Objectives Discovery

The objectives' discovery has been carried out by gradually increasing the level of detail of the analysis. Starting from the very general aim of the process, the investigation proceeded by iteratively researching and pairwise comparing sub-objectives, until achieving a satisfactory level of detail. The final result has been an objective tree, where the main goal at the top is connected to several sub-goals. In preparing the pairwise comparisons and the objective tree, particularly important have been informal interviews and reports of transfers completed in the past. Furthermore, as the literature on technology transfers does not include any study which has analysed the pre-transfer process as defined in this thesis project, the objective discovery phase has been supported by the exploration of several bodies of literature. Technology, innovation and knowledge management for the objectives of the knowledge exchange process; supply chain management for the supplier selection procedures.

Stakeholder Analysis

The stakeholder identification and analysis step has been carried out based on the guidelines provided by Bryson in "*What to Do When Stakeholders Matter*" (2004). Stakeholders have been identified by combining the literature review on the topic with the information collected from the technology transfer managers and the analysis of the standard operating procedure in place at the company. Following their identification, several methods have been used to analyse the functions: importance vs influence diagrams, activity planning maps and a participation planning matrix. The purpose of these analyses has been to investigate roles, responsibilities and accountabilities of each stakeholder and function at different stages in the pre-transfer process.

Requirements Identification

The task of identifying all the requirements of the product technology pre-transfer process has been accomplished through the application of several techniques proposed by Robertson in "*Requirements trawling: Techniques for discovering requirements*" (2001). The author distinguishes between conscious, unconscious and undreamed requirements where the firsts are the ones a stakeholder can communicate while the second ones are requirements the stakeholders are not able to recognise, although they underly the process. Finally, undreamed are requirements which haven't surfaced yet and do not usually occur to the stakeholders. Robertson (2001) proposes several techniques to uncover requirements, each with its strengths and weaknesses. For this study, the *apprenticing*, *brainstorming*, *interviewing*, *use case workshops*, *simulation* and *system archelogy* techniques have been used and will be briefly presented in the next paragraph.

The first technique used is based on the idea of taking the role of an apprentice in an apprentice-craftsman relationship, enabling the apprentice to learn, observe, ask relevant questions and eventually suggest additional requirements to be included in the framework. It is particularly useful to uncover unconscious requirements. The second technique mentioned, brainstorming, is based on the concept of generating ideas through group working and is critical for the identification of undreamed requirements. The third technique used has been interviewing, which is the most common strategy for extrapolating conscious requirements. The fourth is the use case workshops technique which allows reviewing requirements for a particular business case by considering events that may arise and hypothesize requirements that should be fulfilled in such cases. Use case workshops are particularly useful for uncovering conscious requirements. The fifth technique mentioned is simulation, whose basic idea is to tell a story to stimulate stakeholders in identifying requirements associated with the scenarios the simulation is proposing. Simulation has been used in this study by recreating both typical and peculiar dynamics which can be witnessed during the product technology pre-transfer, the result being the discovery of further undreamed requirements. Finally, system archaeology refers to the process of deriving requirements from existing documentation, past projects and reports and has proved to be useful to uncover unconscious requirements.

The table below summarises the last paragraphs by displaying the techniques used in this thesis project and the type of requirements they are best suited to identify. Apprenticing, brainstorming, interviewing and system archelogy have been used to retrieve requirements for both the knowledge exchange and supplier selection section of the manual. In contrast, use case workshops and simulation have been applied to the development of the manual's section on supplier selection.

Table 1 — Requirement Discovery Techniques

	Conscious	***Unconscious***	***Undreamed***
Apprenticing		x	
Brainstorming			x
Interviewing	x		
Use Case Workshops	x		
Simulation			x
System Archaeology		x	

Conceptual Design

Dym and Little (1999) define the conceptual design as a phase in which different schemes are considered, drafted and compared. The goal of this phase is to establish specifications and present alternatives, the final result consisting of a single or multiple conceptual designs and specifications (Dym & Little, 1999). As a source of information for this phase, the authors suggest considering competitive frameworks. About knowledge exchange, the disciplines of technology, innovation, project and knowledge management have been considered. In contrast, the body of literature on supply chain management represented the foundation for the process of modelling supplier selection.

The conceptual design's primary goals have been establishing what should have been part of the manual and the ways these elements should have been presented, laying down the initial manual structure. Furthermore, in developing the conceptual design, a descriptive approach has been used, postponing the application of a prescriptive one to the preliminary design. The two groups of activities included in the pre-transfer (knowledge exchange and supplier selection) have been treated separately during this phase because taking into account the whole process at the same time would have been unfeasible. Moreover, the manual's development pace has been affected by the evolution of the projects observed during this study, the result being that varying levels of detail characterised different parts of the manual at the same point in time. In particular, it has been possible to develop the section of the manual on knowledge exchange earlier than the one on supplier selection, with the development phases aligning only during the detailed design step.

Concerning knowledge exchange, the focus of the study has been on identifying the factors which inhibit the knowledge flow between the parties involved in the transfer and the elements the focal company can leverage on to facilitate the knowledge flow. Then a relationship between these factors and elements has been searched. Regarding supplier selection, the goal of the conceptual design phase has been laying down the backbone of the procedure. The process included identifying the steps the focal company should follow when interacting with and assessing several candidate suppliers and how should these steps be handled. Moreover, an initial assessment of the factors the focal company should take into account for comparing and selecting suppliers has been carried out.

2.2.2 Preliminary and Detailed Design

The preliminary design phase aims at enriching the conceptual design by identifying the fundamental criteria and specifications which need to be part of the framework (Dym & Little, 1999). By transitioning from a descriptive to a prescriptive approach, this phase has required to find the right balances between practical guidelines and theoretical support, and in terms of detail level for tools and templates. The focus has been on researching strategies to maximise the quality of the knowledge transfer and the supplier selection procedures. The manual has been further refined in the detailed design phase (Dym & Little, 1999), in which knowledge exchange and supplier selection have been considered together: workshops, brainstorming sessions and testing have enabled steady improvements through small, agile iterations.

2.2.3 Design Communication

The final phase's goal is to deliver the completed design and its specifications to the client: the focal company dealing with the product technology transfer (Dym & Little, 1999). The assessment and validation of the manual has been carried out following two directions. On the one hand, users have been asked to provide feedback starting already during the conceptual design phase. Indeed, while in a linear type of process, the design communication represents the final stage, design processes are often iterative, and this applies to this case as well. On the other hand, the developed tools have been tested in the project 4 to verify their goodness and the actual improvements provided over former practices. After the last iteration, the thesis has been reviewed and finalised.

The figure below summarises the design process by showing the steps followed, their relationship and their distribution over time. The chart reveals that while the process can be easily described linearly, it has been iterative, as further understanding of the problem at hand had required to redevelop or update phases coming earlier in the process. Notably, the timeline shows how the steps followed can be grouped in three. The first group includes ideation, objectives discovery, stakeholder analysis and requirements identification; three steps characterised by substantial overlap and intensive iterations. The second group comprises conceptual, preliminary and detailed design. As shown in the figure, the conceptual and preliminary design for the knowledge exchange section of the manual have chronologically preceded the section on supplier selection, while the detailed design has been carried out jointly. The third group consists of the design communication phase only, distinguished from the other steps because of the different pattern followed: as Figure 5 shows, it has been carried out for an extended period while the design was ongoing.

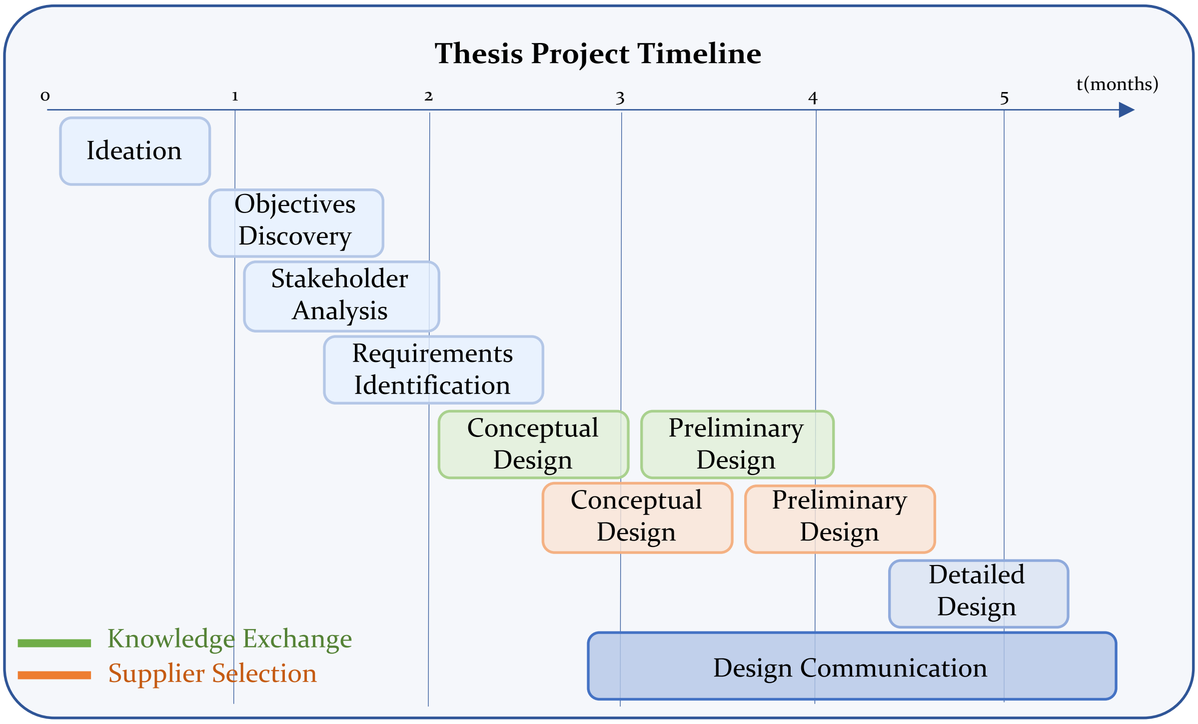

Figure 5 — Steps and timeline of the design process

3. Product Technology Transfer Analysis

Chapter 3 of this thesis project aims at presenting the product technology pre-transfer by describing it in depth as it has been observed in the carried-out study. Section 3.1 outlines the objectives of the pre-transfer, grouped in knowledge exchange and supplier selection ones. Subsequently, section 3.2 analyses the stakeholders on two different levels. On a high-level, the three stakeholders involved in the pre-transfer (the sending site, the focal company and the receiving site) are presented in subsection 3.2.1. On a more detailed level, subsection 3.2.2 deep-dive into the functions included in the focal company's project team. Subsequently, subsection 3.2.3 maps power, importance and influence levels of each of the functions. Finally, section 3.3 reviews the pre-transfer process in light of the new information about stakeholders and functions. The result is a set of activity planning and relationships maps, which allows understanding the pre-transfer dynamics on a very detailed level.

3.1 Objectives of the Pre-Transfer

A product technology transfer can be triggered by cost saving considerations, supplier network consolidation strategies or by the desire to increase the production volumes of a certain portfolio of products. Additional motives include financial or supply chain risks reductions, strategic alignment improvements, adaptations to new business models, or reactions to quality or performance issues. As one of these triggers emerges, the focal company starts-up a project team and initiate the transfer process with the pre-transfer phase.

The process of knowledge exchange begins immediately after the project kick-off. From the point of view of the focal company, the objective of this phase is to transfer knowledge from the sending to the receiving site with a quality high enough to ensure a smooth prosecution of the product technology transfer. To achieve this goal, the focal company needs to complete the processes of knowledge acquisition from the sending site, develop the knowledge package and distribute knowledge to the receiving site.

Initially, the focal company's objective is to *identify the knowledge* that needs to be transferred to execute the process. This includes knowledge about products, technologies, manufacturing processes, artwork and product life cycle management. As a general understanding of the topic is achieved, the second objective is to *discover the sources of knowledge* and how it is stored and can be retrieved. This research dealt with the transfer of products and technologies in their maturity. In this context, knwolegde is to be searched in documents, spreadsheets, drawings and videos. However, it is also embedded in organisational practices and processes, people's experiences, expertise and skills. Individuals, information systems and repositories easily conceal knowledge: finding the sources of knowledge is critical to proceed in the transfer. The third objective for knowledge exchange is to *define a plan to acquire knowledge* in cooperation with the sending site to ensure alignment on the process. Being unable to acquire knowledge properly is a major threat to the completion of the transfer, which might cause unexpected arrests to the transfer process during the implementation phase.

As the knowledge acquisition proceeds, the objective of the focal company is to *plan and implement a structure able to store the acquired knowledge*. This includes the processes of logically aggregating information into shared repositories, as well as selecting practices to spell out tacit knowledge. On a first level, the process needs to lead to the creation of short and straightforward demand profiles to enable candidate suppliers to prepare their proposals. On a second level, the objective is to finalise the knowledge package and plan the distribution process. Once the receiving site is selected, the focal company objective is to *refine the plan for knowledge distribution* and maximise the effectiveness and efficiency of the knowledge flow. Ineffective storing and distribution strategies will pose significant challenges to the implementation phase.

At the start of the pre-transfer phase, while the need for a transfer is already clear, the receiver of the products and technologies is yet to be defined. Therefore, a critical objective of this phase is to *short-list a set of candidate suppliers* which comply with the requirements of the product and technologies to be transferred. The second objective of this phase is to *develop* a compelling *confidentiality disclosure agreement* (CDA) to be sent to the candidate receiving sites. Third, the focal company needs to *develop* an exhaustive *request for proposal (RfP)*, particularly addressing the major drivers for cost, so to receive realistic proposals; this will enable the suppliers to make a bid for the products in scope. Once the suppliers submit their proposals, the focal company's next objective is to *select the best supplier*, following an iterative process of analysis and negotiation. The figure below summarises the last paragraphs by presenting objectives and sub-objectives of the product technology pre-transfer, categorised in knowledge exchange and supplier selection ones.

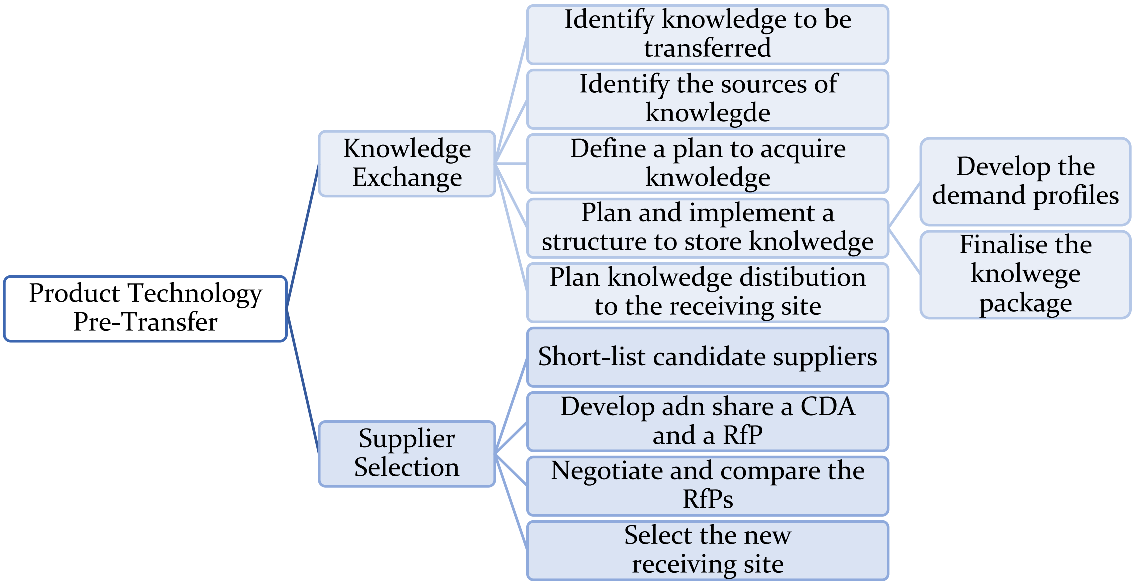

Figure 6 — Objectives of the pre-transfer phase

3.2 The Analysis of the Stakeholders

3.2.1 The Three Stakeholders

The stakeholder system of a product technology transfer can assume four different forms. Firstly, the focal company can decide to transfer the production of a portfolio produced internally to an external partner (internal-external transfer). Secondly, it can choose to transfer from one external partner to another (external-external transfer). A third option is to start producing internally a portfolio currently delivered by an external partner (external-internal transfer). Fourthly, a transfer can occur between two plants owned by the focal company (internal-internal transfer). Regardless of the type of transfer, three different parties interact in the process: the *sending site*, the *receiving site* and the *focal company*, which acts as an intermediary. The first one is the production plant currently manufacturing the products object of the transfer and knowledgeable about the underlying technologies; at the end of the process it will dismiss these products from its production lines. At the other end of the chain, the receiving site is the beneficiary of products and technologies and needs to be capable of capturing the shared knowledge to complete the transfer in a timely and cost-efficient manner. Finally, the focal company can be thought as a facilitator and mediator of the transfer: a figure capable of bridging the knowledge gap between sender and receiver and fill the skill's gaps of the two stakeholders (Battistella et al., 2016). Furthermore, the focal company is the owner of products and technologies and the leader of the product technology transfer.

The involvement of at least an external partner in the transfer might result in more complex processes due to different operating procedures, languages and ways of communicating or lacking transparency. However, in the globalised economy, large companies often outsource non-core tasks to business partners. Often referred to as contract manufacturers (CMs), they can represent the bulk of the upstream supply chain of a company. There are several reasons why this phenomenon is becoming more common by the day. Firstly, large companies can save costs through CMs' economies of scale achievable through multiple customers and by turning significant fixed costs associated with infrastructures and equipment into variable costs (the fees to be paid to the CMs) (Pandya & Shah, 2013). Secondly, outsourcing is a powerful tool for increasing efficiency in the focal company, through a reduction in its structures' complexity (Pandya & Shah, 2013): by focusing solely on its core-activities, more streamlined and agile organisational structures can be achieved. Thirdly, CMs might be able to ensure higher quality standards and provide advanced skills, as the activities they are asked to pursue are part of their core business (Pandya & Shah, 2013). Fourthly, a CM can help the focal company reducing time to market, developing new solutions and grow the brand (Pandya & Shah, 2013).

3.2.2 The Project Team Composition

Because of the wide variety of tasks to be handled during a product technology transfer, each stakeholder needs to create a multi-functional project team. In line with the scope of this thesis project, the analysis that follows focuses on the project team of the focal company. It explains how roles and responsibilities are distributed within the organisation and how they evolve together with the project. The project team includes technical and commercial functions. The former group comprises *technical management*, *engineering*, *research and development (R&D)*, *quality* and *regulatory affairs* while the commercial functions are *purchasing* and *supply chain*.

The processes of knowledge exchange and supplier selection evolve in parallel and, although widely diverse, involve the same project team. Consequently, two team structures coexist at a corresponding point in time: two sets of importance, influence and power ratios can be witnessed at the same time. Acknowledging this peculiarity, in the next paragraphs this study takes on the challenge of harmonising this puzzling picture. The existence of two parallel team structures firstly emerges when recognising that the product technology pre-transfer has two leaders. Particularly, technical management retains the lead in the process of knowledge exchange because of their expertise and skills. However, when transitioning to the supplier selection phase, the leaders are the purchasing managers, the primary decision-makers in the process of selecting the new receiving site. Starting from these, the seven functions are presented in the following paragraphs.

Technical Management

The technical manager needs to possess both managerial and technical skills to remove roadblocks and assure a smooth transfer. Leader in the process of knowledge exchange, it coordinates the procedures for knowledge acquisition and distribution, acting as the point of contact for the technical functions. Moreover, the technical manager frequently interacts with external stakeholders to develop a high-quality knowledge package. Technical managers are responsible for drafting the demand profiles as well as the technical transfer protocols, dealing with technical risks and gap assessments and continuously improving the knowledge flow as the process proceeds towards the implementation phase. Among their responsibilities are training, on-site visits and troubleshooting. During supplier selection, technical managers assist the purchasing departments in preparing the request for proposal and evaluating the suppliers' proposals from a technical perspective. Finally, this function is an important activator of the R&D function. The understanding technical managers possess on the impact certain technologies can have from a technical and regulatory perspective should enable them to identify opportunities for improvements to the current products line-up.

Purchasing

Purchasing is that function in a company that aims to get the best possible price on resources. In a product technology transfer process, this objective translates in the goal of finding and selecting the most inexpensive receiving site. Purchasing managers are in charge of drafting and finalising the request for proposal and send it to the candidate suppliers. The function also leads the analysis and comparison of the proposals, and negotiate them with the candidate sites, finally selecting the best one. In the process, purchasing managers interact with the technical functions to receive feedback on both cost- and non-cost-related aspects of the transfer. For instance, technical mangers should aid purchasing managers in evaluating technical transfer costs, while engineers should support them with regards to investment expenditures.

Engineering

In the technology transfer process, the engineering function plays a supporting role in both knowledge exchange and supplier selection procedures. During the former process, engineers are required to share their expertise in equipment, tools, and machinery. During the latter, they support the purchasing function in evaluating the candidates' proposal when it comes to investments, applying their knowledge to provide benchmarks and evaluations. The task requires them to provide feedback on the extent to which an offer might be negotiable and in spotting mistakes, discrepancies or unrealistic elements in the candidates' proposals.

R&D

In the technology transfer process, the R&D department has the role of proposing modifications to products and technologies to improve quality, reduce costs, simplifying manufacturing processes or the management of the regulatory affairs, reducing the time required for the transfer or the associated risks. Often triggered by technical managers, R&D specialists should assess opportunities throughout the knowledge exchange period and propose modifications of the products line-up to the receiving site once it is selected. If the changes are approved, then a transfer protocol for the new product is developed and signed, and the new product is transferred with the rest of the portfolio. R&D projects modify the basic transfer plan, impacting on all the other functions' tasks, thus affecting the outcome of the transfer project.

Quality

The quality function's mission is to prevent mistakes and defects in the manufacturing process, assuring that quality requirements are met throughout the project. This function comprises administrative tasks, management of procedures, inspections and tests. During supplier selection, quality is responsible for assessing candidate receiving sites in collaboration with the other technical functions. Once the supplier is selected, quality managers should deal with qualifying and approving the receiving site, setting up quality agreements, and approve transfer documents (especially regarding analytical processes and methods). Therefore, they are involved in the knowledge distribution process.

Regulatory Affairs

Handling regulatory affairs is critical in the process of transferring products and technologies, especially in the pharmaceutical industry. During the early phases of the knowledge exchange process, this function assesses the transfer from a regulatory perspective, analysing requirements and regulations in each of the countries in the scope of the transfer, the documents needed for registration and the time that is required to handle these affairs. Similarly, in the process of selecting suppliers, this function provides the leaders with a report on the regulatory risks associated with choosing a particular candidate supplier. Therefore, the regulatory affairs function provides valuable information for assessing the feasibility, risks and costs of a project.

Supply Chain

Supply chain specialists are in charge of preparing the list of stock-keeping units (SKUs) to be transferred and forecasting the production volumes required for each of the products in the scope of the transfer. They should prepare a forecast for two or three different scenarios for the purchasing department, which will need this information to prepare the request for proposal to be sent to the candidate suppliers.

3.2.3 The Importance-Influence Maps

The next paragraphs present the reader with two importance-influence maps which serve two purposes. On the one hand, they have been developed to help understand the composition of and the dynamics in a product technology transfer team within the pharmaceutical industry. On the other hand, they constitute a powerful tool which practitioners are encouraged to apply in different sectors. Indeed, while the validity of the proposed maps might not be extendable to other industries, the value of the tool remains. The first of the two maps shows importance-influence ratios in the knowledge exchange procedures, while the second map addresses supplier selection.

Figure 7 presents on the left the importance-influence map for knowledge exchange. Technical managers lead the process and hence occupy the upper right quadrant of the map. Furthermore, if the re-development of a product or the introduction of new ones is in the scope of the transfer, the R&D function can have a big influence on the transfer process. For this reason, this function can be found in the bottom right quadrant of the map. The regulatory affair function is in charge of the assessment of the regulatory risks associated with the product technology transfer, a key determinant in the highly regulated environment of the pharmaceutical industry: the function occupies the upper left quadrant of the map. Finally, quality and engineering functions play supporting roles and hence can be found in the bottom left corner of the map.

The right half of Figure 7 presents the importance-influence map for supplier selection. The purchasing department has the lead in the process: it can be found in the upper right quadrant of the map. The technical management function retains a first-line position, as it provides support in shortlisting suppliers, evaluating the technical transfer costs and the capabilities of the candidate receiving sites. Moreover, supply chain has the particularly important task of producing forecasts for the products object of the transfer, an essential input in the request for proposal preparation process. For these reasons, these two functions can be found in the upper left quadrant of the map. The quality function is in charge of assessing the candidate suppliers' capabilities in implementing processes and procedures, and it can thus be found in the bottom right quarter of the map. Finally, the regulatory affairs and engineering function provide meaningful insights into the strengths and weaknesses of the candidate suppliers. They can be found in the bottom left quadrant of the map.

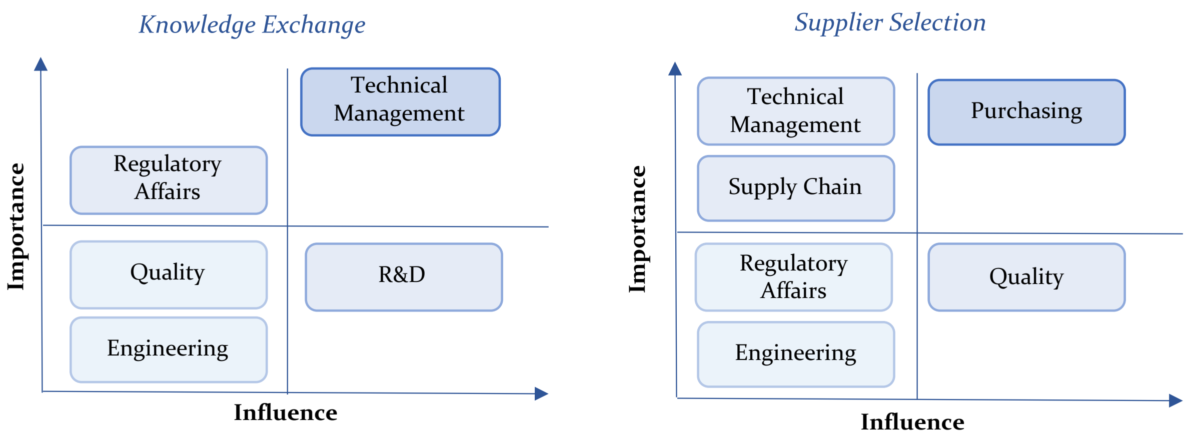

Figure 7 — Influence-importance maps

3.3 A Final Overview of the Pre-Transfer Phase

The carried-out analysis of objectives, stakeholders and functions allows evaluating the pre-transfer process in-depth. The result is a set of activity planning and relationship maps that clarify the process dynamics and wrap-up the problem analysis section of the thesis project.

3.3.1 Dynamics in the Knowledge Exchange Procedures

The process of knowledge exchange comprises *knowledge acquisition*, *package development* and *distribution*. Figure 8 shows the activities the focal company needs to complete throughout the process, categorised by the function in charge of executing them. Moreover, the figure positions knowledge exchange in the broader pre-transfer process by referencing to supplier selection (in green) and implementation (in yellow). It emerges how supplier selection is a phase occurring in parallel to the knowledge package development. Indeed, it starts when the demand profiles are ready and continuous while the knowledge package evolves. Finally, the figure shows that the technology transfer protocols (TTP) are developed while knowledge is distributed. These documents which describe the transfer plan are then signed, and the implementation phase begins.

The functions involved in the knowledge exchange procedures are technical management (the leader in the process), research and development, regulatory affairs and quality. Initially, technical managers are in charge of identifying the knowledge to be transferred and its sources. These operations require them to interact with the sending site and particularly with its technical functions, to jointly plan the structure of the rest of the process. At a later stage, technical managers act as the point of contact for the knowledge package development and ensures that documents, videos and drawings are correctly uploaded in the right sections of the package. In the process, the function interacts with its counterpart at the sending site to maintain alignment on the procedures: the package gradually enriches. In the meantime, technical managers are in charge of developing the demand profiles, based on the information now available in the knowledge package. Finally, as the receiving site is selected, they distribute the knowledge through an iterative process in which the focal company and the receiving site get acquainted, build up a relationship and set-up future steps through the technical transfer protocols. The procedure comprises continuous iterations, as the receiving site needs to absorb the knowledge into its practices and processes.

The other functions involved in the knowledge exchange are research and development (R&D), regulatory affairs and quality. The role of the first is to assess opportunities for improvements including new manufacturing processes, products, packaging and artwork or re-brandings. By contrast, the regulatory affairs and quality functions evaluate a transfer from a risk perspective, then reporting to the leader of the process. Their input is essential to plan the next stages of transfer.

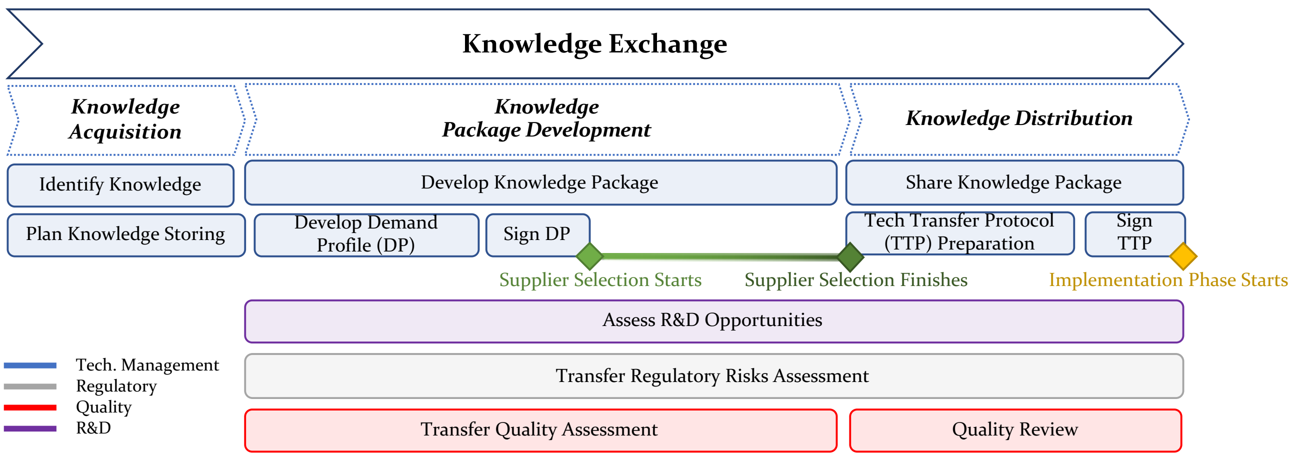

Figure 8 — Knowledge exchange activity mapping

Figure 9 tackles knowledge exchange from a different perspective: it shows the network of interconnections between sites and the focal company, and within the focal company's project team. In particular, the figure resumes objectives and activities discussed in the previous paragraphs and add to them a relational angle. The figure emphasises how relationships between stakeholders are bidirectional, even though the transfer is mono-directional: the processes are iterative, hence requiring intensive inter-organisational interactions. Finally, the figure emphasises the central role of the technical management function, which coordinates both internal and external interconnections.

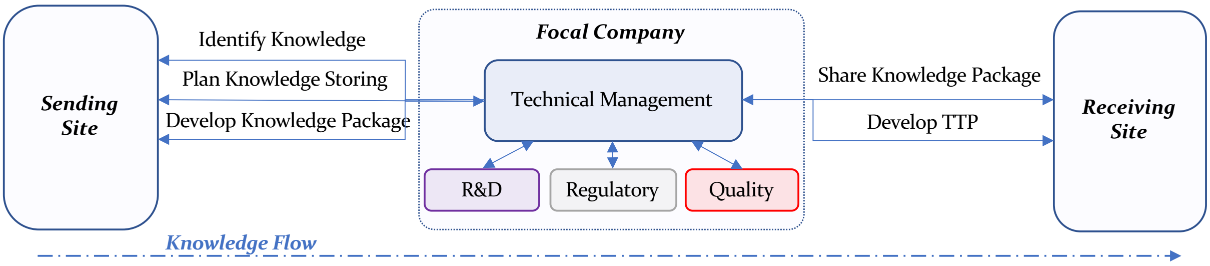

Figure 9 — Knowledge exchange: actors relationships

3.3.2 Dynamics in the Supplier Selection Procedures

Supplier selection requires the participation of purchasing (in the lead), technical management, supply chain, R&D, regulatory affairs, quality and engineering. The procedure comprises four sequential steps: *preparation for selection*, *preparation for negotiation*, *negotiation and analysis*, and *comparison and selection*. The first step includes the processes of finalising the demand profiles, start shortlisting qualified suppliers and develop volume forecasts for the products in the scope of the transfer. The two former activities are carried out by technical managers, while the latter is a responsibility of the supply chain function. Demand profiles and forecasted volumes represent the fundamental inputs for the preparation for the negotiation step. At this stage, the purchasing function prepares the confidentiality agreements, join the process of suppliers' shortlisting, and prepare the request for proposal in collaboration with the technical management function.

The negotiation and analysis step starts when the suppliers forward their proposals to the focal company. Purchasing managers lead the process and are supported by several other functions. Particularly, technical managers assess proposals in terms of technology transfer costs and suppliers in terms of technical capabilities. Furthermore, supply chain, quality and regulatory assessments are executed by the related functions. Finally, investments-related estimates are carried-out by the engineering function. As the analysis is completed, the purchasing function has all the elements necessary to select the new receiving site. The figure below summarises the supplier selection procedures by presenting the activities to be carried out in this phase and the functions in charge of executing them. Functions are colour-coded to maximise legibility, and a few tasks have been marked: these are the ones that set the pace for supplier selection.

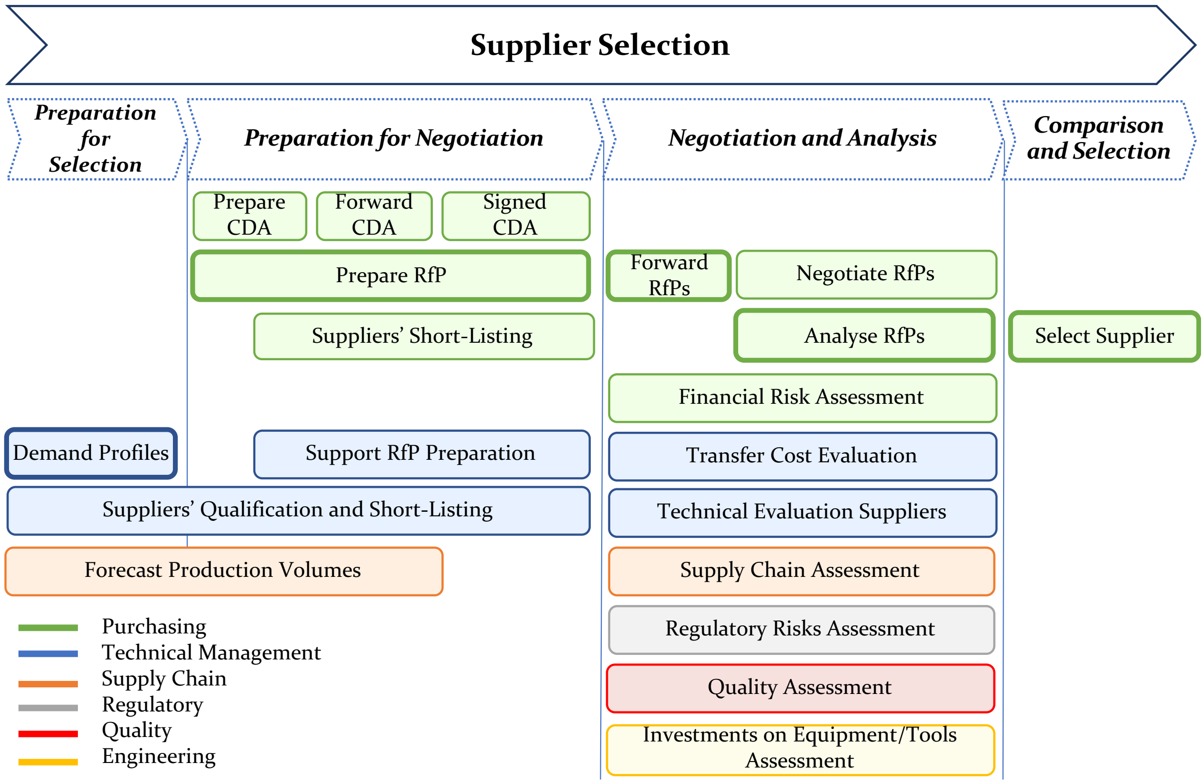

Figure 10 — Supplier selection activity mapping

Figure 11 focuses on the relationships between the actors involved in the supplier selection procedures. Within the focal company, six functions participate in the process, and all of them are coordinated by the purchasing managers who lead the process. Furthermore, purchasing and technical managers act as an interface between the focal company and the candidate receiving sites. The first function deals with the confidentiality agreements, the request for proposal and the negotiation practices. In contrast, the second one discusses the transfer from a technical point of view, providing clarification to the doubts the candidate suppliers express. These discussions can also indirectly contribute to the knowledge package development.

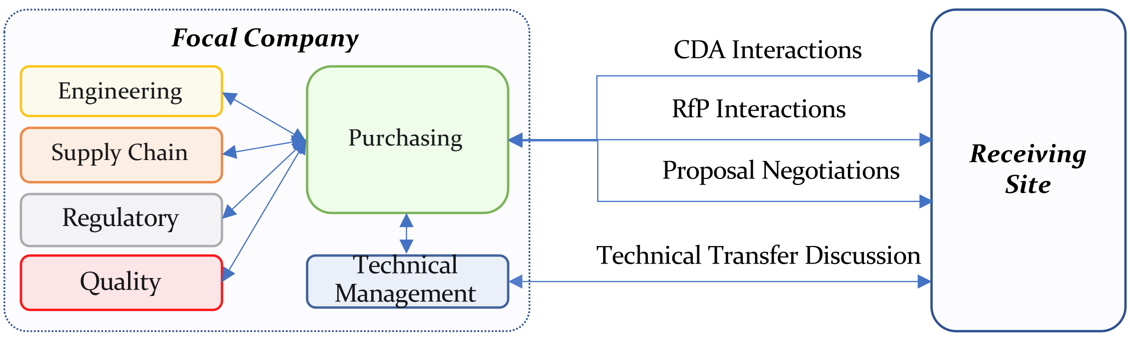

Figure 11 — Supplier selection: actors relationships

3.3.3 The Pre-Transfer Greater Picture

While knowledge exchange and supplier selection are two distinct groups of activities, in a product technology transfer it is not possible to think at one without the other. They unfold contemporarily, and one enables the other. For one, the same project team is involved in both activities. Particularly, technical managers have a substantial impact on both knowledge exchange and supplier selection, but quality and regulatory are engaged in both as well. Furthermore, the figure below shows in which way the two groups of activities interconnect. On the one hand, the demand profiles, developed during the knowledge package development phase, represent the essential input to start the supplier selection procedures. On the other hand, once the suppliers receive the request for proposals, including all the technical information, they will most likely require clarifications on the product technology transfer. As they need additional information and the technical managers provide them, the knowledge package gradually enriches, in an iterative process which contributes shaping the final form of the package and allows to move forward on the process of supplier selection.

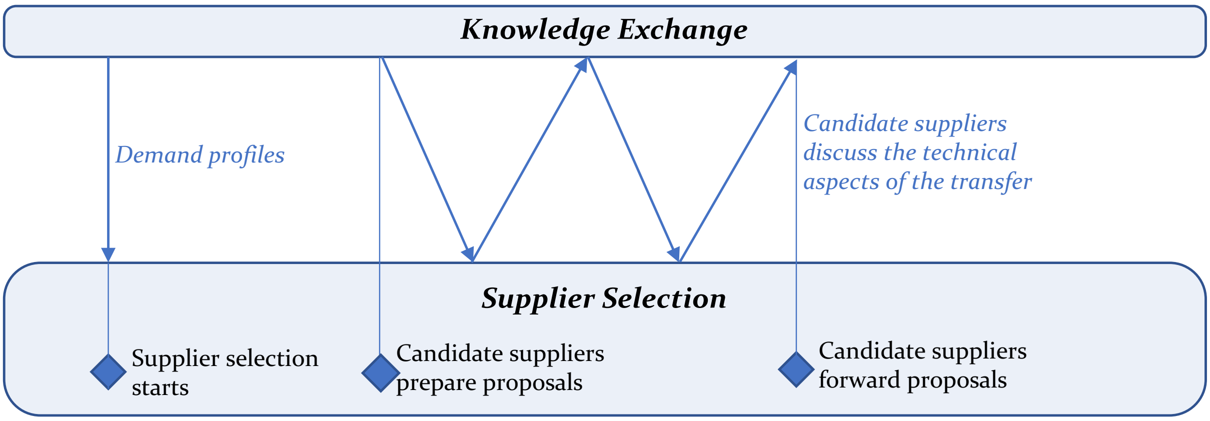

Figure 12— Knowledge exchange' and supplier selection's points of contacts

4. Review of the Literature

Divided into two sections, chapter 4 of this thesis project is devoted to the literature review. Section 4.1 reviews the state of the art on technology transfers, showing that product technology transfer is a mostly neglected branch of the field and how the topic is at the cross point between several different disciplines. The second part of the chapter (section 4.2) deep-dive into the literature instrumental to the development of the manual both for the topic of knowledge exchange (subsection 4.2.1) and supplier selection (subsection 4.2.2). When it comes to the former, the main challenges to transfer knowledge are identified and classified in a way functional to the manual's development. Furthermore, a classification of the levers to facilitate the knowledge flow is provided and represents the foundation for recommendations and guidelines provided in the manual. Section 4.2.2 focuses on the literature on supplier selection by firstly addressing the tendering process through which focal company and candidate suppliers interact and secondly discussing models for supplier selection and criteria identification strategies.

4.1 State-of-the-art on Technology Transfers

4.1.1 The Multidisciplinary of Technology Transfers

The body of literature on technology transfers is widely recognised as diverse and disarticulated (Battistella et al., 2016; Bozeman, 2000; Reisman, 2005) and a wide variety of researchers has covered the topic. Indeed, while the Journal of Technology Transfer has existed for over 50 years, studies on the matter are largely scattered and have been carried out by engineers, sociologists, economists, anthropologists and management theorists (Reisman, 2005). However, an extensive literature review on the topic has shown how little attention has been given to the issue of product technology transfers.

The body of literature has been mostly enriched by researches on the valorisation process; the process of transferring a technology from a university to the industry (see for example Audretsch et al., 2014; Battistella et al., 2016; Bozeman et al., 2015; Malik, 2002; Reisman, 2005; Soar, 2009; Sung, 2009; Watkins & Horley, 1986). In this context, the terms technology transfer and knowledge transfer have been used interchangeably, to the point that only a few authors have acknowledged the existence of any difference between the two (Gorschek et al., 2006). For this reason, the literature on technology transfers has represented a building block for studying and developing the section of the manual on knowledge exchange, while it has not contributed particularly to the section on supplier selection.

In the field of knowledge management, authors have generally defined the knowledge transfer process as a combination of the processes of knowledge sharing and knowledge flow and studied it in different contexts and with different scopes (see for example Ajith Kumar J. & Ganesh L.S., 2009; Amesse & Cohendet, 2001; Argote & Ingram, 2000; Cummings & Teng, 2003; Ferdows, 2006; Liyanage Champika, 2009; Zander & Kogut, 1995). Other significant contributions to the topic of technology transfers have come from the technology management (see for example Autio et al., 1996; Autio & Laamanen, 1995; Chiesa & Manzini, 1996; Flannery et al., 1994; Lichtenthaler & Ernst, 2007) and innovation management fields (see for example Hargadon & Sutton, 1997; Howells, 1999, 2006; Shrivastava & Souder, 1987; Stock & Tatikonda, 2000; Tatikonda & Stock, 2003). Surprisingly however, only a few studies concerning the project management level has been found (Caputo A.C. et al., 2002; Stock & Tatikonda, 2000) and finally, the topic has been discussed by sociologists and anthropologists (see for example Zhao & Reisman, 1992). In this scenario, this study addresses the multifaceted nature of the topic.

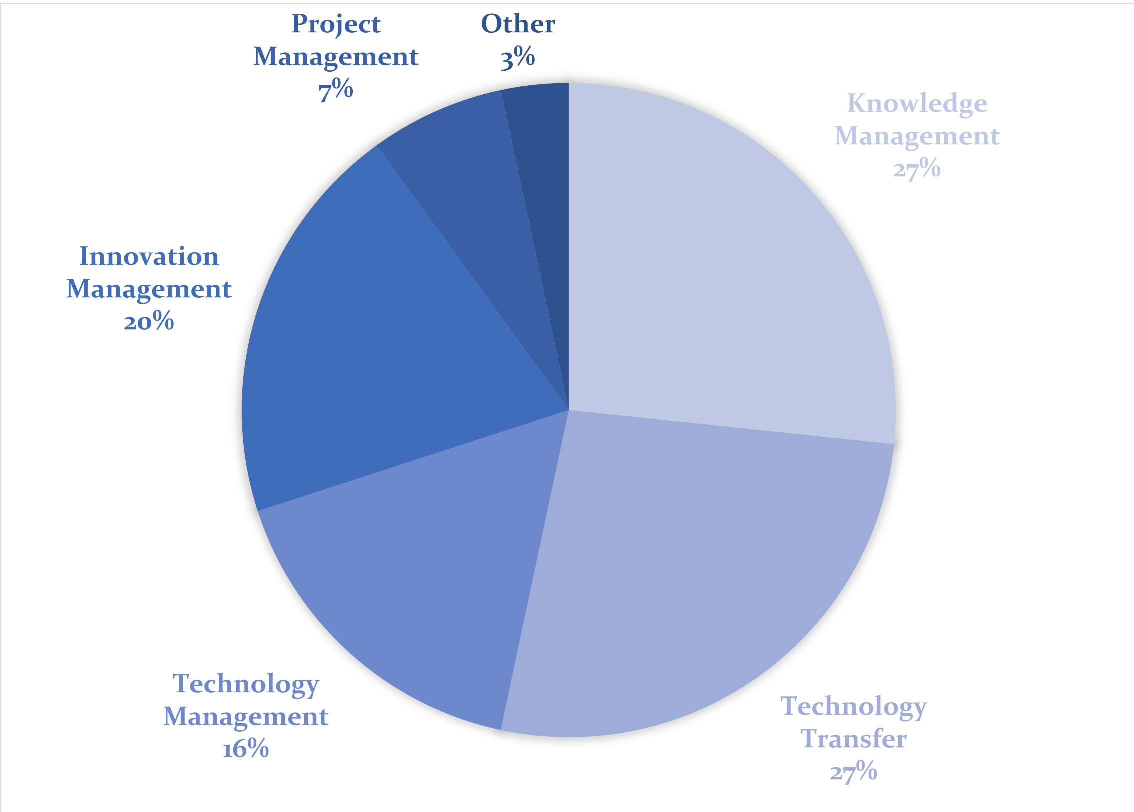

Figure 13 — Disciplines addressing the topic of technology transfers

4.1.2 A Classification for Technology Transfers

A multi-level classification for product technology transfers has been developed and summarised in Figure 14 to better show where this topic is positioned in its literature. On the first level, a classification can be achieved by taking into account the product life cycle, distinguishing two classes: new and mature technologies. The former type of transfers is the most extensively researched and focuses on the critical transition of technologies from R&D to commercialization (Battistella et al., 2016). The majority of the articles in this class concerns transfers from universities or government laboratories to the industry (see for example Audretsch et al., 2014; Bozeman, 2000; Bozeman et al., 2015; Caputo A.C. et al., 2002; Flannery et al., 1994; Shohet & Prevezer, 1996; Shrivastava & Souder, 1987; Soar, 2009; Sung, 2009). Also, some scholars have studied this type of transfer between organisations (see for example Autio et al., 1996; Cummings & Teng, 2003; Grosse, 1996; Howells, 1999; Liyanage Champika, 2009), while others have focused on intra-organisational transfers (Lichtenthaler & Ernst, 2007; Malik, 2002). Furthermore, even though most of the researchers have focused solely on the transfer of a technology, some have addressed the transfer of both products and the related technologies in the early stages of their life cycle (see for example Ajith Kumar J. & Ganesh L.S., 2009; Amesse & Cohendet, 2001; Autio & Laamanen, 1995; Stock & Tatikonda, 2000; Tatikonda & Stock, 2003).

This study addresses inter-organisational transfers of mature products and the related technologies, a far-less studied branch of technology transfers (Battistella et al., 2016; Tatikonda & Stock, 2003). Nonetheless, these transfers are an essential milestone for the redesign of the supply chain of a company and can finally determine the outcome of the process.

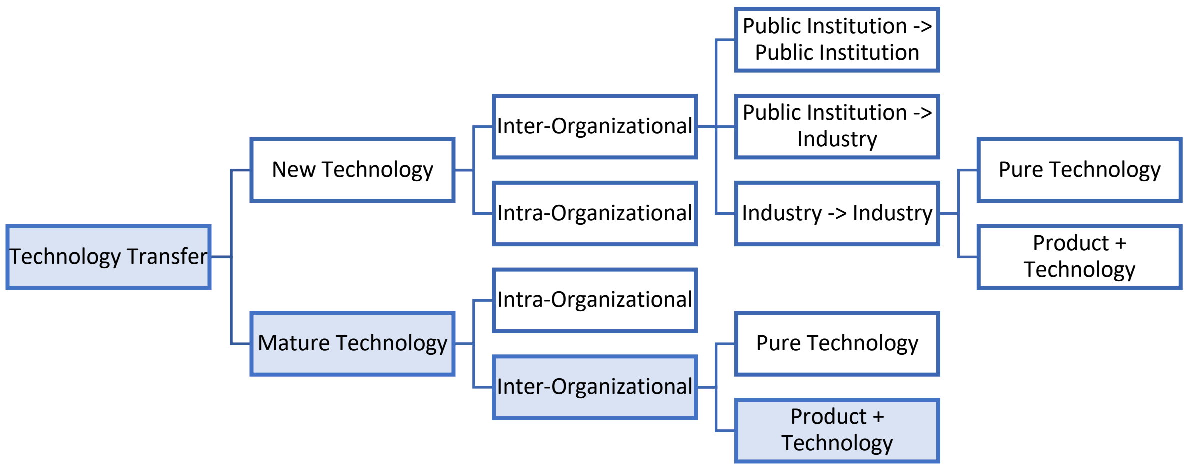

Figure 14 — A classification for technology transfers

4.1.3 A Comparison with the Valorisation Process

To better illustrate the characteristics of the product technology transfer, this type of transfer has been compared with the valorisation process. In comparing them, three differences have been found, and the first is in the stakeholder system. Models on valorisation processes generally include two stakeholders: the sending site (the university) and the receiving site (the organisation which aims at commercialising the technology). Eventually, external intermediaries such as consultants are considered, but their role is generally outlined as supportive. By contrast, product technology transfers involve three different parties in the supply chain. By shifting from two to three stakeholders, a different point of view was required in this thesis project: studies on the valorisation process generally take the perspective of the sender, the owner of the technology. However, in a product technology transfer the owner of products and technologies is the focal company. This is a reason why this study has looked at the product technology transfer process with the eyes of the focal company.

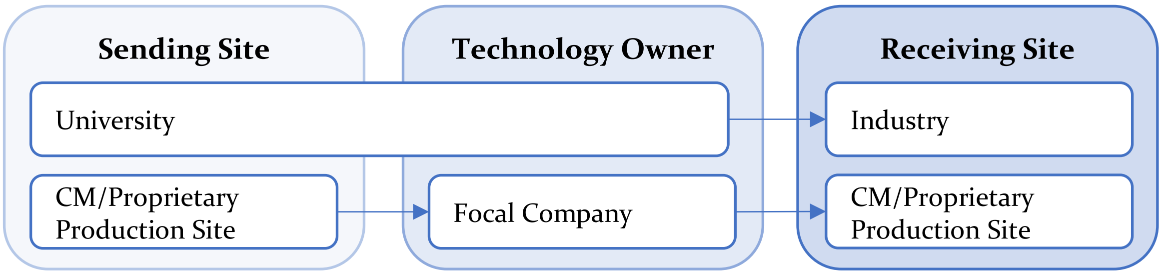

Figure 15 — Two stakeholders' system vs three stakeholders' system

The second element of distinction between the two processes is in the object of the transfer. For valorisation processes, the object is a new technology, while for product technology transfers is a product or portfolio of products and the related (mature) technologies. As what is transferred is different, so are to some extent the processes. For both, critical is the process of exchanging knowledge. However, in a product technology transfer other processes such as supplier selection and manufacturing implementation are particularly important as well. This characteristic of the valorisation process explains why the topic has been of such interest for studies in the knowledge management literature (see for example Ajith Kumar J. & Ganesh L.S., 2009; Amesse & Cohendet, 2001; Argote & Ingram, 2000; Cummings & Teng, 2003; Ferdows, 2006; Liyanage Champika, 2009; Zander & Kogut, 1995).

As for the third difference, the receiving site is considered as given in studies on valorisation processes, while in the product technology transfer, it is to be selected. The focal company will need to set up a supplier selection process to identify the best possible receiving site, and once the candidate is selected, it will be possible to plan and then initiate the implementation phase of the process.

4.1.4 Geographical Scope in Technology Transfers

An alternative way to classify studies on technology transfers is with respect to the geographical scope. Some authors have decided to focus on a specific country, looking for the reasons why these processes so often fail in achieving the expected results. For instance, Sung (2009) focused on the South Korean market, while Al-Mabrouk and Soar on the Arab Countries (2009). The need for focusing on a specific country or region emerges for two reasons: regulations and public-private interdependence. The former term refers to the widely diverse regulatory frame characterising different regions, while the latter to the need for institutional support to facilitate and finally accomplish a technology transfer. Regulatory affairs concern the transfer of both early life cycle and mature products and technologies, whereas institutional support is more important for early life cycle technologies. Finally, instead of focusing on a specific country, several authors have decided to carry out more generalizable studies, eventually limiting geographical references to the country in which their case studies took place (Audretsch et al., 2014; Ferdows, 2006; Malik, 2002).

4.2 The Foundations of the Manual

The product technology transfer topic has never been discussed as in this thesis, therefore requiring an ad-hoc combination of different bodies of literature. The next sections address this issue by complementing what discussed until now with a manual-development-oriented review of the topics of knowledge exchange (subsection 4.2.1) and supplier selection (subsection 4.2.2).

4.2.1 A New Perspective on Knowledge Exchange

A variety of researchers has addressed the most critical challenges of the knowledge exchange process in the context of a technology transfer. By addressing the topic from different perspectives, the outcome of these researches has been a large assortment of partly overlapping classifications, each one of them favouring certain dimensions over others. The taxonomy developed in this project is new to the literature and has been designed to address the unique characteristics of the product technology transfer has described in this thesis project. Particularly, the dimensions the focal company is challenged with during the knowledge exchange process have been group based on the following considerations. Firstly, the project team of the focal company has to deal with *an imperfect knowledge market*, a perspective supported by several authors (Howells, 1999; Shohet & Prevezer, 1996; Watkins & Horley, 1986).

Secondly, it has to *overcome distances* between the parties involved in the transfer (Cummings & Teng, 2003). These two perspectives are not new but, while they present little overlap between each other, they have never been considered together to the knowledge of the author. By contrast, in this study they are functional to the development of the manual for knowledge exchange and are both part of the related theoretical framework.

Dimensions of the Imperfect Knowledge Market

The identification of the reasons behind the existence of an imperfect knowledge market and the related challenges for knowledge exchange is not new to the literature. Although different studies identify various factors, it is undeniable that a certain level of overlap occurs between them and for this reason in time different naming schemes have been proposed. This study adopts the naming system proposed by Tatikonda and Stock (2003) for two reasons. Firstly, their study addresses product technology transfers in the context of a supply chain redesign explicitly. Secondly, their naming scheme has been specifically developed to facilitate the understanding of a technology transfer's knowledge exchange process. The market for knowledge is imperfect because *knowledge is tacit, novel and complex* (Tatikonda & Stock, 2003). While this view is widely accepted, it is worth noticing that often the body of literature in which a study falls determines which of these factors have been considered and which neglected (Tatikonda & Stock, 2003). Studies on innovation management focus on technology novelty and complexity while disregarding tacitness. By contrast, studies on technology, transfer and knowledge management address tacitness above all other factors (Tatikonda & Stock, 2003).

It is crucial stressing that in their study, Tatikonda and Stock (2003) refers to these factors as the *components of technology uncertainty*, rather than dimensions of imperfectness in the market for knowledge. Their choice can be justified when considering that their focus has been on *new product developments (NPDs)*. By contrast, this study does not specifically address NPDs, as it focuses on the transactional nature of knowledge and the elements that challenge its flow. The next paragraphs investigate knowledge tacitness, complexity and novelty in the scope of this thesis project.

Knowledge Tacitness

In their renowned article "the knowledge-creating company: how Japanese companies create the dynamics of innovation", Nonaka and Takeuchi (1995) distinguished *two forms of knowledge*: *explicit and tacit*. The former is knowledge formalised, articulated, codified in a way it can be easily shared between parties. The latter is knowledge embedded in individuals, in objects such as tools or equipment and in organisational routines, processes and structures (Cummings &

Teng, 2003). It is unformalized, unarticulated and hence very difficult — if not impossible — to spell out (Argote & Ingram, 2000; Cummings & Teng, 2003; Davenport & Prusak, 1998; Howells, 1999; Nonaka & Takeuchi, 1995). According to Nonaka and Takeuchi (1995), the knowledge most difficult to codify is the one residing in individuals' minds and abilities; it is *sticky* (Von Hippel, 1994). Tacitness causes ambiguity, making it more complicated to identify the factors, skills and capacities which determine the successful implementation of a technology (Argote & Ingram, 2000; Cummings & Teng, 2003). Furthermore and according to the resource-based view of the firm, the existence of this component of knowledge is inevitable, as it represents the foundation of the competitive advantage of a firm in its market (Battistella et al., 2016).

Knowledge Complexity

Through their review on technology complexity, Tatikonda and Stock (2003) identified three components which add-up to complexity: internal interdependence, external interdependence and the scope of the technology. The first two terms have often been categorised as knowledge contextuality (Battistella et al., 2016). Still, this study uses the classification of Tatikonda and Stock (2003) given the relevance of the difference between the two categories. Internal interdependence measures the level of complexity generated by the system of interconnections and relationship within the company implementing the technology. External interdependence is a measure of the extent to which a technology is intertwined with existing systems, leading to potentially extensive constraints to its application in different contexts. The same term has also been used to describe the geographical or physical dispersion of the technology or the extent to which the same one is developed in collaboration between different parties (Tatikonda & Stock, 2003). Finally, the authors refer to the scope of the technology as a measure of the number and complexity of elements and technical functions of which it is constituted.

Knowledge Novelty

The novelty of a technology has been assessed in different overlapping ways in the literature. Some authors have measured novelty in terms of familiarity or experience with the technology or similar ones (see for example Abernathy & Clark, 1985; Adler et al., 1992; McDonough III & Barczak, 1992; Stock & Tatikonda, 2000; Yoon & Lilien, 1985). Some other authors have defined novelty as the extent to which it differs with respect to existing and known technologies (Tatikonda & Stock, 2003). This parameter has been described as radicalness or magnitude, aiming at representing the organisational disruption a new technology is causing to its receiver. A technology can be either incremental or radical and more or less disruptive and destructive (Christensen, 2013; Leifer et al., 2000). Overall, it emerges that the novelty of a technology is not uniquely and objectively defined but rather an organisation-specific dimension (Tatikonda &

Stock, 2003). Hence, a company might struggle because of novelty even with mature technologies.

Dimensions of Distance

Several authors have identified in distances between sending and receiving site a barrier to the effective transfer of products and technologies (Battistella et al., 2016). This study uses the classification developed by Cummings and Teng (2003), which has been used several times (Battistella et al., 2016) and provides a fascinating perspective for this study on product technology transfers. The authors identified five different distances, which will now be presented: *organisational, physical, cultural, normative* and *of the knowledge base*.

Organisational distance depends on the relationship between the entities carrying out the transfer (Cummings & Teng, 2003) and in general, the stronger the link, the more effective the transfer is as the flow, depth and breadth of information will be better (Battistella et al., 2016). The existence of a *physical distance* between the parties is widely recognised as a cause for reduced effectiveness in the transfer (Battistella et al., 2016; Cummings & Teng, 2003). Easily interpreted as a geographical measure of distance, its existence can limit the opportunities of learning by observing or through informal social relationships and ties (Battistella et al., 2016). Furthermore, physical distance limits the possibilities of identifying where knowledge resides and how to retrieve it (Battistella et al., 2016).

The third form of distance between sites depends on the extent to which they possess *different knowledge bases*: the shorter is this distance, the simpler the execution of the transfer will turn out (Battistella et al., 2016). Indeed, if the gap is too broad, then it will be challenging to close, to the point that Nonaka and Takeuchi (1995) call for the need of overlapping knowledge and redundancy as a necessary step to transfer successfully. The distance of the knowledge base provides a different perspective on the challenges to a successful product technology transfer caused by knowledge. Still, it overlaps significantly with the dimensions of knowledge previously presented. This factor is not included in the theoretical framework to avoid confusion but has been mentioned for completeness and to provide a different angle to the topic.

The last two distances are cultural and normative. *Cultural distance* arises from differences in values, principles, behaviours, language and background, and can lead to operational difficulties as well as hinder the capacity to share knowledge (Battistella et al., 2016). Similarly, *normative distance* depends on the social norms characterising a specific group of individuals: different groups will respect different work values, practises and norms. Hence they will have different perceptions of what should and should not be done and how things should be executed (Cummings & Teng, 2003).

Factors to Maximise the Knowledge Exchange Effectiveness

Following the review on the factors inhibiting the completion of the knowledge exchange, the focus of this literature review shifts towards the identification of the tools over which the focal company can leverage to compensate for the negative factors. Several authors have addressed the topic, mentioning mostly the same elements and using different nomenclatures depending on the focus of their research (Battistella et al., 2016). By combining action research and interviews with the literature review, it has been possible to tackle the topic effectively, overall identifying two groups of tools to leverage on: *individual's capabilities* and *relational levers*. The first group includes *experience, expertise* and *absorptive capacity* (Battistella et al., 2016). The first term refers to the knowledge acquired through doing and observing, while the second one refers to the technical knowledge possessed by an individual because of its background (Battistella et al., 2016). The third identified capability is absorptive capacity: the ability to identify, acquire and apply new meaningful information to a particular task (Tatikonda & Stock, 2003).

The group of tools referred to as relational levers or inter-organisational interaction includes three elements: *communication*, *coordination* and *cooperation* (Tatikonda & Stock, 2003). To exchange knowledge, the focal company should establish effective interactional mechanisms. Their quality can significantly influence the level of imperfectness of the knowledge market and impact on the distances between the three stakeholders. As emphasized by several authors (Abernathy & Clark, 1985; Adler et al., 1992; McDonough III & Barczak, 1992; Stock & Tatikonda, 2000; Tatikonda & Stock, 2003; Yoon & Lilien, 1985) communication should be frequent, interpersonal and rich. Furthermore, cooperation supports the development of the knowledge package impacting on the perceived knowledge complexity and novelty, and the physical, cultural and normative distances. High levels of cooperation are triggered by shared objectives, a strong commitment to the project and a good relationship between the parties (Tatikonda & Stock, 2003). Finally, coordination represents the extent to which multi-party interactions are organised and structured effectively and depends on the level of joint planning, the rigidity of the established procedures and the expected length of the cooperation.

4.2.2 A Process Perspective on Supplier Selection

It is glaring that the literature on technology transfers has not tackled the problem of selecting suppliers. By contrast, in the product technology transfer, this is an essential step, and for this reason, it has been decided to complement the literature review section of this thesis project with an analysis of the *state of the art on supplier selection*. Most of the studies on the topic concern the process of selecting one supplier among several through models and decision-making methods. However, the same term is used to describe a much lengthier procedure which begins when the focal company contacts several suppliers and ask them to prepare a proposal to become a new member of its supply network. The next paragraphs firstly review the literature on request for proposals (RfPs), identifying the main challenges to be overcame, and the most critical requirements an RfP should comply with. Secondly, the focus shifts towards models for supplier selections: the most common are reviewed, compared and analysed and the most frequently chosen criteria are presented.

Request for Proposals

Within the topic of requirement engineering processes, the term request for proposal (RfP) refers to the process through which a company finds vendors able to fulfil its needs in terms of products or services supply (Andrea, 2003; Paech et al., 2012). Depending on the industry and on a company's specific procedures, a distinction might be made between request for information (RfI), request for proposal (RfP) and request for quotation (RfQ). The first document is generally used when a company has very little knowledge about the market it is about to enter or the products in the scope of the transfer. If an RfI is developed, then it is usually followed by an RfP. Finally, an RfQ is a more detailed version of the RfP, which covers all the specifications of the products or services in scope.

In this thesis project, the only document included as part of the supplier selection procedures is the request for proposal for two reasons. Firstly, in a product technology transfer the focal company should possess enough knowledge of the products in the scope, as the process of knowledge acquisition precedes supplier selection. The sending site constitutes a reliable and comprehensive source of information; therefore, an RfI should not be needed. Secondly, the difference between an RfQ and an RfP is so small that often the two terms have been used interchangeably, and little reasons can be found to send them sequentially to the same suppliers (S. Lauesen, 2004). Therefore, it is argued that a comprehensive supplier selection procedure for a product technology transfer should include a request for proposal only.

Receiving little attention by scholars so far (Paech et al., 2012), the processes of preparing an RfP and analysing the related bids are highly time-consuming and often carried out in an ad-hoc manner. The literature review on the topic allowed to identify the main challenges in RfP processes and the requirements that the process should satisfy. Firstly, while the object of the transfer can be achieved only by satisfying a wide range of requirements, *the tender process must fit in a very tight time frame*, two elements clashing between each other (Paech et al., 2012). Additionally, while the nature of the process requires intensive communication between the parties involved, this is often not the case in reality. The consequence is that a lack of clarity or quality of the expressed requirements will force the candidate supplier to guess meanings, increasing the propensity for errors (Paech et al., 2012). Hence, a request for proposal process should be designed to be *maximally clear and high in quality*. The literature review has further shown the importance of finding strategies to *maximise the automation of the process and its standardisation* and to *minimise the preparation time* (Chambers et al., 2005; Posner, 2003a, 2003b).

Several authors have addressed the automation topic and patented their solutions (see for example Chambers et al., 2005; Posner, 2003a, 2003b; Spencer, 2002), while other authors have proposed agile approaches to RfP's development (see for example Andrea, 2003; Paech et al., 2012; S. Lauesen, 2004; Y. Saito et al., 2012). However, while recognising its importance, little attention has been given to the topic of standardisation. Finally, authors have primarily focused on the tender process for software, while neglecting the matter of transferring products and the related technologies.

Criteria for Supplier Selection

When it comes to selecting suppliers, decision-makers need to define a set of criteria over which suppliers will be evaluated. The review on the topic carried out by Ho et al. (2010) provides an excellent overview of the criteria selected by a wide variety of scholars, and several relevant insights can be extracted. Firstly, there is no widespread agreement on the set of criteria which should be included in supplier selection, nor a defining industry-related pattern can be found. Secondly, authors have framed the same criterion in different ways, giving a clear cut to its interpretation, hence complicating comparison between studies. Thirdly, various strategies have been applied in deciding the extent of the set of criteria: from as few as three or four to as much as twenty (Ho et al., 2010). Overall, the process of selecting criteria appears to be strongly context-dependent, and the methods used to select suppliers will have an impact on both the type and number of criteria chosen.

In their review, Ho et al. (2010) showed that among the hundreds of criteria proposed, *quality* was included in almost 90% of the papers, while *delivery* turned out to be second-most selected criteria, being included in more than 80% of the articles. Widely considered the primary determinant of supplier selection in the past, *cost/price* was only third in this particular ranking, being included as a criterion in roughly 80% of the reviewed researches (Ho et al., 2010). Among the other criteria, *manufacturing and technical capabilities* have been often included, together with factors representing supplier performance in terms of *innovation*, *capacity to improve processes* and *organisational culture*. Nonetheless, as acknowledge by Ho et al. (2010), the set of criteria should be tailored around the business needs of the company.

Models for Selecting Suppliers

For a few decades now, researchers have experimented with a wide variety of tools to select suppliers. In their review, Ho et al. (2010) analysed the researches of the last decade on the topic to discover what were the tools preferred by the researchers. They found that scholars slightly prefer to apply individual models over integrated ones and that the most used were *Data Envelopment Analysis (DEA)* (18% of the articles), *Mathematical Programming* (12% of the items), *Analytical Hierarchy Process AHP* (9%) and *Case-Based Reasoning (CBR)* (9%) (Ho et al. 2010). Moreover, when it comes to integrated models, researchers commonly combined AHP with other tools such as DEA and multi-objective mathematical programming (Ho et al., 2010). These methods widely differ between each other in terms of complexity, strengths and weaknesses.

The *DEA* method measures the efficiency of suppliers as a ratio between benefit criteria (inputs) and cost criteria (outputs) (De Boer et al. 2001). The method is rapid and straightforward to apply; however, authors have used contrasting logics to distinguish between inputs and outputs. Therefore, an argument can be made against DEA regarding its consistency (Ho et al., 2010). By contrast, the *AHP* is a method which in its simplicity, ensure consistency. When applying the AHP, decision-makers are required to qualitatively pair-wise compare each of the criteria in the established set. Through this process, it is possible to extrapolate weights to assign to each criterion and to verify whether the pairwise comparison has or has not been logically assessed (De Boer et al. 2001). However, this method can be cumbersome, especially when dealing with a broad set of criteria (Rezaei, 2015). The third most used method — *CBR* — resorts to past experiences to make informed decisions on the current case (De Boer et al., 2001). Finally, *mathematical programming* models are designed so that the optimal solution to the supplier selection model can be obtained by solving an objective function and respecting a set of constraints. These models are more objective then rating models; however, they can hardly capture qualitative criteria (De Boer et al., 2001).

In general, it is not possible to identify an overall best method for supplier selection. Instead, different methods will need to be chosen with respect to the context and the business needs of the company aiming at selecting a new supplier. Notably, more complex models such as mathematical programming might be able to yield better results in certain situations. However, their conceptual and practical complexity might cause the decision-makers to prefer simpler methods such as the AHP or a basic categorical method, in which suppliers are scored as positive, neutral or negative over each of the selected criteria (Ho et al., 2010).

4.2.3 Key Learnings from the Literature

The review carried out in this study has shown how in the literature on technology transfers, the topic of this thesis project is strongly underrepresented. By contrast, the valorisation process has been widely explored, and the points of contact between the two processes have constituted the foundations for the section of the manual on knowledge exchange. Overall, it emerged that the market for knowledge is imperfect because knowledge is tacit, complex and novel. Furthermore, organisational, physical, cultural and normative distances between the stakeholders involved in the transfer constitute critical barriers to an adequate knowledge flow. However, these barriers can be overcome by the focal company, through individual's capabilities and relational levers. Therefore, the company should leverage on experience, expertise and absorptive capacity, as well as on communication, coordination and cooperation.

A successful supplier selection passes through the design of a high-quality request for proposal and the selection of the right methods and criteria. Requests for proposal have not been widely researched, especially concerning products and technologies and have to comply with several requirements. Researchers generally agree on identifying automation, standardisation, and minimum preparation and analysis time as fundamental requirements for a successful RfP process. Moreover, as frequent interactions between the parties involved in the process are often not possible, the RfP document should be developed in a way that maximises clarity, comprehensiveness and overall quality.

5. A Manual for Product Technology Pre-Transfer Management

Chapter 5 of this thesis project presents the manual for managing the pre-transfer phase of product technology transfers. It is divided into two sections, the first one addressing knowledge exchange, the second one supplier selection. In section 5.1, the manual on how to handle the first group of activities unfolds by highlighting requirements and providing recommendations and guidelines for managing the processes. Particularly, it shows the relevance of the factors inhibiting an adequate knowledge flow between the parties. It emerges that a successful knowledge exchange will be possible only if the challenges posed by these factors are overcome. Hence the manual presents recommendations and guidelines to improve the knowledge flow and therefore increase the effectiveness of the process. Finally, section 5.2 models the supplier selection phase of the pre-transfer process, by considering several steps: preparation for supplier selection, preparation for negotiation, analysis and negotiation of the proposals, and final selection. At the beginning of each of these subsections, requirements are outlined, and in response, the manual provides recommendations, guidelines and tools to deal with them.

5.1 Managing Knowledge Exchange

The manual on knowledge exchange proposed in this thesis project is founded on the conceptual framework presented in Figure 18. This framework is the result of the literature review on knowledge exchange (see subsection 4.2.1) and for the greatest part combines and re-think the concepts proposed in two existing frameworks. The first one has been developed by Cummings and Teng (2003) in their article "Transferring R&D knowledge: the key factors affecting knowledge transfer success" and is presented in Figure 16. The framework distinguishes between knowledge context, relational context and recipient context. The quality of the first context depends on knowledge articulability and embeddedness. Moreover, organisational, physical, normative, cultural and knowledge base distances are viewed as characteristics of the relational context between the actors involved in the transfer. Finally, the framework emphasises how the attitude toward the transfer and the absorptive capacity of the receiver can enhance transfer effectiveness.

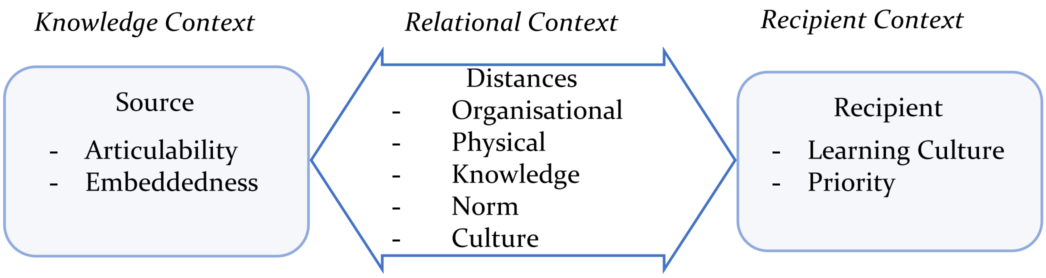

Figure 16 — Adapted from Cummings and Teng (2003): the relational context in a technology transfer

The second framework has been developed by Tatikonda and Stock (2003) and can be examined in Figure 17. In the authors' view, tacit knowledge, knowledge complexity and knowledge novelty are sources for technological uncertainty. Moreover, communication, cooperation and coordination constitute the major dimensions of interaction between the stakeholders involved in a product technology transfer. Finding the right fit between these elements is critical to complete the product technology transfer effectively.

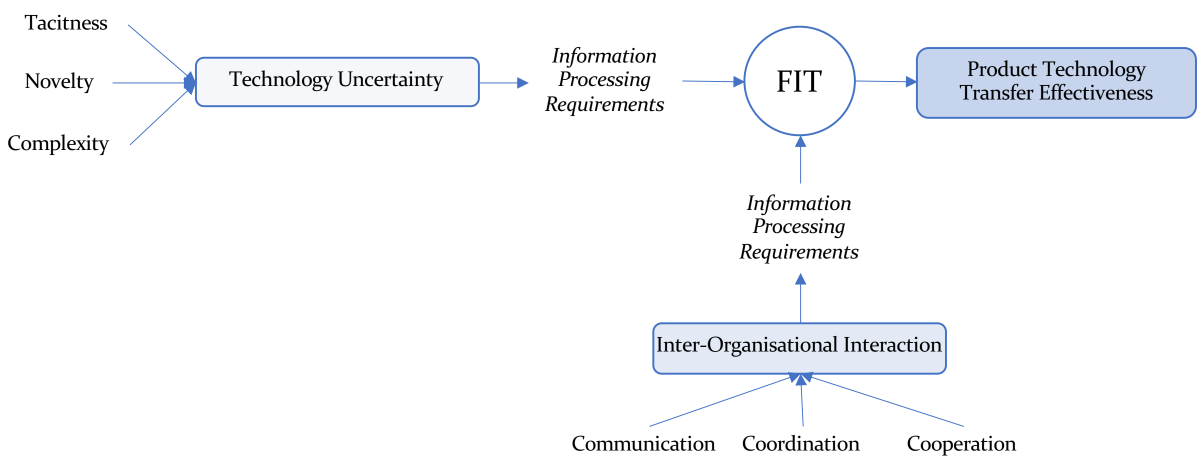

Figure 17 — Adapted from Tatikonda and Stock (2003): the product technology transfer framework

Figure 18 illustrates the theoretical framework developed in this thesis project. The figure shows that knowledge tacitness, complexity and novelty harm the effectiveness of the knowledge exchange. However, while Tatikonda and Stock (2003) classify the three knowledge factors as the source of technology uncertainty, in this thesis project they are captured as components of the *imperfect knowledge market*. Technological uncertainty is a perspective which fits well in a *new product development* context but seems out of place in a study which does not specifically address the topic. By contrast, the chosen viewpoint is believed to emphasise the transactional nature of knowledge better, as suggested by Shohet & Prevezer (1996), and the multi-stakeholder dynamicity of the knowledge exchange process. The second dimension that negatively impacts the knowledge exchange process is *distance*. The article by Cummings and

Teng (2003) takes a descriptive perspective to distances. By contrast, the framework developed for this thesis project emphasis how distances can negatively impact the quality of the relational context between senders and receivers in a technology transfer.

The framework identifies two mediating variables in the knowledge exchange process: *individuals' capabilities* and *relational levers*. Individuals' capabilities include *absorptive capacity*, a dimension proposed by Cumming and Tengs, *experience* and *expertise*. Among the relational levers there are *communication*, *cooperation* and *coordination*. It is worth noticing that these same dimensions are referred by Tatikonda and Stock (2003) as means for inter-organisational interaction. By contrast, in this thesis project, they are viewed as relational levers. The adopted perspective stresses the capability of these factors to influence the outcome of the knowledge exchange process. Therefore, it is best suited to provide recommendations and guidelines on knowledge exchange. Conversely, the point of view chosen by Tatikonda and Stock (2003) fits best a descriptive approach to the topic. Moreover, the model developed by Tatikonda and Stock (2003) correlates inter-organisational interaction with the imperfect knowledge market, while in this study it mediates with both that dimension and the dimensions of distance. The next paragraphs emphasise the relevance in a product technology transfers of the elements outlined and extract requirements, recommendation and guidelines.

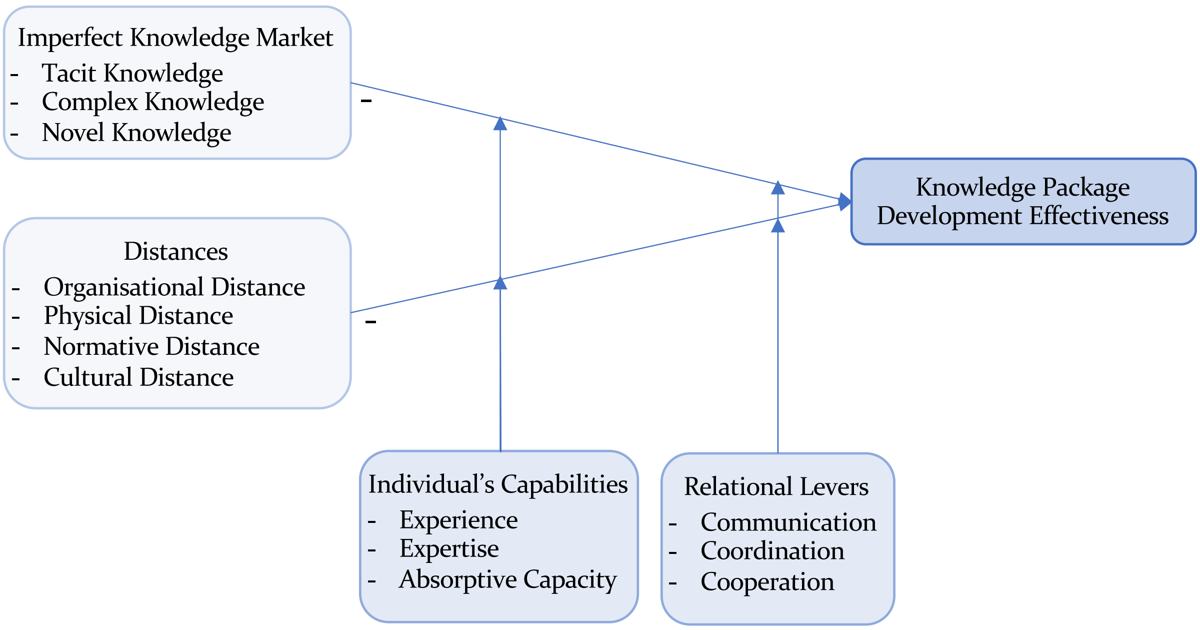

Figure 18 — The theoretical framework for knowledge exchange

5.1.1 The Relevance of the Imperfect Market for Knowledge

Tacit knowledge has a substantial impact on the process of knowledge exchange. While this impact is maximum when transferring early-life cycle technologies, it remains significant for mature technologies. Notably, it has been found that part of the knowledge that needs to be transferred still resides in individuals and organisational practices and remains not spelt. Hence, knowledge tacitness represents a crucial challenge in the process of exchanging knowledge. Similarly, *knowledge novelty* can impact the knowledge flow between both the sending site and the focal company, and between the latter and the receiving site, once selected. Indeed, knowledge novelty is not absolutely defined but relative: the newer the technology for a party in the transfer, the more difficult the transfer will be.

Finally, *knowledge complexity* can be extremely high when the fundamental knowledge depends on widespread interdependencies and experiences (Stock & Tatikonda, 2000). When working for a long time on a particular portfolio, the keepers of this system of interconnections might be long gone complicating the process of decomposing the system in its elements and replicate it in a different context. This could be the case at a sending site, making it a particularly relevant factor to take into account for the focal company. Furthermore, the transfers observed at the time of the study confirmed that more complex technologies increase the complexity of a transfer.

Requirements from the Imperfect Market for Knowledge

Several requirements should be met to complete the knowledge exchange. Firstly, the project team of the focal company should be able to *rapidly assimilate the knowledge* incoming from the sending site, *critically evaluate it* and *effectively store it* in a comprehensive and structured knowledge package. The focal company's project should closely work with the sending site: *inter-organisational interactions procedures* ought to be established. The focal company's project team should also assess products, technologies and processes, identifying opportunities for improvements and re-developments. Particularly, the project team of the focal company should find ways to *recognise complexities* in products and technologies and choose the best way to tackle them accordingly. Finally, the package should allow reproducing the processes in place at the sending site, at the receiving one in a *straightforward way*. Hence, the team should implement mechanisms to *share the knowledge package rapidly and effectively* to the newly selected receiving site.

5.1.2 The Relevance of the Dimensions of Distance

In a product technology transfer, it is of interest to determine the *organisational distance* between the sending site and the focal company and between the receiving site and the focal company. In both cases, it is possible to have arm-length contracts, collaborations or alliances for inter-organisational transfers and tighter connections for intra-organisational ones. In the process of knowledge exchange, the sending site is either a long-lasting partner of the focal company or an owned production plant; hence social ties are dense, and the organisational distance should not be excessive. On the other hand, the organisational distance between the focal company and the receiving site will largely depend on the type of agreement the two companies will reach.

Physical distance relates to the geographical location of the stakeholders involved and can limit the opportunities for close collaboration and joint informal relationship development. The projects investigated in this study showed that this type of distance is exceptionally relevant for international inter-organisational transfers involving stakeholders located in different countries. Hence, practices to shorten the physical distance between the parties involved in a product technology transfer ought to be researched.

The causes for *cultural and normative distances* are differences in vision, values, principles, ways of working or social norms between stakeholders. The problem is particularly relevant in international transfers of products and technologies. Indeed, social norms are rooted in the everyday practises of the receiving and sending sites and reflected in the way they handle products and technologies. Underestimating these distances can have catastrophic consequences on the outcome of the product technology transfer.

Requirements to Shrink the Distances

The existence of distances between organisations must be taken in due consideration in a knowledge exchange process. Overall, the focal company needs to facilitate inter-organisational interactions by considering each type of distance in turn. Firstly, it should carefully *decide on its relationship* with the new receiving site to minimise the organisational distance while taking into account other business requirements. Secondly, strategies to reduce the physical distance between the parties involved in the transfer should be programmed and implemented. Specifically, project structures and procedures must ensure maximum *process efficiency*. Finally, the focal company needs to perform actions to *bridge cultural and normative gaps* between stakeholders.

5.1.3 Recommendations on Human Resources Management

The two mediating variables in the conceptual framework, individuals' capabilities (experience, expertise and absorptive capacity) and relational levers (communication, coordination and cooperation) are keys to a successful knowledge exchange process. The following paragraphs deep dive into the first set of factors, showing the impact they can have in practice and what should be done. It will be apparent that the successful completion of the knowledge exchange phase largely depends on the human resources involved in the process, their traits and skills.

Individual's capabilities play a crucial role both in coping with the imperfect knowledge market and in bridging distances between the parties involved in the transfer. Expertise and experience on the products and technologies to be transferred can help the focal company to explicate tacit knowledge more efficiently, reduce the perceived complexity of the technology and minimise the impact of the technology's novelty. Therefore, in designing the project team, the focal company should look among its resources for individuals possessing the type of expertise and experience fitting the project. These individuals should preferably possess a strong background on the technology either deriving from studies or previous experience with it and the capabilities to interact with multiple stakeholders over an extensive period. Similarly, previous experience in transfers is an asset to be considered.

These resources are scarce by nature and might be already assigned to other projects. A possible way around this problem is to institute the figure of the *internal consultant*; an individual included in a side team which can become active or take an active role only in the moments of need. As an example, the team might be missing the expertise necessary to estimate the investments required at the receiving site to accommodate the new production process. In response, the focal company's team should be able to consult an expert outside the core-team to handle this specific task.

The third capability identified in this study is absorptive capacity: the capacity to identify, acquire and apply new meaningful information. It is widely recognised to be an essential leaver to tackle novel technologies (Tatikonda & Stock, 2003) and is relevant both for the focal company and the receiving site. Absorptive capacity can impact on the efficacy of training, or ease of teaching (Zander & Kogut, 1995) and depends on the affinity of the workers with the transferred technology, as well as the novelty and complexity of the technology itself. Several authors have recognised the two-ways connection between absorptive capacity and knowledge, affirming that a shared knowledge base can have a positive impact on the absorptive capacity of the receiver and therefore on knowledge exchange (Battistella et al., 2016). Hence, previous experience on the technology by the stakeholders can be crucial for a successful transfer. Finally, the project teams should be designed in a flexible way, so as to absorb the impact of the continuous evolution product technology transfer experience.

5.1.4 Recommendations to Act Upon the Relational Levers

This study identifies three relational levers: communication, coordination and cooperation. The use of ad-hoc procedures to deal with them has been discovered to be a factor negatively influencing the efficiency and effectiveness of the inter-stakeholder interactions. Therefore, the focal company is recommended to *define standard operating procedures* (SOPs) to deal with sending and receiving site and use them in every transfer. In the context of international transfers, SOPs should include information regarding *the design of direct and indirect forms of communication*, *cooperation and coordination*.

Direct Communication, Cooperation and Coordination

In a product technology transfer, all the parties share the same goal of executing the transfer as fast as possible. However, establishing a trustworthy relationship can vary in difficulty, affecting coordination and cooperation. Effectiveness of the mechanisms in place can impact several dimensions both in the relationship between sending site and focal company and between the latter and the receiving site. High level of coordination and cooperation can help to deal with the complexity and novelty of the technology, enabling a more transparent flow of knowledge between the parties. Furthermore, effective coordination can reduce the organisational distance between the parties, thanks to stronger ties.

Previous collaborations between sending site and focal company should support interactions, thanks to a supposedly good relationship developed over time. By contrast, the relationship between the focal company and the receiving site is to be built from the ground up if the new site is not owned by the focal company or is not already part of the focal company's network. To develop this relationship, the focal company should relate to the receiving site frequently. Furthermore, to maximise coordination, the focal company should work on the project plans together with the sending and the receiving site (once it is selected). Finally, formal contracts and agreements should establish what is expected by each party at different stages of the process, and the forms of organisational interaction.

On-site visits and face to face training and meetings are compelling tools to improve communication, and while different stakeholders can be thousands of kilometres away from each other, globalisation has made the world so small that face to face multipurpose visits' benefits outweighs the costs of these trips. Furthermore, new information and communication technologies are reducing distances like never before. Online meetings should be scheduled regularly to keep the stakeholders posted on the latest news and continually align on the way forward. Meetings should be frequent, and their characteristics (type, frequency, participants) fixed from the beginning of the project while keeping the necessary flexibility to include ad-hoc meetings in the frame if needed. To favour the quality of the relational levers, temporarily co-locating part of the focal company team to the sending and receiving site should be considered to reduce organisational and physical distances and to bridge the imperfect market for knowledge. Furthermore, to overcome cultural and normative distances, the focal companies should consider including in the team individuals sharing the same social values and norms of the human resources of the sending and receiving site.

Indirect Communication, Coordination and Cooperation

Direct forms of interconnections should be coupled with indirect ones, with the goal of minimising redundant and avoidable interactions and be more effective when directly interacting with each other. When it comes to indirect forms of communication, the parties should take advantage of platforms to share documents in a structured way. The focal company should be in charge of managing the platforms, establishing access rights, structuring the shared spaces in a standard manner, maintaining them and ensuring order and logic. Figure 20 proposes a framework for structuring the shared platforms and distinguishes between two main sections: the *knowledge package* and the *project folder*. The proposed structure has proved useful in the product technology transfers observed, and the categories have been defined through a process of generalisation, starting from the structure used by the focal company object of this study.

The *knowledge package* section should be managed and maintained by the focal company and shared with the sending site. The goal of this section is to orderly collect all the documentation available for the portfolio of products to be transferred. It should include documents, spreadsheets, videos, drawings, notes and any other format able to collect information meaningful to complete the product technology transfer. Materials should be organised in sections by product and category. The knowledge package should include as many sub-sections as the number of products in the scope of the transfer are, and each of these should be structured in precisely the same way to ensure *standardisation* and maximise *clarity*, *maintainability*, *accessibility* and *user-friendliness*.

To summarise the available information, the shared space should include a document easily accessible by the participants containing a summary of available and missing information (*00_Check list*). Furthermore, the information should be classified logically. Extrapolated by the existing structure used at the focal company, the proposed framework categorises information firstly on a chronological basis: from starting materials (*02_Raw Materials*) to production (*03_Manufacturing, 04_Packaging, 05_Final product*), to distribution (*07_Logistics*). Furthermore, the proposed classification distinguishes in terms of the source of the document: the regulatory authorities (01_Dossier) or the production site. Each folder should include sub-folders if needed, and this sub-structure should be replicated throughout the knowledge package. An example applicable to the pharmaceutical industry is available in the figure below; however, practitioners are encouraged to adapt the framework to their needs.

Knowledge Package Product 1	
1. Dossier	1.1 Current Dossier 1.2 Dossier Variations 1.3 Old Dossiers
2. Raw Materials	2.1 Specifications 2.2 Testing Instructions 2.3 Master File 2.4 Certificate of Analysis 2.5 Reference Standards 2.6 Supplier Information 2.7 Additional Information
3. Manufacturing	3.1 Master Batch Record 3.2 Executed Batch Record 3.3 Technical Drawings 3.4 Key Equipment 3.5 Validation Reports 3.6 Other Requirements 3.7 Stability/Holding Time 3.8 Flowcharts
4. Packaging	4.1 Packaging Specifications 4.2 Drawings 4.3 Artwork 4.4 Bill of Material 4.5 Key Equipment 4.6 Supplier Information

5. Finished Product	5.1 Specifications 5.2 Customer Requirements 5.3 Testing Instructions 5.4 Certificate of Analysis 5.5 Reference Standards 5.6 Validation Reports 5.7 Other Information
6. Stability and other Quality Topics	6.1 Storage Condition 6.2 Shelf Life Specifications 6.3 Testing Instructions 6.4 Stability Reports 6.5 Product Quality Review 6.6 Quality Issues 6.7 Safety Data Sheets 6.8 Precautions 6.9 Cleaning Procedures 6.10 Other Information
7. Shipping and Distribution	8.1 Shipping Validation Reports 8.2 Wrapping and Labelling Requirements 8.3 Transport Conditions
8. Additional Information	

Figure 19 — Knowledge Package Detailed Structure

The *project folder* should be shared between the receiving site and the focal company and managed by the latter. The output of the most important meetings, such as the kick-off, should be reported in a dedicated folder (*00_Minutes*), while another one should concern the project organisation and the progress tracking documents (*01_Project Set-Up*). Particularly, this folder should include timelines, transfer protocols, project charters and other organisational files.

Moreover, a version of the knowledge package carefully filtered from information the receiving site should not be receiving should be included as well (*02_Knowledge package*), as it constitutes the fundamental input enabling the new supplier to implement the transfer process. Finally, the project folder should include several other spaces jointly prepared by the focal company and the receiving site. These should consist of financial and contract-related topics, analytical and manufacturing implementation-related information and documentation, and quality issues (*03_Finance, 04_Implementation, 05_Regulatory, 06_Quality*). Additional folders should be made available for industry-related topics, and one last folder should allow to include information which is believed not to fit anywhere else (*08_Additional information*). Adding this last folder can be helpful for the participants to the shared space: if they think a certain data does not fit in the framework, they will not be forced to include it somewhere wrong. It will then be easier for the administrators to re-locate the unclassified piece of documentation.

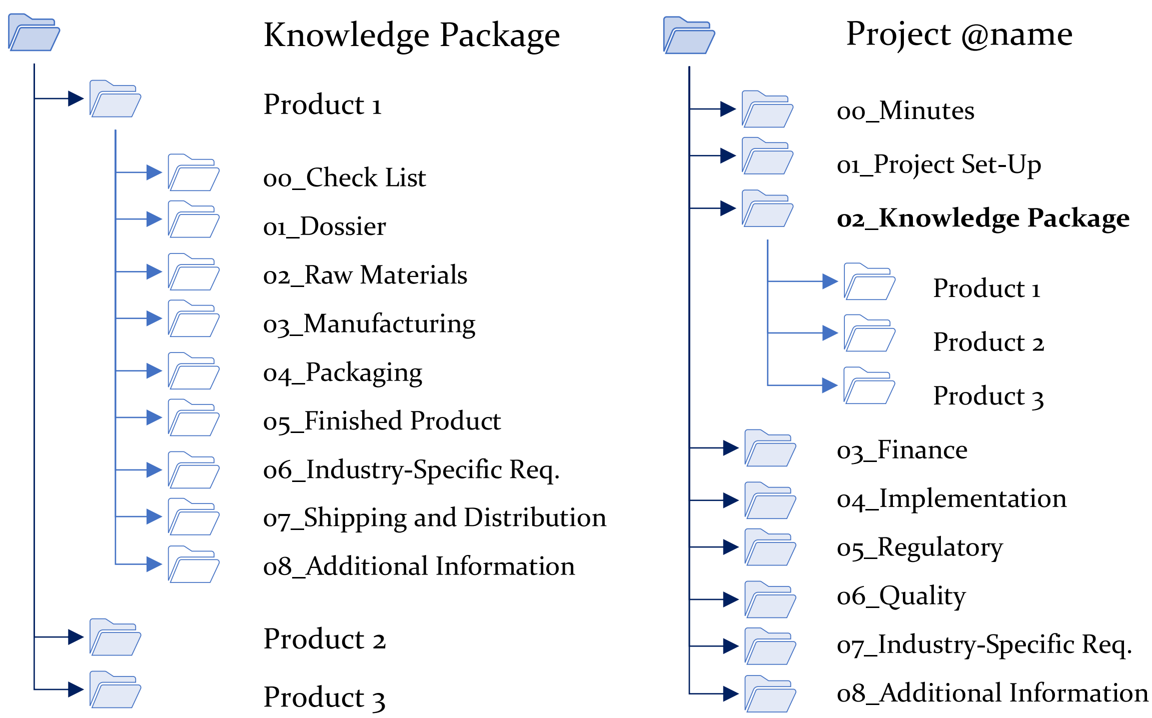

Figure 20 — Knowledge package and project folder structures

In the process of developing and enriching the knowledge package, checklists are useful tools for coordinating action toward the completion of the process: using them is strongly encouraged. This document should reflect the folder structure of the knowledge package and specify for each section the already uploaded documents and the ones still missing. Extremely easy to update, document checklists can simplify coordination procedures and speed up the process of alignment between sending site and focal company. Table 2 provides a partial example of a document checklist, matching the structure of the knowledge package and able to provide the reader with a rapid overview of the documents missing.

Table 2 — Document Check List Example

Section	Subsection	Available	Name	Reference
01 Dossier	-	Y	Dossier_Product X	A001
02 Raw Materials	2.1 Specifications	Y	Spec_RawMaterial 1	B001
		Y	Spec_RawMaterial 2	B002
		Y	Spec_RawMaterial 3	B003
		N	Spec_RawMaterial 4	-
		N	Spec_RawMaterial 5	-
	2.2 Testing Instructions	Y	Insp_RawMaterial 1	C001
		Y	Insp_RawMaterial 2	C002
		N	Insp_RawMaterial 3	-
		N	Insp_RawMaterial 4	-
		N	Insp_RawMaterial 5	-
	2.3 Master File	Y	Reference_Std 1	D001
	...			
03 Manufacturing	3.1 Batch Records	Y	BatchRecord_v4.0	H001
	...			
04 Packaging	4.1 Specifications	N		-
	...			
05 Final Product	5.1 Specifications	Y	Spec_Final Product	Q001
	...			
06 Industry Specific				
07 Logistics	7.1 Distribution			
	...			
08 Additional Info	...			

5.1.5 Final Remarks on Knowledge Exchange

The process of exchanging knowledge requires the focal company to acquire it from the sending site, store it in a knowledge package and distribute it to the receiving site. To complete these steps, the focal company needs to build up a team able to rapidly absorb the knowledge shared by the sending site and promptly redirect it to the receiving site. Maximising the chance of success further requires the team to include members experienced in product technology transfer processes and on the products and technologies in the scope of the specific transfer. Furthermore, the focal company should design a project team with the right expertise, including all the functions outlined in the stakeholder section of this thesis project (see subsection 3.2.2). Finally, team members' personality traits should be taken into account when deciding on the teams' composition.

Fundamental in a knowledge exchange process are direct and indirect forms of interconnections between stakeholders, and the focal company should devise mechanisms to enhance communication, cooperation and cooperation. It is recommended to plan and take advantage of face to face and online meetings, training, workshops and brainstorming sessions. Furthermore, the focal company should design standardised, easy to prepare, user-friendly, accessible and easy to maintain shared spaces where the focal company's project team can interact with both the sending site and the receiving site. These shared spaces are the host of the knowledge package and all the other project-relevant information. They should be resilient and flexible enough to be reused in any project with minimal modifications or adjustments.

5.2 Modelling Supplier Selection

This section of the manual on product technology pre-transfers addresses the procedures for supplier selection. The process has been divided in 4 steps which are addressed sequentially: preparation for supplier selection, preparation for negotiation, analysis and negotiation, and comparison and selection. For each step, requirements, recommendations and guidelines are outlined.

5.2.1 Preparation for Supplier Selection

The preparation for supplier selection step involves the supply chain and technical management functions. The former is in charge *of forecasting production volumes* for the products in the scope of the transfer. Quantities should be forecasted for several years in the future and based on multiple scenarios. The former is in charge of finalising the *demand profiles*, which are extracted from the knowledge package and start *shortlisting suppliers*.

The process of supplier qualification ought to include an evaluation of the financial status of the company, its history, quality and regulatory certificates and protocols in place, manufacturing and technical capabilities and information on capacity availability, current partners and business models. The best practice is to proceed iteratively, by gradually shrinking the list of candidate suppliers based on an increasingly detailed set of information. One of the most significant challenges of this phase is the retrieval of valuable information. Indeed, candidate suppliers will probably not be willing to share information without any reassurance on inclusion in the supplier selection process, both for confidentiality reasons and because it is a time-consuming activity (Andrea, 2003). Furthermore, sources of information besides the company itself are often scarce, thus limiting the efficiency and effectiveness of the supplier qualification process. Ideally and to counteract, it is recommended to include in the last stages of this process on-site visits, face to face interviews and meetings to be able to make an informed decision on the best supplier set.

5.2.2 Preparing for Negotiation

The *confidentiality disclosure agreement* (CDA) is the fundamental document enabling the start of discussions and negotiation between the focal company and several suppliers over the products to be transferred. By signing the CDA, the suppliers commit to respecting the confidentiality of the information they will receive from the focal company. The confidentiality agreement should be a standard document, designed to be reused by the company. Furthermore, each supplier should receive the same CDA, with the same information and conditions and, as suggested in the ISPE Technical Transfer Guideline Manual (ISPE, 2018), enough time should be given them to consider the CDA's terms and eventually sign it. During this waiting period, the focal company should focalise in developing the *request for proposal (RfP)*.

Requirements for a High-Quality RfP

The development of the RfP will need to be carried out jointly between purchasing, technical management and supply chain. At the supplier end, the involvement of the same functions is required to understand the document in its technical aspects and develop a bid. The carried-out literature review has brought light to several requirements an RfP should comply with. The document should be prepared in a *short time frame* without compromising on its *clarity* and *quality*. Furthermore, the RfP should be as *standardised* as possible, to be re-used in other projects and should be *maximally automated* to reduce the risk of making mistakes and its preparation time.

Several additional requirements have been found during this study and have been addressed in the manual's design. The RfP should be *comprehensive and transparent*, providing the suppliers with the information they need to develop an informed bid, while not overloading them (Andrea, 2003; Paech et al., 2012). Therefore, it needs to include the necessary technical information, with a particular focus on the main *cost drivers* and the *forecasted volumes* for the products in the scope of the transfer. This group of requirements is very industry and project dependent, so they will need to be identified at the beginning of the project: they cannot be fully anticipated. Besides, the RfP ought to allow the suppliers to *easily make their quotations*, by ideally structuring the costs according to the way they calculate them internally. At the same time, the designed RfP should *facilitate the focal company in the subsequent analyses and comparisons*. It has been observed that these two requirements clash between each other: a trade-off will need to be found. It is recommended to favour the supplier perspective on the most complex topics, while favouring internal analysis on the remaining.

The RfP should include strategies to ensure the *consistency* of a candidate's offer, making it easy to spot discrepancies or mistakes. Furthermore, it should be designed to *minimise the analysis time*, once the suppliers have filled it. Finally, authors have primarily focused on the tender process for software, while neglecting the topic of transferring products and the related technologies. In doing so, an additional challenge of the process has not emerged: its *multifunctionality*. The functions involved in the process tend to limit the interactions between each other to a minimum, the result being a reduction of this process efficiency. An adequately designed RfP should favour *inter-functional interactions*.

Recommendations and Guidelines for Designing the Request for Proposal

This manual proposes a seven-sections structure to the RfP which, validated during the study, maximises clarity for the bidding suppliers and simplifies the analysis of the proposals for the focal company. Clarity minimises the support suppliers will require in preparing the proposal, reduces the time they will need to complete the task and diminishes the risk that they will use alternative templates or tools to present their offer. Simplifications for the focal company are achieved through a standard, easily manageable and maintainable, easy to understand, simple to use and comprehensive multi-functionality tool jointly developed by the three interested functions. Therefore, the proposed structure for the RfP effectively streamlines the process and can be observed in Figure 21.

The seven sections in which the template is divided are *instructions*, *products presentation*, *additional information*, *quotation for volume A*, *quotation for volume B*, *transfer costs breakdown* and *transfer costs analysis*. The first section's goal is to provide instructions to the members of both the focal company filling the template and the suppliers in their process of preparing the bid. Instructions should be short, comprehensive and accessible. Particularly, besides outlining the remaining of the RfP and suggesting how it should be prepared, it

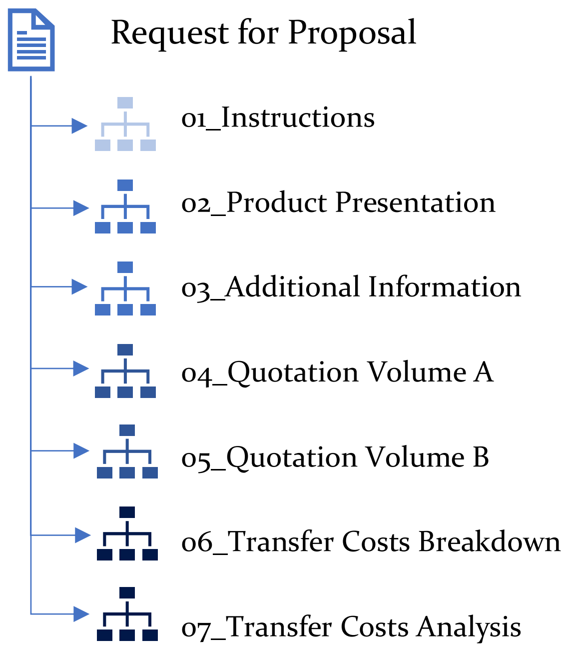

Figure 21 — RfP Structure

is recommended to include a flow chart like the one presented in the picture below to clearly show the inputs and operations to be accomplished in the process of developing the RfP and the functions in charge of each step.

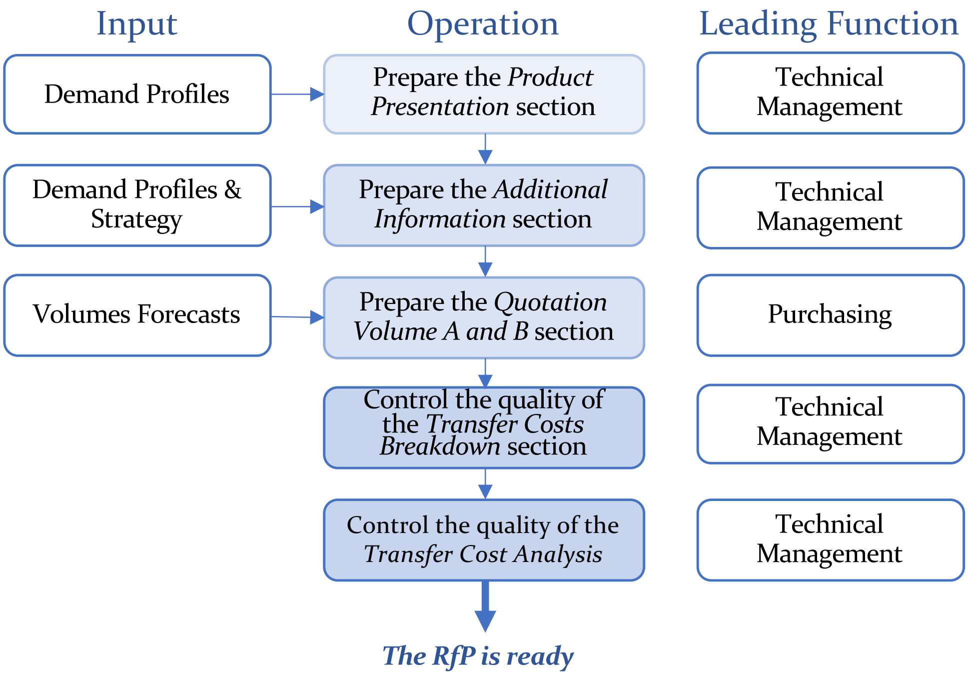

Figure 22 — A flowchart for the RfP development

Following the introduction, sections 2 and 3 of the RfP provide technical information to the supplier, while the last four ones concern the cost quotations. The next paragraphs analyse these sections in three groups: product overview, quotations and transfer costs.

Product Overview

The product presentation section summarises in a simple, compact design the characteristics of the whole product line-up in the scope of the transfer, subdividing information with the same logic used in the demand profiles and without overloading the supplier with not-needed ones. When deciding on the level of detail, the decision should be driven by information relevance as a driver for costs. For instance, the product presentation section will not need the level of detail used on the demand profile to describe the manufacturing process. However, it should provide extensive information about the methods and testing procedures to be implemented as these are essential drivers for one-time transfer costs.

While the *product information* section provides an overview of the products based on the demand profiles without adding any further information, the *additional information* section supplies the reader with a few category-organised instructions and data. They might not be available in the demand profiles but are crucial for preparing the quotations for the product. Overall, this section should be tailored around the main cost drivers the supplier needs to take into account and should include reminders regarding costs often miscalculated and neglected. Widely context-dependent, this can consist of manufacturing-specific parameters or techniques and in-process controls which the focal company want the suppliers to focus upon.

Overall, coupling the additional information section with the product information one, the suppliers should be provided with enough elements to develop their proposal without any further need of interactions, besides some minimal clarifications. The two sections of the RfP outlined above should be designed based on a large group of industry- and project-dependent requirements. To collect them, it is suggested to organise (face-to-face) meetings, workshops and brainstorming sessions within the team, and eventually consider the support of consultants external to the project team. The figure below provides an overview of the recommended structure to be used for this first two sections of the RfP, while the full template addressing the pharmaceutical industry is available as a spreadsheet appendix to this thesis document.

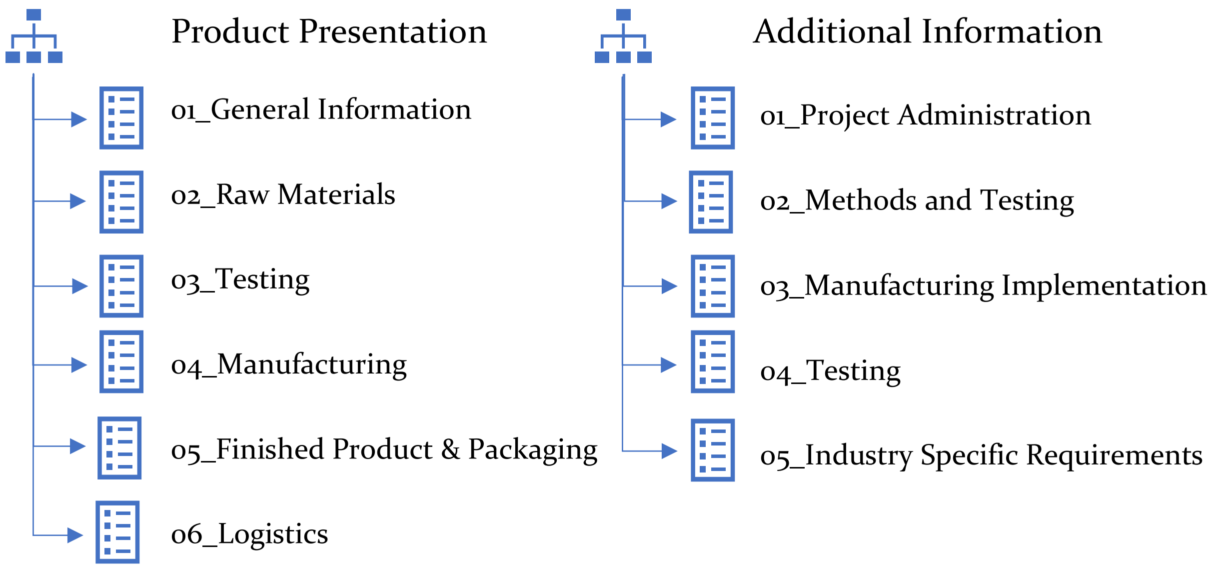

Figure 23 — RfP Section 2 & 3: Product Presentation and Additional Information

To decide on the level of detail for each type of information, a simple decision-making process (outlined in the figure below) can be followed. Firstly, the product information tab should include all the topics of interest in a general form. Secondly, for the ones deserving a higher detail level, the same tab should include subsections. Thirdly, if a need to further specify requirements on some aspects is recognised, then these elements should be included in the additional information tab. The result of this procedure is a clean, simple product overview, including all the relevant categories and a right balance between complexity and high legibility, in a format easy to standardise. Furthermore, the additional information section allows focusing on some critical details which might otherwise be underestimated.

In case the request for proposal currently in development is particularly complex, to the point that the focal company do not have complete knowledge over the products in the scope of the transfer and hence the topics to be addressed in the RfP, an *iterative agile approach* can be used (Andrea, 2003). Following the same decision-making pattern proposed above, the RfP can be developed in subsequent iterations driven by the feedback provided by the candidate suppliers. The downside of this approach is in its length: the process of developing and negotiating over the RfP will take much longer, hence becoming more costly, less standardised and increasing the volatility of the transfer process to undesired levels. If these are elements highly considered by the purchasing department, then a *waterfall approach* might be the best option.

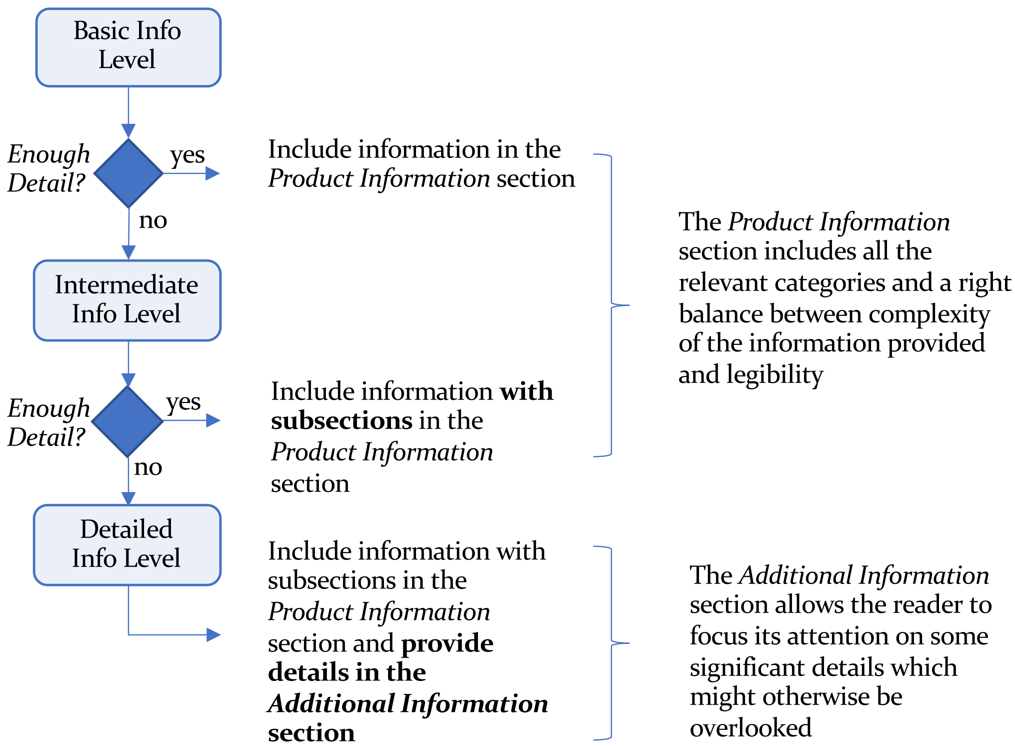

Figure 24 — Decision-making process for designing the RfP

Quotation of Volume A/B

Section 4 and 5 of the RfP require the suppliers to make their quotation on the recurring and investment costs for the products in the scope of the transfer. While the development of the two previous sections requires significant inputs from the technical management function, in these two sections the supply chain function plays a vital role. It is in charge of forecasting the market demand volumes for each of the SKU in scope for an extended time horizon. Hence, supply chain provides the fundamental inputs to complete the preparation of these two sections, where the reason why two forecasts are produced is an industry-wide accepted trend, necessary to ensure a certain slack around the estimates. Another possible strategy would be to provide one forecast and specify a measure of precision around it expressed as a percentage. The former has been preferred over the latter approach because it simplifies the bidding process for the candidate suppliers and increases the probability they will be able to populate the sections in an orderly fashion.

As shown in figure 25, the quotation section includes several categories containing information to be provided by both the focal company and the supplier. In the figure, the data inputted by the focal company are unmarked, while the inputs required from the supplier are marked in italic and underlined. The *general information* section provides essential elements such as the SKU list with their identification number and name and the market to which each SKU is directed. The *product information* section provides inputs on the pack size, which could be selected as a unit to calculate costs, as well as the (annual) volumes the suppliers will need to guarantee. Instead, the *quotation section* asks the supplier to make its bid in terms of costs per pack or bulk unit, where costs should be segmented to maximise easiness in their analysis. Finally, the *administrative section* includes payment terms and incoterms related information. The detailed structure proposed here has been validated during the study and should be adaptable to various industry contexts. Instead, the template provided in the appendix provides an example ideal for applications in the pharmaceutical industry.

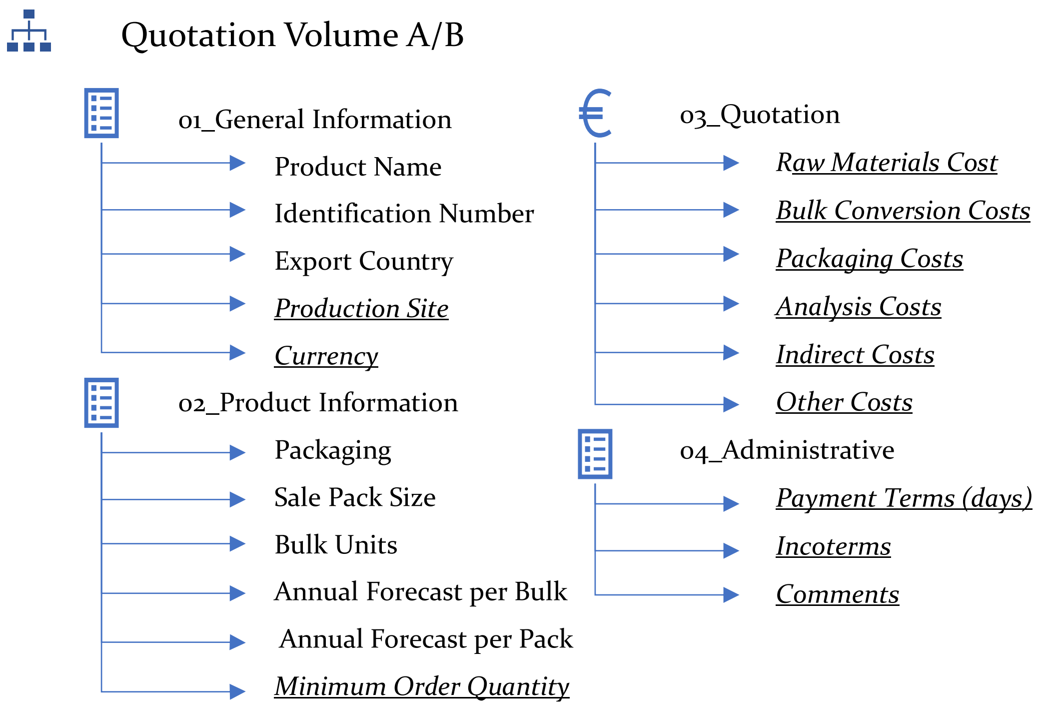

Figure 25 — RfP section 4 & 5: quotation

Transfer Costs Breakdown and Analysis

The last two sections of the RfP deal with the technical transfer costs and have been designed following a different pattern in comparison with the others. These one-time costs are often challenging to estimate for the supplier as they often lack the necessary expertise and experience to make informed bids. Moreover, as these costs can be calculated in several ways, the lack of a standard template makes life difficult for the technical managers in charge of evaluating them. In the *transfer cost breakdown*, the CM makes its best proposal in terms of technical transfer costs, subdivided by category and by product. Figure 26 proposes a possible structure of this section which should include *project administration* and *equipment qualification* (investments should not be included), *methods, manufacturing and validation process implementation*, as well as industry-specific costs. For instance, for the pharmaceutical industry, this category comprises stability studies and technical writing which can be profoundly impacting on the total one-time costs.

The *transfer cost analysis* section provides the supplier with an overview of its one-time transfer costs offer. The reason behind it lays in the tendency of suppliers to struggle in developing a good proposal. Indeed, while the focal company need to receive costs divided by category for a compelling analysis and later comparison with the other suppliers, the suppliers calculate costs mostly based on the functions, departments and workforce which will be involved in each of these tasks. By proceeding this way, it is relatively easy to miss opportunities to apply bracketing approaches or overestimate costs of a particular step. Hence, the supplier's offer will result in being less attractive, giving an edge to other suppliers. To design the transfer cost analysis section, a simple decision-making process should be followed: for each category, the designer should identify the aspects which are most often misjudged or misunderstood by the candidate suppliers. For each of them, it should ideate an index or a performance indicator and display it in the cost analysis section, so to make avoidable mistakes evident. Moreover, this section should autofill based on the inputs of the previous ones, so to enable the supplier to evaluate its offer, eventually spotting mistakes or inconsistencies.

To sum up, the development of the request for proposal is a highly complex, multi-functional task which should be carried out by keeping in mind both the needs of the suppliers receiving it and of the focal company in the process of analysing it. Directed by the purchasing function, the RfP should be developed by providing a proper level of technical and commercial information. Furthermore, the design of the RfP should aim at minimising the risk of making mistakes from both the focal company and the supplier, by providing clear instructions, maximising automation and standardisation. Finally, to ensure consistency throughout the multi-party interaction process, it is crucial to limit the opportunities of interfering with the functionalities of the tools, for instance by locking all the fields that are not supposed to be edited.

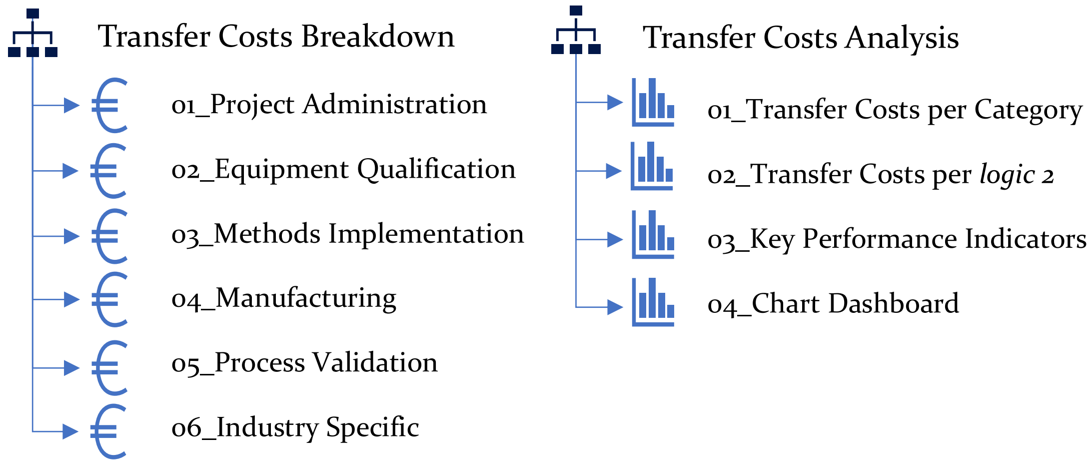

Figure 26 — RfP section 6 & 7: transfer costs

The figure below provides an overview of the connection between the sections of the RfP. The two non-shaded boxes at the top are the inputs for this phase while the blue-shaded ones represent the parts of the RfP (the introduction has not been included, and the two quotation sections have been aggregated into one box). The figure shows how the demand profile permits to populate the first two sections of the RfP, which in turn are strongly connected with the parts on transfer costs. The categorisation pattern should be coherent throughout the document, some information should be reported several times, and the various sections should reference each other to maximise automation. Finally, inputs from the quotation sections are mostly related to the forecasted volumes and complemented with some technical information. An overview of the whole RfP structure is available in the Appendix A.

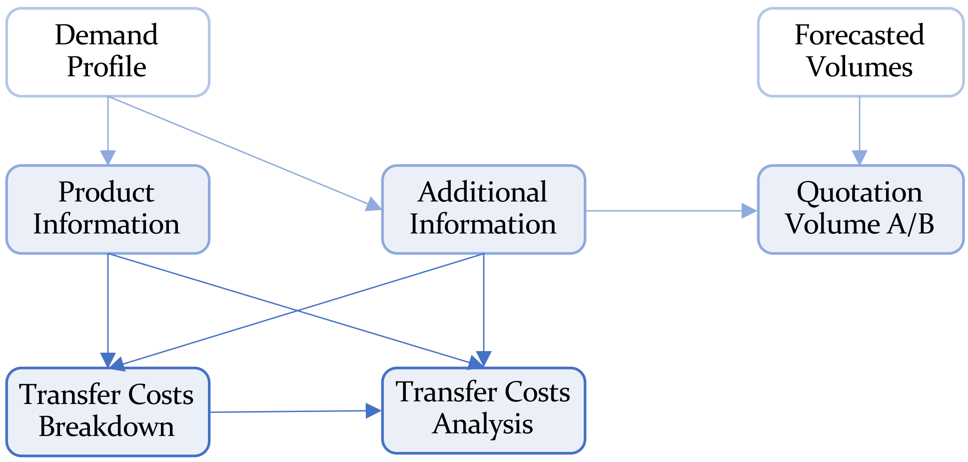

Figure 27 — RfP structure

5.2.3 Analysis and Negotiation of the Proposals

Once ready, the purchasing function sends the request for proposal to the shortlisted suppliers and wait for their reply. The process is time-constrained from both sides: both the suppliers and the focal company provide a time limit after which the offer is not valid anymore. This mechanism ensures the focal company enough time to compare all the received proposals, negotiate them and finally select the best one. This section will unfold following a pattern similar to the previous one. The first paragraph outline the requirements for analysis and negotiation, while the remaining of the text provides guidance to the practitioners.

Requirements of the Tendering Process

The requirements outlined in the previous section of this chapter remain valid for the analysis and negotiation processes. These processes need to be carried out *rapidly and efficiently*, to accelerate the practices of bargaining and finally select the new receiving site (Paech et al., 2012). Furthermore, to provide decision-makers with quick but detailed information, the tools in use should be standardised, accessible, easy to use and modify, and maximally automated. Moreover, several functions at the focal company ought to cooperate by analysing the candidate suppliers from different perspectives: integrating *cross-functionality support mechanisms* is of utmost importance.

Guidelines on the Analysis of the Proposals

The structure proposed for this section of the manual is subdivided into four blocks: *data input*, *dashboard*, *technical functions input* and *comparison matrix.*

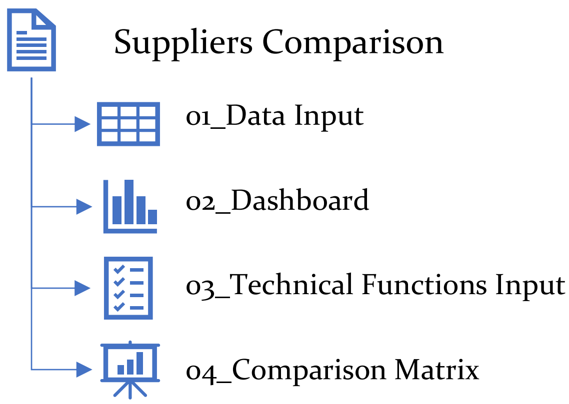

Figure 28 — Supplier comparison reporting structure

The Dashboard

The *data input* section supports the process of inserting the data of the RfPs in the analysis tool. This is not a value-added process, so it should be easy and fast to do. Depending on the platform at hand, data from the RfP could be copy-pasted into a conveniently designed data-input template or directly referenced. The used platform should trigger the decision on the design strategy. For instance, cross-files references are very fragile in excel and therefore discouraged, while several enterprise systems do a better job in this regard.

Based on the input of the first section, the second part of the supplier comparison file should automatically fill, providing the purchasing manager with a set of charts, tables and cost evaluation tools. Cost comparisons should focus both on singular offers and in comparing different ones. The former set is aimed at identifying outliers or inconsistencies and as a starting point to negotiate the offer. In contrast, the latter set of comparisons focalises on identifying similarities, differences and general patterns between the suppliers' offers. The study has shown how managers often feel overwhelmed by the amount of information to be scanned and analysed; therefore, it is recommended to design an interface that put in the foreground only a few meaningful charts while leaving the bulk of the data aside. The figure below shows an example of such dashboard design, while a full-scale dashboard can be consulted in the spreadsheet file available in the appendix of this thesis project.

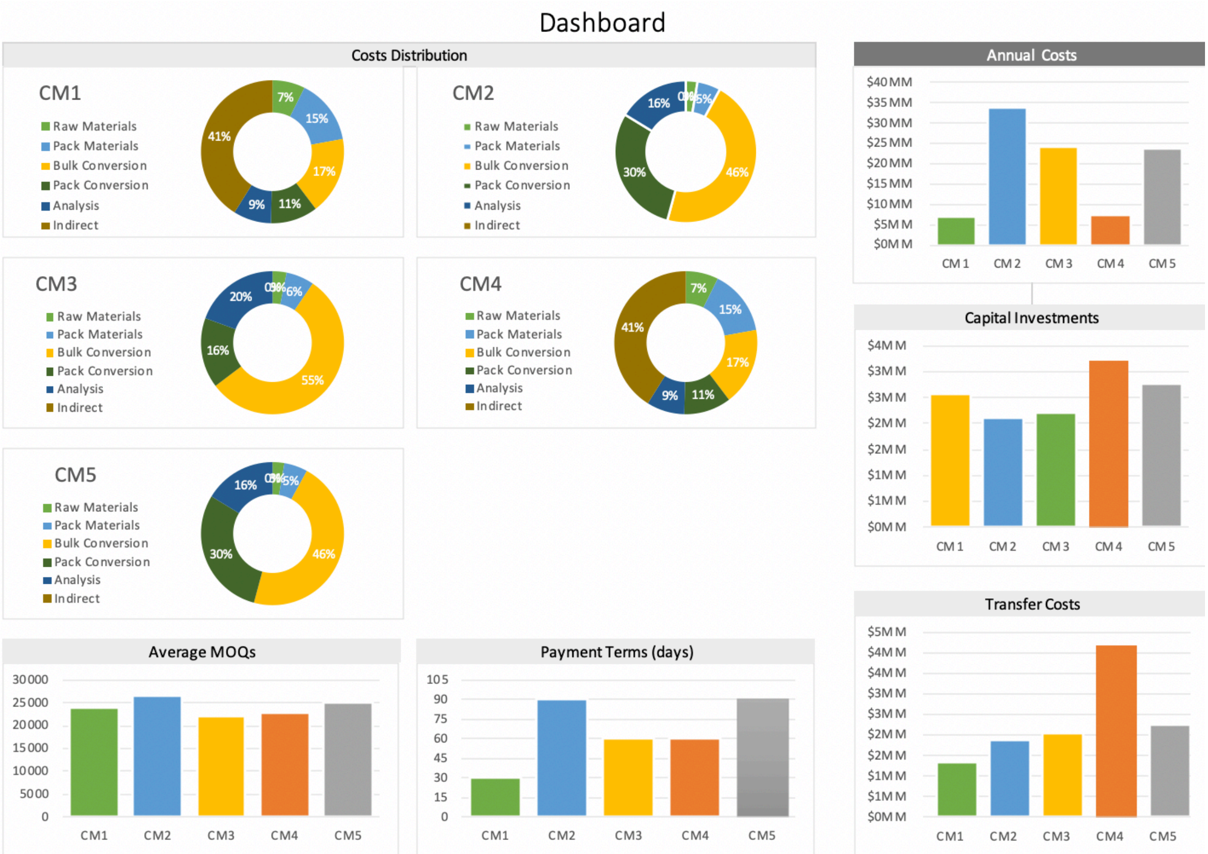

Figure 29 — Example of a dashboard

The purchasing department should lead the cost evaluation process, in terms of both analysis and negotiation of the offer. Furthermore, engineering should be in charge of providing benchmarks to evaluate investments costs, while technical managers should focus on one-time transfer costs. A summarised overview to compare on-going and one-time transfer costs should be included in the dashboard and to evaluate the overall costs, consistent and reliable techniques such as the *net present value* are recommended. Moreover, involving the *finance and accounting function* in the process should be taken into consideration when significant investments characterise the transfer. In this case, these functions should develop a business case, evaluating several scenarios and providing the outcome of their analysis to the purchasing function.

Technical, Quality and Regulatory Inputs

Besides evaluating one-time transfer costs, technical managers should report to the purchasing department concerning the capabilities of the receiving site, possibly backing their relations through on-site visits and direct, regular contacts with representatives of the candidate supplier. Similarly, quality and regulatory should evaluate the compliance of the receiving site regarding production processes, protocols and requirements of the products to be transferred. The importance of these two functions is widely project and industry-dependent; for instance, the pharmaceutical industry is characterised by strict regulations and quality standards the receiving site will need to comply with.

5.2.4 Comparison and Selection

The last step in the process of assessing suppliers consists of the selection of the one that scores best on the selected parameters. Therefore, the project team of the focal company will need to decide which criteria to account for in comparing suppliers, the weight these criteria should be given and the system to evaluate suppliers on each of them. Section 4.2.2 of this thesis project presents several approaches that could be used for supplier selection, each of them with its strengths and weaknesses. Given the variety of functions involved in the process, it is suggested to keep the process of developing the comparison matrix as simple as possible, while ensuring consistency and quality of the result. Therefore, it is best to restrain from developing a too numerous list of criteria, so to avoid the matrix to grow excessively. At the same time, there should be at least one criterion for each function represented within the board of the decision-makers. Hence, the number of criteria should be no lower than four, to represent the purchasing, technical management, quality and regulatory functions.

Ideally, criteria should be chosen in a meeting seeing the participation of all the interested parties, and in deciding upon them, the criteria's selection of past projects should be taken into account as well, favouring standardisation of the procedures and the possibility to leverage on experience. While it is not in the scope of this study to provide the set of criteria and it is believed that this set is a business- and context-dependent decision, based on the literature review, observations from the projects studied and brainstorming sessions, the following are reasonable criteria to include: *price*, *delivery performance*, *quality, technical capabilities, manufacturing capabilities* and *reputation*.

Once the criteria are selected, a weight should be assigned to each of them, and the literature review on this topic has provided a wide array of available techniques (see section 4.2.2). While different contexts might require different techniques, for this case, it has been immediately apparent that the selected method should have been simple to use, not time-consuming and not cumbersome. Depending on the situation and on the preferences of the decision-makers, techniques of different complexity might be applied. For example, weights might be decided through an unformalized interaction process between functions and then immediately used in a comparison matrix. By contrast, a more formalised method might be preferred by certain decision-makers.

Widely used in the field, the *Analytical Hierarchy Method (AHP)* seems to fit quite well these requirements, being easy to use and understand, ensuring consistency and facilitating revising. However, the primary deficiency of the AHP lies in its tendency to be highly time-consuming. Indeed, especially when considering a wide range of criteria, reaching consensus on them can be particularly cumbersome. Since this could be the case for the project at hand, with several functions involved in the process, it is argued that the *Best-Worst Method (BWM)* could be a better alternative (Rezaei, 2015). For the interested readers, a detailed implementation of the BWM has been made available in Appendix C, and an application in excel of the same method is provided as an external appendix to this thesis project and can be tested and used. However, a uniformalised criteria-weighting procedure is encouraged based on the results of this study.

Once the weights have been calculated, the last step in the supplier selection requires the project team to score the suppliers on each of the criteria. Here, simplicity in the scoring system is to be preferred above all other parameters; therefore, a simple four levels scoring system has been used and is suggested. In particular, each function is required to specify whether a supplier is excellent, good, sufficient or insufficient for the criteria it is in charge of evaluating. These four levels can be converted in numbers (1 for insufficient, 2 for sufficient, 3 for good and 4 for excellent) to calculate the final scores. Once the matrix has been filled, the final score is given by the weighted average of the ratings. Table 3 shows an example of a filled matrix from which the third supplier emerges as the clear winner: the new receiving site has been selected.

Table 3 — Comparison Matrix

	Weights	Score CM1	Score CM2	Score CM3	Score CM4	Score CM5
Cost	0.447	Excellent	Excellent	Excellent	Sufficient	Sufficient
Quality	0.193	Good	Excellent	Good	Sufficient	Good
Reputation	0.042	Good	Insufficient	Good	Excellent	Excellent
Experience	0.128	Excellent	Insufficient	Good	Excellent	Excellent
Regulatory Compliance	0.103	Sufficient	Good	Good	Insufficient	Good
Technical Capabilities	0.086	Sufficient	Good	Good	Insufficient	Insufficient
Total Weighted Score		3.43	3.32	4.00	1.32	2.32

Figure 30 shows the process flow of these final steps in the supplier selection. The first input to this phase consists of the filled RfPs prepared by the candidate suppliers, whose cost-related information is used to populate the dashboard. Contemporarily, the technical departments verify the compliance of the candidate suppliers, their current and potential performance and report the result of their analysis to the purchasing function which assesses the suppliers and finally select the best one. The curved arrow represents the possibility to negotiate over the supplier's bid, a process which will lead to new inputs and new analyses.

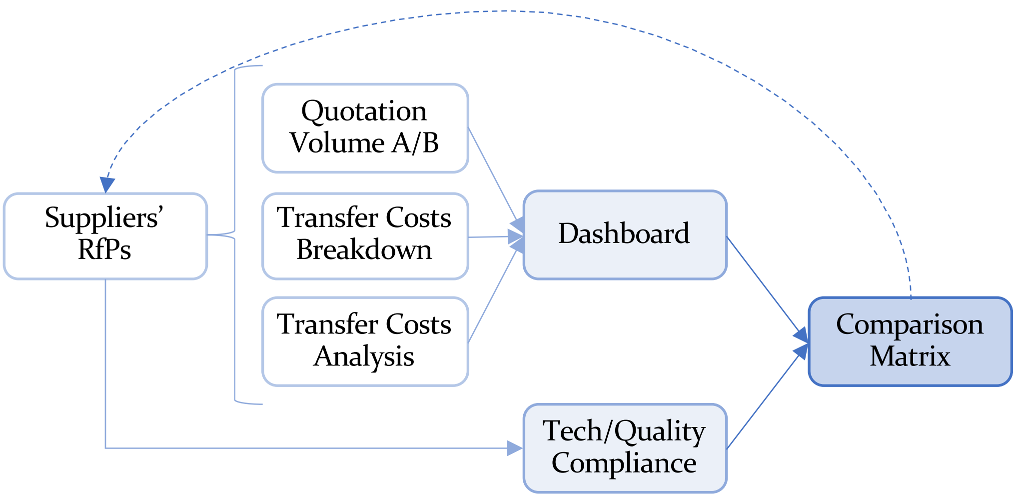

Figure 30 — Analysis and negotiation process

6. Discussions and Conclusions

In an ever more interconnected and integrated world, supply chains are undergoing continuous radical redesigns. The completion of these processes depends on the successful transfer of product and technologies from current manufacturers to new ones. The early stages of the process require the company redesigning its supply chain (the focal company) to transfer the knowledge residing at the current manufacturer (the sending site) to the new one (the receiving site), and to select the latter among a list of candidates. This research aimed to *deliver a manual for managing the early stages of product technology transfers*, by addressing the processes of knowledge exchange and supplier selection. Achieving this goal was made possible by the unique settings in which this study took place. It has been carried out in a large pharmaceutical company in the process of drastically redesigning its supply chain following an acquisition and has leveraged on the numerous international transfers occurring at the company.

Knowledge exchange comprises the processes of knowledge acquisition, knowledge package development and knowledge distribution. Based on the analysis of several past and present transfers and the literature review on technology transfer and knowledge management, it has been possible to identify the challenges of these procedures: the effectiveness of the knowledge flow is hampered by two sets of factors. Firstly, by the presence of an *imperfect market for knowledge*, caused by knowledge tacitness, complexity and novelty. Secondly, by the existence of organisational, physical, cultural and normative *distances* between the stakeholders. However, it has been discovered that knowledge exchange can be supported by leveraging on *individual's capabilities* (experience, expertise and absorptive capacity) and *relation levers* (communication, coordination and cooperation).

The situation analysis laid the foundations for the development of recommendations and guidelines regarding knowledge exchange. The process flow can be enhanced by carefully designing the focal company's project team. It should include both technical functions (technical management, quality, engineering, R&D and regulatory affairs) and commercial ones (purchasing and supply chain). Each team member should be selected based on its experience and expertise and by considering personality traits that can favour inter-organisational interactions. Brainstorming sessions and informal interviews have brought further light to these interactions. Their quality can be enhanced through meetings, training, workshops, and on-site visits. Furthermore, shared platforms are powerful tools to maximise knowledge flow. The process of requirements identification has resulted in identifying standardisation, user-friendliness, reliability, maintainability and process control has the crucial elements to be considered when designing the platforms. This thesis project has proposed a framework addressing these requirements.

Rarely studied comprehensively, supplier selection is the process through which the focal company short-lists candidate suppliers, ask them to make a proposal for the object of the transfer, analyse and negotiate the proposals and finally select the best one. The analysis of this process has enabled uncovering requirements and presenting a framework, recommendations and guidelines. A review of past projects and of the literature on the topic, coupled with workshops and brainstorming sessions has made possible to identify standardisation, automation, ease of use, maintainability and resiliency as crucial requirements. Furthermore, the focal company ought to devise mechanism to help the candidate suppliers in identifying the most relevant drivers for cost and minimise the risk of mistakes. Supplier selection should also be designed to make the process of preparing and analysing proposals minimally time consuming. Finally, in the context of a product technology transfer the supplier selection procedures should be designed to favour cross-functional cooperation. By running simulations, and developing and testing prototypes, it has been possible to design a tool matching the requirements. The tool has been successfully applied in a real project.

The manual configures as a first attempt to frame into a unified picture a mosaic of activities and disciplines comprising business, science, engineering and law. The two groups of activities included in this phase, knowledge exchange and supplier selection, are profoundly distinct but irredeemably entwined, making the pre-transfer a one-of-a-kind process. Acknowledging the ever-evolving nature of pre-transfers, the developed manual has presented recommendations on how to design a flexible process structure in which roles, responsibilities and accountabilities of functions and stakeholders adapt over time to the tasks to be carried out.

6.1 Limitations

The main limitation of this manual is generalisability. The manual has been developed in the context of the pharmaceutical industry, based on several international transfers of mature products occurring in a single company. While generalisability should hold for the main features of the manual, the framework might not perfectly fit the characteristics of different industries in its details. However, the approach used allowed to observe product technology transfers from a unique perspective. The result is a wide range of new insights with significant theoretical and practical relevance.

A second limitation emerges from the novelty in perspective used in this thesis project and the broad range of topics covered. To the knowledge of the author, this study covers the product technology pre-transfer like never before. Notably, no studies have been found that relate knowledge exchange and supplier selection, by acknowledging them as part of the same process, and involving one, continually evolving project team. This one-of-a-kind approach is not supported by existing researches and is founded on studies belonging to several bodies, including knowledge, technical, transfer, innovation and supply chain management. Hence, its validity should be confirmed by re-applying it in new studies.

Finally, with regards to the supplier selection procedures, the framework developed does not include considerations on the negotiation processes, strategies and techniques as it focalises on preparation and analysis. Including them could lead to a slightly modified process and framework, including new recommendations and guideline. Hence, negotiation processes are a nice-to-have inclusion for future versions of the manual.

6.2 Contributions

This thesis project successfully brought light to the design processes for knowledge exchange and supplier selection in a product technology transfer. On the one hand, the new framework has become part of the standard operating procedures of the company object of this study and provides several new insights whose value is not limited to companies operating in the pharmaceutical industry. On the other hand, the manual succeeds in the task of improving existing theoretical models on knowledge exchange and supplier selection processes, while paving the way for future studies on the subject. Overall, this thesis project successfully answers its research question, as it proposes an effective and system wide solution to manage the pre-transfer phase of product technology transfers.

6.2.1 Practical Relevance

This thesis project focuses on the topic of product technology transfers like never before by addressing in a single study the procedures for both knowledge exchange and supplier selection. This approach to the problem is particularly beneficial for practitioners dealing with these processes. Indeed, for a company facing the challenge of transferring products between suppliers, knowledge exchange and supplier selection are two facets of the same project, involving the same cross-functional project team. This approach also provides practitioners with a greater understanding of the range of dynamics and interconnections within and across companies which are very often difficult to take into account, making the pre-transfer extraordinarily confusing and challenging to manage. In turn, this leads to inefficiencies, time losses and resources wasting.

The manual proposed in this thesis project provides practitioners with a broad set of recommendations to design the knowledge exchange procedures properly. Indeed, the manual highlights the requirements of the process and based on them, it guides the design of the project team and the process of dealing with inter-organisational interactions. With regards to direct forms of interaction, the manual suggests which means should be used and how to design them. Moreover, concerning indirect forms of interaction, the manual proposes a framework to structure the process of knowledge exchange. This framework is based on several fundamental requirements and serves as a guideline to design the process in industries different from the pharmaceutical as well. Through the provided recommendations and tools, practitioners will not need to execute the knowledge exchange process in an ad-hoc way anymore.

Practitioners will also benefit from the section of the manual on supplier selection procedures. Notably, this section structures a process often under-standardised, in a way flexible enough to apply to different projects, contexts and sectors. This section of the manual not only provides practitioners with recommendations on how to design the supplier selection procedures but also supply them with a comprehensive template. This template, available as a spreadsheet file in the appendix of this thesis, puts in practice all the recommendations and guidelines provided in the manual. While it is purposely designed for the pharmaceutical industry, it is easily adaptable to other sectors. The spreadsheet allows interested parties to appreciate how accessibility, standardisation, automation and user-friendliness can be obtained in something as simple as an excel file.

6.2.2 Theoretical Relevance

Addressing the topic of product technology transfers like in this thesis project configures as a significant contribution to the cross-functional body of literature on technology transfers by innovatively applying a system thinking approach to the topic. So far, the connection between supply chain management and knowledge exchange was only briefly hinted by Tatikonda and Stock (2003) and has thus far received hardly any attention. By acknowledging this connection, this thesis project offers a new angle to both the issues. Particularly, while the latter is often solely considered of concern for purchasing managers, this thesis project shows how a supplier selection can be completed only by engaging several functions in a complex network of interconnections.

The framework developed in this thesis project enriches the literature on knowledge exchange in several ways. Firstly, it addresses transfers of mature products, while researchers have so far mostly focused on early product lifecycle transfers. Secondly, the focus of this study is the transfer of products and technologies between suppliers, while most of the researches on knowledge exchange concern transfers of technologies from public institutions to privates. Thirdly, the conceptual framework innovatively captures in a single design two different perspectives on the topic.

The framework builds on the one developed by Tatikonda and Stock (2003) in *"Product technology transfer in the upstream supply chain"* and includes elements proposed by Cummings and Teng (2003) in *"Transferring R&D knowledge: the key factors affecting knowledge transfer success"*. The conceptual framework developed in this thesis project rethink the dimensions of technology uncertainty suggested by Tatikonda and Stock (2003), as challenges in the market for knowledge, emphasizing their transactional nature. Furthermore, the framework includes a second set of dimensions: the barriers posed by inter-organisational distances. The concept has been adapted from the framework developed by Cummings' and Teng's (2003) and describes the damage distances between stakeholders can do to the knowledge exchange process. Hence, this framework gives a new meaning to the independent variables proposed by Tatikonda and Stock (2003) and seamlessly integrate in the model a second set of dimensions.

Tatikonda and Stock (2003) identify in communication, coordination and cooperation the key to a successful transfer. The developed framework returns to these elements and evaluates their impact on the dimensions of the imperfect market for knowledge and the distances between the actors involved in the transfer. Furthermore, the model proposed in this project includes an additional mediating variable: individuals' capabilities. Its mediation effect is evaluated against the previously mentioned dimensions. Finally, while the study by Tatikonda and Stock (2003) focuses on describing the model and its dimensions, this one makes a step further in providing recommendations and guidelines based on the model developed.

The second section of the manual contributes to the literature in several ways. Firstly, most of studies on the topic concern supplier selection processes for software transfers. By contrast, the manual developed in this thesis project provides a tool to deal with the transfer of products and the related technologies. This thesis project highlights several requirements so far neglected including resiliency and minimisation of the preparation and analysis time. Moreover, it addresses the cross-functional aspects of supplier selection processes, a new perspective on the topic. Finally, with regards to multi-criteria decision-making processes for supplier selection, this thesis project proposes a solution contrasting with the current trends of the body of literature. Notably, while the literature is growing through ever more sophisticated models, the requirements from the decision-makers collected in this study have suggested how simple, consistent solutions could be more desirable.

6.2.3 Management of Technology Relevance

This thesis project perfectly fit into the frame of the Master of Science in Management of Technology. This master educates its students as technology managers. Their role is to understand what it takes and what can be done to deal with an ever-evolving world in which companies strive for constant improvement and growth to survive in harsh environments where the competition is more robust by the day. This master stimulates the students' entrepreneurial and analytical thinking, and their critical spirit towards new technologies and their applications in a variety of contexts. This means that students are provided with a system-wide understanding of the dynamics within and between companies in a technological context.

The product technology transfer perfectly fit in the frame depicted in this master, as it is a multi-stakeholder, cross-disciplinary process whose objects are technologies and the related knowledge. Specifically, this study "shows an understanding of technology as a corporate resource and is done from a corporate perspective". This project addresses the issue of re-thinking how an organisation should deal with knowledge to keep up with a rapidly evolving and extremely challenging context. In particular, it addresses the processes through which a company acquires knowledge, captures it and uses it to innovate and gain a sustained competitive advantage over the competition. Furthermore, it addresses the cross-functional procedures through which a company changes its supply network structure to cope with the evolving environment. Finally, this study highlights the connection between supplier selection and knowledge exchange, capturing them into a unified technology management process perspective.

The manual on product technology transfers is the result of the application of scientific methods and techniques learnt during the master degree. Notably, the course on *research methods* proved essential to develop the methodology for this thesis project. Furthermore, the course on *leadership and technology management* allowed understanding how knowledge can be framed as a corporate research and the importance of its management for restructuring a company's business models, structures and processes.

While not directly participating in it, the course on *logistics and supply chain innovation* provided tools to this research, like the activity planning maps, which have proved powerful means to understand and correctly structure the processes of knowledge exchange and supplier selection. Moreover, the course on *business process management* has inspired this thesis project as it showed how processes can be supported, redefined and improved by technology and how human resources and technologies can and should integrate to maximise the output of a business process reengineering. Finally, the course on *inter- and intra- organisational decision making* taught how decisions are often ill-structured and chaotic in real life and cannot be framed into a fixed structure. This learning has been taken into account when designing the tools included in the manual. Acknowledging the variability of the processes characterising a product technology transfer, the tools have been developed by keeping flexibility as a priority. This way, the decision-making processes occurring throughout the pre-transfer have not been constrained within excessively restricting boundaries.

6.3 Future Research

This thesis project configures as precursor for future researches on the product technology pre-transfer process. Considering the novelty of the topic, new studies should re-address it in industries different from the pharmaceutical and possibly by observing several companies within the scope of a single study. New studies on the topic will allow to validate or critically evaluate recommendations, guidelines and tools provided in this thesis project. It could be particularly interesting to compare product technology transfers in different industries to understand how roles, responsibilities and activities change in importance and characteristics. For instance, it can be hypothesised that less research-intensive industries will find fewer obstacles in terms of the imperfectness of the market for knowledge. Furthermore, less regulated industries might witness a much lower involvement of the quality and regulatory functions in the pre-transfer process and a higher involvement of the engineering one.

The conceptual framework for knowledge exchange opens the way for future studies on the topic. On the one hand, new researches can attempt at finding quantitative measures for the dimensions included in the model or for the relationships between one another. On the other hand, case studies could be executed to confirm the validity of the model in different contexts. Specifically, evaluating the model in different sized companies dealing with diverse transfers might be a particularly prolific research field.

Finally, future research could improve the section of the manual on supplier selection by including in the framework a section dedicated to negotiation techniques. Specifically, future studies should evaluate which ones best fit the supplier selection in a product technology transfer, particularly considering its time-frame limitations and the peculiar cross-functionality of the negotiation practices when discussions range from technical to commercial. Finally, the impact different negotiation strategies could have on both the selection for the supplier and on the knowledge exchange process could be researched.

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Appendix

Appendix A — The RfP Structure

The figure below captures in one image the full structure of the RfP, its sections and subsections. The main sections are instructions, product presentation, additional information, quotation volume A and B, transfer costs breakdown and transfer costs analysis.

Request for Proposal

- 01_***Instructions***
- ***02_Product Presentation***
  - 01_General Information
  - 02_Raw Materials
  - 03_Testing
  - 04_Manufacturing
  - 05_Finished Product & Packaging
  - 06_Logistics
- ***03_Additional Information***
  - 01_Project Administration
  - 02_Methods and Testing
  - 03_Manufacturing Implementation
  - 04_Testing
  - 05_Industry Specific Requirements
- ***04_Quotation Volume A***
  - 01_General Information
    - Product Name
    - Identification Number
    - Export Country
    - *Production Site*
    - *Currency*
  - 02_Product Information
    - Packaging
    - Sale Pack Size
    - Bulk Units
    - Annual Forecast in Sales Pack
    - Annual Forecast in Bulk Units
    - *Minimum Order Quantity*
  - 03_Quotation (cost per pack/bulk unit)
    - *Raw Materials Cost*
    - *Bulk Conversion Costs*
    - *Packaging Costs*
    - *Analysis Costs*
    - *Indirect Costs*
    - *Other Costs*
  - 04_Administrative
    - *Payment Terms (days)*
    - *Incoterms*
    - *Comments*
- ***05_Quotation Volume B***
- ***06_Transfer Costs Breakdown***
  - 01_Project Administration
  - 02_Equipment Qualification
  - 03_Methods Implementation
  - 04_Manufacturing Implementation
  - 05_Process Validation
  - 06_Industry Specific Requirements
- **07_Transfer Costs Analysis**
  - 01_Overview of Transfer Costs per Category
  - 02_Overview of Transfer Costs per *logic 2*
  - 03_Key Performance Indicators
  - 04_Chart Dashboard

Figure 31 — The RfP full structure

Appendix B — Dashboard Examples

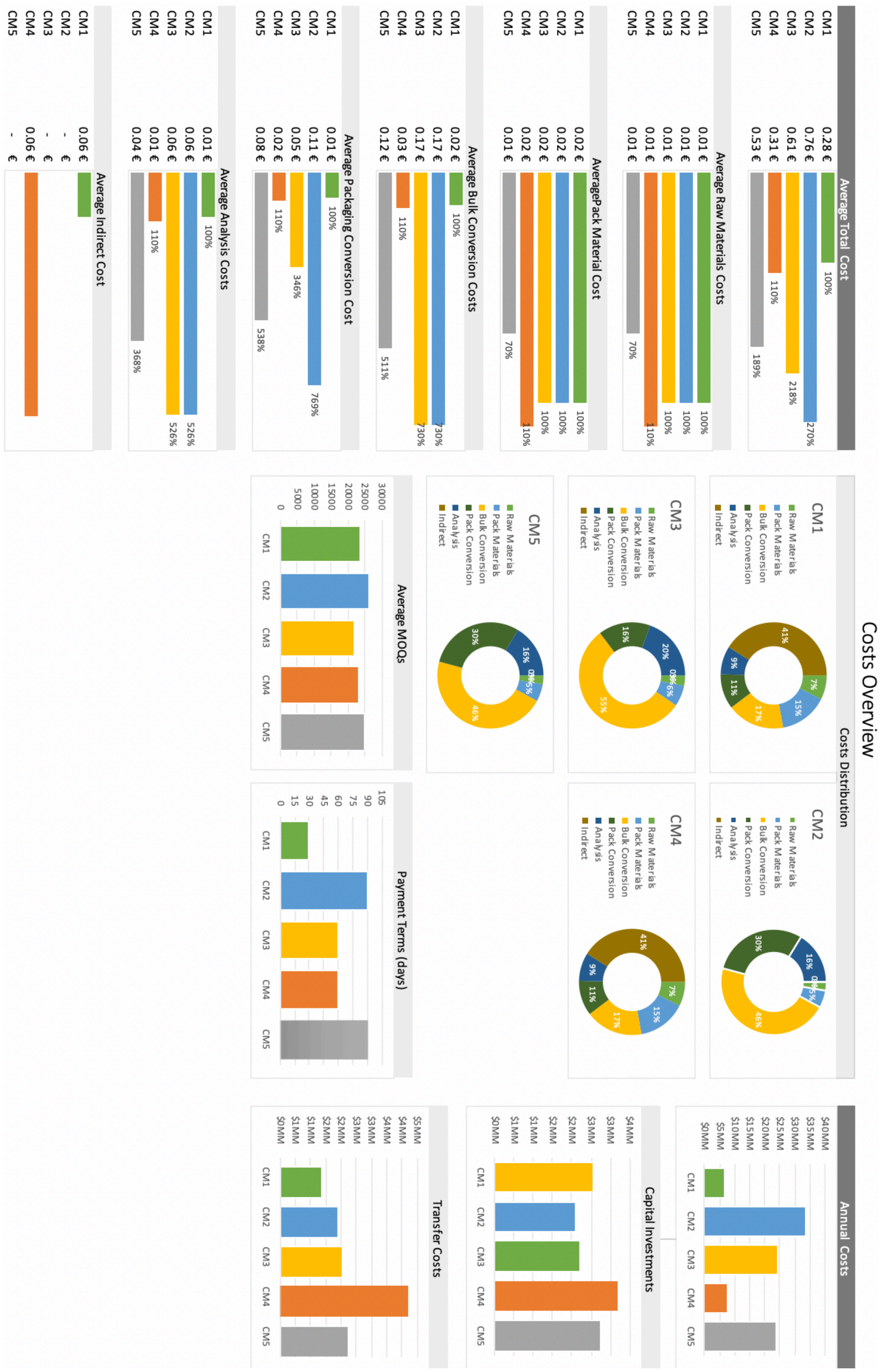

Figure 32 — Dashboard example 1

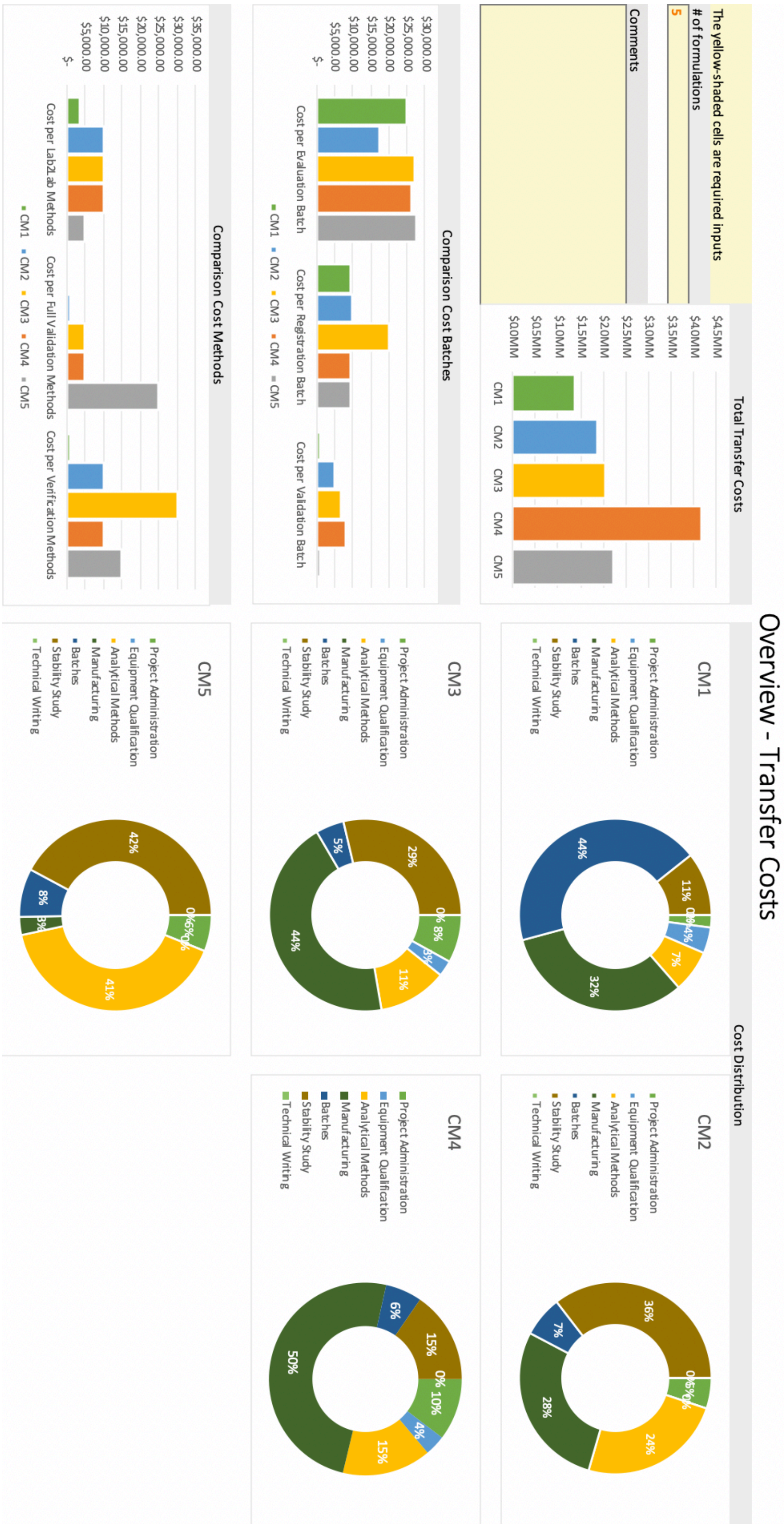

Figure 33 – Dashboard example 2

Appendix C — The Best-Worst Method

Firstly presented by Rezaei (2015), the BWM addresses the main criticalities of the AHP, while still ensuring the consistency and quality of the weights assigned to the selected criteria. The method is relatively simple: once the set of criteria is defined, the decision-makers are asked to select the best and the worst criterion and to develop two vectors. The first is the best-to-other vectors in which the best criterion is compared to the remaining ones. Particularly, the best one is assigned a score equal to one and decision-makers have to give a score from 1 to 9 to the remaining criteria, by answering the question: how less important is score *i* in comparison to the best one. With a similar procedure, the worst to others vector is compiled. Finally, by maximising the difference between the scores, a final weight for each of the criteria is calculated (Rezaei, 2015). In the below figure an example of the BWM is provided for clarity.

Rezaei (2015) proposes two variants of the model: one calculates scores through a non-linear min-max model which can yield multiple solutions, while the second one is a linear model based on the same idea and which will surely provide a unique solution. Among the two models, it is recommended to select the second one for this application because, while it provides satisfactory results and grants the same consistency of the first, being a linear model is much easier to implement on a variety of tools. Moreover, it is easier to understand for a new user, and therefore simpler to maintain and modify if needed, for example when a different number of criteria is desired. Finally, for the objective that needs to accomplish, having multiple optimal solutions is not of interest.

Before proceeding in the development of the comparison matrix using the weights to decide among the suppliers, it is crucial to evaluate the consistency of the achieved results. When applying the linear model, the consistency score is the value that is minimised when solving for the objective function and should be as close to 0 as possible. A higher value represents the existence of a certain level of inconsistency in the process of ranking criteria which derives from conflicting scores between the two vectors. However, a strength of this model is in the simplicity to fix the issue: by looking back at the two vectors, a comparison will rapidly show where the inconsistency lies, making it easy for the decision-makers to discuss it and choose the best ranking scores. The last figure provides an example to show the difference between consistent and inconsistent criterion scoring. On the left, the criteria have been scored consistently between the two vectors, hence the consistency score is low (0.18), while the opposite is true for the case on the right. Indeed, while on the best-to-other vector, price and technical capabilities where at the antipodes, in the worst-to-other vector they are scored similarly.

Step 1: Select the set of criteria

Criteria	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5
Name	Price	Quality	Manufacturing Capabilities	Technical Capabilities	Reputation

Step 2: Select the best and worst criterion

Best Criterion	Price

Worst Criterion	Reputation

Step 3: Develop the best-to-others and worst-to-others vectors, using a scale from 1 to 9

Step 3.1: How many time worse is criterion *i* when compared to the best?

Step 3.2: How many time better is criterion *i* when compared to the worse?

Best-to-Others Vector

Criterion	Score
Price	1
Quality	3
Manufacturing Capabilities	3
Technical Capabilities	5
Reputation	9

Only minimal inconsistency regarding manufacturing capabilities.

Worst-to-Others Vector

Criterion	Score
Price	9
Quality	7
Manufacturing Capabilities	6
Technical Capabilities	5
Reputation	1

Step 4: Solve the optimisation problem to maximise the difference between the score and obtain the final scores

Criterion	Price	Quality	Manufacturing Capabilities	Technical Capabilities	Reputation
Weight	0.40	0.23	0.16	0.09	0.02

Criteria	Criterion 1	Criterion 2	Criterion 3	Criterion 4
Name	Price	Quality	Manufacturing Capabilities	Technical Capabilities

Best Criterion	Price
Worst Criterion	Reputation

Best-to-Others Vector

Criterion	Score
Price	1
Quality	4
Manufacturing Capabilities	6
Technical Capabilities	8

Worst-to-Others Vector

Criterion	Score
Price	9
Quality	4
Manufacturing Capabilities	6
Technical Capabilities	1

Consistency	0.18

Best Criterion	Price
Worst Criterion	Reputation

Best-to-Others Vector

Criterion	Score
Price	1
Quality	4
Manufacturing Capabilities	6
Technical Capabilities	8

Worst-to-Others Vector

Criterion	Score
Price	2
Quality	7
Manufacturing Capabilities	6
Technical Capabilities	1

Consistency	0.48

Figure 34 —BWM Example