



T.C.

ANKARA YILDIRIM BEYAZIT UNIVERSITY
INSTITUTE OF SOCIAL SCIENCES

**DETERMINING SUITABLE INNOVATION STRUCTURE
WITH OPEN INNOVATION APPROACH: AN
APPLICATION OF A DECISION MAKING MODEL**

PhD DISSERTATION

Ercan YILDIRIM

MANAGEMENT AND ORGANIZATION PhD PROGRAM

Ankara, 2020



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APPROVAL PAGE

Thesis titled as “DETERMINING SUITABLE INNOVATION STRUCTURE WITH OPEN INNOVATION APPROACH: AN APPLICATION OF A DECISION MAKING MODEL” and prepared by Eran YILDIRIM was accepted by the following committee members unanimously/by majority as a thesis for the degree of Doctor of Philosophy in Ankara Yıldırım Beyazıt University, Institute of Social Sciences, Department of Management and Organization.

Title Name Surname	Institution	Signature
Prof. Dr. Türkay DERELİ	Hasan Kalyoncu Üniversitesi	
Prof. Dr. İlker Murat AR	Ankara Yıldırım Beyazıt Üniversitesi	
Prof. Dr. Birdoğan BAKİ	Karadeniz Teknik Üniversitesi	
Prof. Dr. Nilay Alüftekin SAKARYA	Ankara Yıldırım Beyazıt Üniversitesi	
Doç. Dr. İskender PEKER	Gümüşhane Üniversitesi	

Thesis Defence Date: 22.12.2020

I certify that this thesis satisfies all the requirements as a thesis for the degree of Doctor of Philosophy in Ankara Yıldırım Beyazıt University, Institute of Social Sciences Department of Management and Organization.

Manager of Institute

Title Name Surname

.....

DECLARATION

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Date (22.12.2020)

Ercan YILDIRIM



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ABSTRACT

Determining Suitable Innovation Structure With Open Innovation Approach: An Application of a Decision Making Model

Open Innovation (OI) model is an important way of setup of the innovation structure for organizations and provides several benefits. It has gained quite a lot of attention both in terms of research and practical areas. There are many studies for the drivers of OI and its types and the structure for OI projects. These studies give useful insights and help in building an understanding of theoretical concepts and terminology of OI. The aim of this study is to make an end-to-end analysis of OI stages for the suitable setup of innovation structure and develop a decision making model by linking the processes of determining innovation type (open vs. closed), OI type (inbound vs. outbound vs. coupled) and collaboration type (science-based vs. market-based) in three consecutive stages. For that, an integrated Delphi technique and Fuzzy Analytical Network Process (FANP) method was used. Criteria for each process was determined from the extensive literature review and evaluated and finalized with the application of a three round Delphi technique. Criteria relationships for each stage were determined by expert evaluation, followed by the pairwise comparison process and finally the application of FANP method for determining the weights and rankings.

According to results of this study, the most important criterion for decision of setting up an innovation structure with OI approach is *open innovation awareness*. Then, the most important criterion for decision of selecting the OI type for setup of an OI structure is *knowledge acquisition*. Finally, the most important criterion for the selection of collaboration type for setup of an OI structure is *network building*. The study, as a result, proposes a decision making model for determining the suitable innovation structure for innovation projects and aims to support in reducing the uncertainties in the setup of the OI structure by having impacts on various areas ranging from resource allocation to the development of inter-institutional cooperation. The study is unique in providing a detailed analysis on OI and its related concepts, linking OI processes to each other in an end-to-end perspective and providing a decision making model for setting up the suitable innovation structure.

Keywords: Open Innovation, Decision Making Model, Fuzzy Analytic Network Process, Collaboration Type.

ÖZET

Uygun Yenilik Yapısının Açık Yenilik Yaklaşımı ile Belirlenmesi: Bir Karar Verme Modeli Uygulaması

Açık yenilik modeli organizasyonlar için yenilik yapısını kurmakta önemli bir yoldur ve birçok fayda sağlamaktadır. Gerek araştırma gerekse uygulama alanları açısından oldukça fazla ilgi görmektedir. Açık yeniliğin itici güçleri ve türleri ile açık yenilik projeleri yapısı konusunda birçok çalışma bulunmaktadır. Bu çalışmalar, açık yeniliğin teorik kavramlarının ve terminolojisinin anlaşılmasına yardımcı olmakta ve yararlı bilgiler sağlamaktadır. Bu çalışmanın amacı, uygun yenilik yapısının oluşturulması için, açık yenilik aşamalarının uçtan uca bir analizini yapmak ve yenilik türünün belirlenmesi (açık ya da kapalı), açık yenilik türünün belirlenmesi (içe doğru, dışa doğru, ya da birleşik) ve işbirliği türünün belirlenmesi (bilime dayalı ya da pazara dayalı) süreçlerini ardışık olarak bağlayarak bir karar verme modeli geliştirmektir. Bunun için entegre bir Delphi tekniği ve bulanık Analitik Ağ Süreci yöntemi kullanılmıştır. Her bir süreç için kriterler kapsamlı literatür taraması ile belirlenmiş ve üç turlu Delphi tekniğinin uygulanmasıyla değerlendirilerek sonuçlandırılmıştır. Her aşama için kriter ilişkileri uzman değerlendirmesi ile belirlenmiş, ardından ikili karşılaştırma süreci uygulanmış ve son olarak bulanık Analitik Ağ Süreci metodu uygulanarak ağırlıklar ve sıralamalar oluşturulmuştur.

Bu çalışmanın sonuçlarına göre, açık yenilik yaklaşımı ile bir yenilik yapısı kurma kararı için en önemli kriter *açık yenilik farkındalık*'dır. Daha sonra, bir açık yenilik projesinin yapısını oluşturmada açık yenilik türünü seçme kararı için en önemli kriter *bilgi edinme* olarak belirlenmiştir. Son olarak, bir açık yenilik projesi yapısı oluşturmada işbirliği türünün seçimi için en önemli kriterin *ağ oluşturma* kriteri olduğu tespit edilmiştir. Sonuç olarak bu çalışma, yenilik projelerinde uygun yapının oluşturulması için bir karar verme modeli önermekte ve açık yenilik projelerine kaynak tahsisinden kurumlar arası işbirliğinin geliştirilmesine kadar çeşitli alanlarda etkilere sahip olarak açık yenilik projelerinin uygun yapıda oluşturulmasındaki belirsizliklerin azaltılmasına destek olmayı amaçlamaktadır. Çalışma, açık yenilik ve ilgili kavramları hakkında ayrıntılı bir analiz sağlama, açık yenilik süreçlerini uçtan uca bir yaklaşım ile birbirine bağlama ve uygun yenilik yapısının kurulması için bir karar verme modeli sağlama açısından benzersizdir.

Anahtar kelimeler: Açık Yenilik, Karar Verme Modeli, Bulanık Analitik Ağ Süreci, İşbirliği Türü.

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INDEX of ABBREVIATIONS

AHP	: Analytical Hierarchy Process
ANP	: Analytic Network Process
DEMATEL	: Decision Making Trial and Evaluation Laboratory
ESCI	: Emerging Sources Citation Index
FANP	: Fuzzy Analytic Network Process
FMCDM	: Fuzzy Multi Criteria Decision Making
HR	: Human Resources
ICT	: Information and Communication Technologies
IP	: Intellectual Property
KM	: Knowledge Management
LRP	: Literature Review Paper
MCDM	: Multicriteria Decision Making
NIH	: Not Invented Here
NSH	: Not Sold Here
OCB	: Organizational Citizenship Behaviour
OI	: Open Innovation
QFD	: Quality Function Deployment
R&D	: Research & Development
SCI	: Science Citation Index
SCIE	: Science Citation Index Extended
SSCI	: Social Science Citation Index
SME	: Small and Medium-sized Enterprise
TFN	: Triangular Fuzzy Number
TOPSIS	: Technique for Order of Preference by Similarity to Ideal Solution
UIC	: University Industry Collaboration
VIKOR	: Vlekkriterijumsko KOMPromisno Rangiranje

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1. OPEN INNOVATION (OI)

OI concept is introduced in this part. The origin of OI, its historical evolution, OI types and related terms about OI are described in detail.

1.1. Origin of OI

Traditional way of developing new technologies and products for industrial firms is making these internally. Most of the organizations was applying closed innovation strategies up to recent years. With the closed innovation process, organization tries to employ the smartest people in the area, the research is done internally within the organization and organization believes that working with closed boundaries to the outside world will make it the winner and provide better control of the Intellectual Property (IP) (Chesbrough, 2003b, 2003c). Due to the need for firms to complement their internal knowledge bases, they have started to acquire external technologies by certain collaboration methods like strategic alliances or in-licensing and with that closed innovation strategies have begun to change. Knowledge management also has faced a similar development. Out licensing and strategic alliances have begun to be chosen as the means of commercialization of technological knowledge (Lichtenthaler, 2011). These developments are accompanied by increasing global competition, rising Research and Development (R&D) costs and the need for shortening product life cycles. Thus, organizations could no longer consider closed innovation as beneficial. Innovation process has started to develop towards utilization of external sources of knowledge and collaboration with other organizations that have relevant knowledge.

In such an environmental context, Henry Chesbrough introduced the “Open Innovation” concept. In his related research he highlighted that firms are utilizing the external knowledge and external R&D in their innovation processes more and more and that results in shorter times to market and lower costs (Chesbrough, 2003a). He developed theoretical bases for the OI process and suggested OI as a new paradigm for the management of innovation (Chesbrough, 2003a).

Within the timeline since first Chesbrough introduced till date, OI has been studied by several scholars and the concept has developed to several application areas. It also has become widely studied area of innovation research (Dahlander & Gann, 2010). During that

interval several definitions are made by different scholars. Lastly, in 2014 Chesbrough & Bogers (2014) defined OI as “a distributed innovation process based on purposively managed knowledge flows across organizational borders”. Current research on OI is covering many areas. Some examples are Small and Medium-sized Enterprises (SMEs), social innovation, startup firms, University Industry Collaborations (UIC), cross-border collaborations, small and large firm collaborations, cooperation for green energy production and climate change avoidance, government driven research collaborations.

1.2. Definition of OI

OI concept was firstly introduced by Henry Chesbrough in 2003 and shortly defined as “Firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology” (Chesbrough, 2003a).

After introduction of the concept by Chesbrough, OI has gained quite a lot of attention both in terms of research and practical areas. Many scholars have studied the OI paradigm and extended the concept to large areas of application. The definition of it also has been argued and extended. In 2006 and later on 2014, Chesbrough et al. (2006) clarified the concept and stated the definition as “OI is the use of purposive inflows and outflows of knowledge to support internal innovation and extend the markets for external use of innovation” (Chesbrough et al., 2006). Especially, it covers the opening up the innovation to the external world beyond the firms’ boundaries and get contribution to the overall innovation process externally (Chesbrough, 2012). OI process is shown in Figure 1.1. As the figure also shows, with OI paradigm the innovation pipes of the firms are leaky and flow of knowledge and ideas and roads to the market are bi-directional, both from internal to external and vice versa. However, with closed innovation model, innovation process starts on the left and proceeds inside the firm until product delivery to the market on the right side.

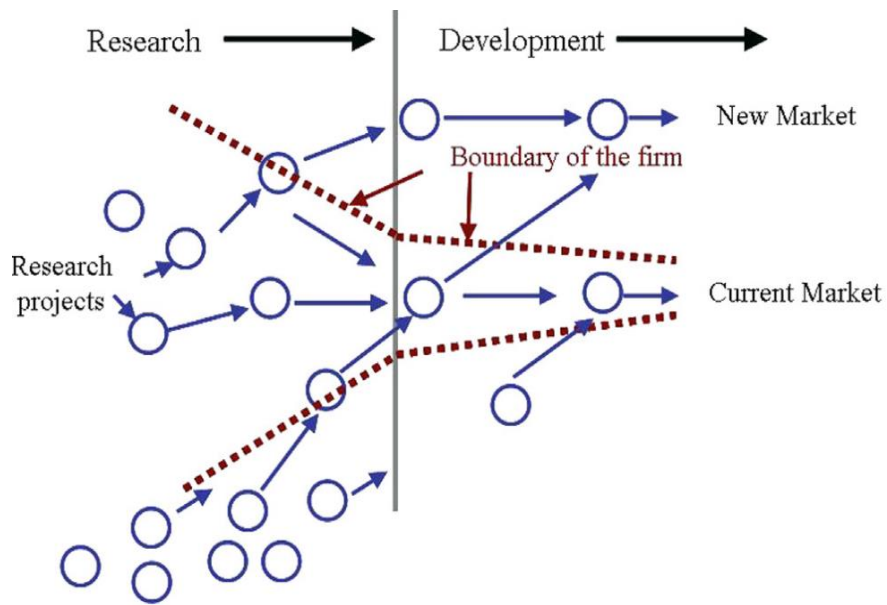


Figure 1.1. OI paradigm (*Chesbrough, 2006*).

Since the first introduction in 2003, definition and further clarification of OI concept have been covered by many studies. Table 1.1 shows the definitions from various studies in the literature, including the definitions compiled by Gianodis et al. (2010) and provides an overview and historical evolution of the definitions of OI.

Table 1.1. The various definitions of OI

<i>Definition</i>	<i>Source</i>
While firms search to develop and improve their technologies, they might and should benefit both from internal and external entities, and internal and external routes to the market.	Chesbrough (2003a)
It is the opening of firms' rigid borders to allow knowledge inflows from the external world to bring opportunities for collaborative innovation process with partners. It also covers the outward flow of internal ideas, IPs and valuable knowledge to benefit from them and to deliver them faster to the market.	Gassmann & Enkel (2004)
OI is the process of planned outward and inward flow of knowledge to expedite and expand internal innovation process as well as to broaden the markets for the use of innovation externally. It considers that while firms seek to develop and improve their technologies, they might and should benefit both from internal and external entities, and internal and external routes to the market.	Chesbrough (2006)
It is methodologically promoting and supporting the searching and exploring the external and internal sources for creating innovation possibilities, purposively combine the results with the firm resources and capabilities and extensively make use of the outcomes through various possible paths.	West & Gallagher (2006)
It is the accumulation of knowledge by multiple parties for innovation aims and in a shared way so that the stakeholders can reach to the contributions of each other and have equal rights on the outcomes.	Chesbrough & Appleyard (2007)
It is an open setup and the borders or the overall process and the knowledge pipe is porous. Inputs to the pipe and process come from the partners. It is dynamic in terms of participating parties; it happens that some inputs are provided by a party and processed by the others.	Dittrich & Duysters (2007)
It is a process comprised of innovation activities from a network of multiple organizations.	Perkmann & Walsh (2007)
It is the innovation activities that is based on the external search, recognition of the alternatives and selecting the suitable ones to improve and further development.	Terwiesch & Xu (2008)
It is methodologically performing external knowledge search, transforming and make use of it within and outside firms' borders during all the innovation stages.	Lichtenthaler (2011)
It is a spreaded innovation process built on conscious setup of knowledge exchanges and sharing's through firm borders by the use of various means compatible with the firms' strategies.	Chesbrough & Bogers (2014)

1.3. Evolution of OI

OI has been a research topic and studied with various aspects over the years, after it is coined by Chesbrough in 2003. Over the last decade, firm's innovation strategies have been changed towards implementing innovation in collaboration with external partners. The approach of setting up of innovation process internally has changed (Appleyard & Chesbrough, 2017; Paula et al. 2018). The path for the innovation process has become collaborative more and more and several different actors such as customers, universities, suppliers and even competitors have been involved in the innovation process (Paula et al., 2018; Mention, 2011). Even though it was firstly introduced as a research item by Chesbrough, the concept and idea behind the OI model was not totally novel (Chesbrough & Bogers, 2014; Appleyard & Chesbrough, 2017). In 1990, Cohen & Levinthal (1990) introduced the concept of absorptive capacity. It describes the firms' capability to become aware of the benefit of acquisition of external information, acquire it transform and apply it to its processes. It basically describes the process of utilizing external knowledge. In addition, scholars have already studied some facets of innovation, like dynamic capabilities. It describes a similar process with absorptive capacity and addresses the firms' capabilities in terms of integrating, building and setting internal and external competencies (Teece et al., 1997) and the exploration of new possibilities based on the utilization of organizational learning which was considered to be an important asset (March, 1991). However, the process formation for intentionally exploring external resources, make use of them internally and utilizing internal opportunities out of the firm boundaries was set up after the introduction of the OI concept by Henry Chesbrough.

As discussed above, the initial description of OI have been modified and extended by scholars over the last decades after it is coined by Chesbrough. During that time frame OI have influenced both research and practice areas excessively. It has been studied by several scholars and is appearing in many research publications. The evolution from closed innovation to OI and then the evolution of OI itself and its related constructs has caused changes and new ways of innovation management. These changes impacted several management aspects like technology amount involved in research and development, processes, structure, content and the way of managing IP (Gassmann et al., 2010).

1.4. OI Approaches

OI process flow can be in different directions. It can be from outside to inside of the organization, from inside to outside or can be in both directions. The direction of the process flow determines the type and approach for the OI process. Outside to inside process direction is conceptualized under inbound OI process, inside to outside is conceptualized under outbound OI approach and mixed direction is conceptualized under coupled OI process. Inbound OI approach includes all the activities of getting innovation related aspects like innovation projects, ideas, technologies and knowledge from outside to the inside of the organization. Organizations carry out an insourcing process for either technology or knowledge try to add the value from this insourcing process on top of existing internal R&D assets (Chesbrough & Crowther 2006; Chiaroni et al., 2010, 2011; Bianchi et al., 2011). As defined by Bianchi et al. (2011), inbound OI is the utilization of technologies and inventions of the external firms and needs the interactions with the external entities to access their technical and scientific capacities.

Inside-out or outbound OI process covers all the activities of innovation related aspects like innovation projects, ideas, technologies, licenses, IP rights and knowledge from inside to the outside of the organization. Outsourcing, out licensing and technology multiplications to the external entities are some example processes of outbound OI approach (Chesbrough & Crowther, 2006; Chiaroni et al., 2010; Bianchi et al. 2011; Spithoven et al., 2011). As defined by Bianchi et al. (2011), outbound OI is the process of interaction with external organizations to transfer firm specific technologies to create value.

Coupled OI process is the combination of both inbound and outbound processes. The innovation process flow is bi-directional, both from inside to outside and from outside to inside. The most commonly used practice for coupled OI process is the implementation of strategic alliances and the interactions within the innovation networks.

Inbound OI is also called outside-in OI. It consists of intentional inflow of knowledge and technology from external sources of knowledge. Similarly, outbound is also called as inside-out OI. In outbound OI process, mostly firms seek for external partners that have better fitting business models to utilize and commercialize a technology. Outbound OI covers intentional outflows of knowledge or technology to the outside of the firm boundaries. This means utilizing existing technological capabilities outside the boundaries of the organization. There are several ways for that. Some commonly used ways are selling

of IPRs and technology multiplications by transferring internal specific technologies to external partners (Naqshbandi et al., 2016).

The innovation process flow and related OI approaches are highlighted in the OI literature also. Enkel et al. (2009) describe the innovation processes are in three different directions: outside-in, which is inbound OI, inside-out which is outbound OI and both directions which is coupled OI process. Organizations develop the knowledge base and related competences by the use of external ideas, knowledge and resources in inbound OI process. In outbound OI processes, organizations try to get benefit from their internal knowledge, developed technologies and assets like IPRs by offering them to the external environment. Coupled innovation process involves the external parties which either can complement internal technologies and knowledge base or which can be collaborated for technology and knowledge co-creation.

The analysis of OI literature shows that inbound OI approach is the most widely used and practiced type of OI (Chesbrough & Crowther, 2006; Schroll & Mild, 2011). Moreover, in comparisons to other approaches of OI, application of inbound OI process brings more outcomes and its impact on firms' innovation performance is higher (Schroll & Mild, 2011; Michelino et al., 2015).

1.5. OI Types

There are three main categorizations of OI types. These types define the processes and actions on how firms manage the flows within their boundaries for their innovation activities. As stated in the previous section, these types are *inbound*, *outbound* and *coupled* OI. Each type is analyzed in more details in the following sections.

1.5.1. Inbound OI

Firms try to establish relationships with other external firms in inbound OI. It is a means of entry to the external firms' competencies and knowledge bases to have better results for its own innovation. It is intentional inflow of external knowledge and technology. When the high amount of cost, time and efforts are required to develop skills, competences or technologies internally, firms develop inbound OI strategy which brings the firms the possibility to look for these in the external environment. Research institutions, universities, suppliers, customers and competitors can be the source of the skills, competences or

technologies that firms need (Tether & Tajar, 2008). The size of the set that accommodates the possible sources that can be collaborated by firms is described as firms' external search breadth (Dahlander et al., 2016). The intensity and strength of the search from different external sources is described as firms' external search depth (Laursen & Salter, 2006).

1.5.2. Outbound OI

Outbound OI comprises external technology exploitation (Chesbrough, 2003c; Chesbrough & Crowther, 2006; Lichtenthaler, 2008). It implies the outflow of firms' innovation inputs and technological knowledge. Commercializing existing IPRs, multiplication of existing technology and outward knowledge transfer to the external environment are the main inclusions of outbound OI process (Chesbrough, 2003a; Lichtenthaler, 2009). It is way of technology transfer to the external firms. For that, firms can seek for external entities with business models that are suitable to commercialize the transferred technology (Chesbrough & Crowther, 2006). Therefore, outbound OI refers to the all activities which aim to chase the utilization of firms' technology externally. Such technologies can be utilized internally at the same time and can be the firms' knowledge assets such as out licensing (Lichtenthaler & Ernst, 2006). With outbound OI traditional organizational boundaries are expanded to the external environment. In addition, networks are established to commercialize the technology and knowledge produced within a firm's borders. Knowledge or technology are shared with external environment (Huizingh, 2011). Studies show that, while firms share technology to the external environment, they mainly share technical knowhow (Hung & Chou, 2013; Naqshbandi et al., 2016), IP (Lichtenthaler, 2009; Van de Vrande et al., 2009; Hung & Chou, 2013), and knowledge (Hung & Chou, 2013).

Benefits of the outbound OI is studied in the literature. The main benefit of outbound OI is that the firm does not limit itself anymore to the environment it usually serves (Enkel et al., 2009). Firms applying outbound OI gain access to new markets and in these markets the firms who seeks for utilizing the inside-out flows operate (Kutvonen, 2011). Out licensing is one of the most commonly used practice that extends a firm's target market and it is considered as the main form of outbound OI (Lichtenthaler, 2015). Therefore, outbound OI process results in the expansion of the firm's target market.

1.5.3. Coupled OI

Coupled OI is the combination of both inward and outward flow of ideas, knowledge and technologies. It is mix of inbound and outbound OI processes. The common implementation of coupled OI is done through the co-creation and cooperation with mainly complementary partners such as alliances and joint ventures. The bi-directional flow of innovation knowledge base is critical for innovation success (Enkel et al., 2009). It is a type of co-innovation with complementary partners and knowledge share between collaborators is the base for the overall process. External knowledge from sharing process is recombined with existing knowledge to produce better innovation outcome.

If a firm and its innovation partner both own IPRs and both have pools of knowledge assets, then innovation is expected to be bi-directional (Gambardella & Panico, 2014). This type of partnership implies the process of coupled OI. Co-creating value for collaborators through formation of alliances, partnerships and joint ventures is the common way of implementing coupled OI process. In such formations outside-in and inside-out processes are combined and complementary resources are shared between collaborators (Enkel et al., 2009).

Un et al. (2010) highlight the variety of partners in coupled OI strategy and state its implication of collaborations with a number of diverse partners. The intensity of these collaborations can be very high or low depending on the aim of the collaboration need of the firms (Kang & Kang, 2009). There may be various goals for a firm for engaging in coupled type of collaboration. These goals may be short time-to-market, improving innovation capability, expanding its market, increasing the flexibility of its internal R&D (Chesbrough & Schwartz, 2007), exchanging of tacit and explicit knowledge (Faems et al., 2007), reducing technology market inefficiencies (Lichtenthaler, 2013) and mitigating some of the risks and costs of technological activities (Belderbos et al., 2010). However, there may be disadvantages for that engagement. Collaborating with external parties with a coupled approach may require additional efforts and costs as compared to only acquiring knowledge from them.

Some of the important outcome of coupled OI processes are patents jointly created between partners, also called co-patents (Lin et al., 2012). Collaborating for joint patent creation can be the main aim of coupled process between OI partners. Most of the time such collaboration partners are already owning patents and they are aware of their value. This awareness become a driver for collaborating in a coupled approach to generate more valued

and advanced patents. Usually the process of generating commonly owned patents takes longer times needs more intense interactions. However, the co-creation process may reduce costs and may generate new products with higher quality and more advanced technology (Mazzola et al., 2012).

1.6. Related Terms About OI

In this part, the terms that are mostly related to OI are described in detail. These most relevant terms are *collaboration*, *knowledge management* and *exploration* concepts.

1.6.1. Collaboration

The most common practice is innovation cooperation between the related firms and external entities in OI. Cooperation in innovation projects has several dimensions. Two or more parties or organizations team up together and set up a structure for a common purpose. The team up process between two or more parties or organizations is conceptualized as collaboration. This purpose is mostly the creation of a product, process or service within a defined duration. This requires the application of a set of tools and techniques and processes. Such setups with different actors are called collaborative projects. All parties open their boundaries to each other and the degree the direction of the openness depend on the applied type of OI approach. The collaborative R&D and technological innovation projects require the joint use and joint creation of knowledge and the combination of technologies and resources across the involved firms' organizational boundaries.

In OI collaboration context, firms may cooperate with different types of organizations. These can be research intensive, scientific or R&D intensive organizations or market oriented organizations. Collaboration with research intensive, R&D intensive or scientific organizations is called science-based collaboration. Such collaboration mainly involves universities, private or public research centers and aims to cooperate with entities that can provide fundamental or applied research or scientific knowledge. Collaboration with market oriented organizations is called market-based collaboration. Such collaboration mainly involves suppliers and customers, which are important entities in firms' supply chain, and sometimes competitors.

There are several benefits of collaborations with the firms in the supply chain in which suppliers and customers are important parties. Mostly they interact with not only a single

firm, but with multiple firms and are in the supply chain of several different firms. Due to that, they can be seen as sources of knowledge and additionally they can be means of getting knowledge about the competitors. Business partners such as technology providers, logistics and distribution centers also can be important collaboration partners depending on the innovation strategy (Bigliardi & Galati, 2013). Sometimes collaboration with competitors can be seen as mutually beneficial for collaborating parties. If the innovation requires scientific knowledge or needs for research and development, universities or research centers can be important entities for collaboration.

Collaborating with partners and selecting the most suitable ones is the most important aspect of OI. Each collaborator or partner in an OI project is a stakeholder of the innovation project. Stakeholders can be any entity, group or organization that can have impact on setup and outcome of the innovation project (Freeman, 1984). Stakeholder analysis is an established approach from project management. It focuses on actors who are essential and critical for the success of a project.

There are many studies in the literature for involvement processes of partners in collaborative OI projects. Lazzarotti & Manzini (2009) suggested a structure for the identification of OI modes and this framework analyzed concepts/variables named as partner variety and innovation project openness. Partner variety is the number and type of partners with which the firm collaborates with, whereas innovation project openness is the number and type of phases of the innovation project for which setup is done with an OI approach. Based on these variables, four basic modes of OI are proposed: closed innovators, open innovators, specialized collaborators and integrated collaborators. Closed innovators are the ones who have lowest partner variety and lowest innovation funnel whereas open innovators are the ones who have the highest partner variety and highest innovation funnel. The integrated collaborators are the firms who are collaborating with limited number of partners, only a few partners, mainly suppliers or customers. Specialized collaborators are the firms who can collaborate with many different partners, but the focus of the collaboration is a single projects. They conducted an empirical study results of which showed that these models are adopted in practice.

There are studies arguing that openness which is related to the quantitative side of partners and ignoring the qualitative characteristics of the collaboration limits innovative performance (Huang et al., 2018). When degree of openness is high and if the collaboration is with homogeneous partners, there is high probability that the acquired external knowledge is overlapping the firms' or other partners' already existing knowledge. Also, due to

similarities in the product range and knowledge backgrounds of homogeneous partners, the probability of technology overflows is high in homogeneous partner collaborations. Thus, for collaborations partners are recommended to be heterogeneous and complementary to the firm that is intended for OI. That results in that the collaboration partners should be heterogeneous, and this is called partner heterogeneity (Huang et al., 2018).

Huang et al. (2018) classified firms' collaborators into two types. First type includes the partners and is named as *industrial partners* such as customers, suppliers, competitors and out of same industry entities. Second category is *knowledge partners* which cover research institutions, technology intermediaries, IP organizations, and government agencies. Usually knowledge partners have low degree of similarity with the particular firm, which means that firm lack knowledge required for intended innovation and needs to complement this from external knowledge partners (Huang et al., 2018).

Among the external collaborators for OI, universities play a vital role. For the economic development of countries, knowledge transfer from universities and research centers is very important. From the firm perspective, collaboration with universities is one of the main means of knowledge acquisitions improving innovation capability. With the implication of OI model, firms tend to reduce their research activities and want to explore the academic and scientific research opportunities by collaborating with universities or research institutions. Industry–science collaboration has been encouraged by government policies as well in many countries. Recently innovation is seen an important aspect of economic growth for countries. Governments think that scientific research is a major source of inventions and firms play key roles to transform these inventions into commercial products. Due to that, universities have become one of the major partners for innovation collaboration. The industry-science collaboration has thus increased considerably.

In some cases, collaboration with competitors is chosen for large scale projects, mainly for cost reduction, risk mitigation or for joint work on common subjects, specifically when the innovation scope is out of the competition area (Tether, 2002). By applying that type of collaboration firms aims to complement the resources, mutually mitigate risks and reduce uncertainties.

1.6.2. Knowledge Management (KM)

One of the most important aspects of OI is knowledge and its management. KM refers to the process of creating, using, sharing, exchanging and protecting knowledge. For the

competition firms need to develop strategic competencies and consequently have to identify innovation-relevant knowledge. OI paradigm implies acquisition of knowledge externally and integration of it with internal knowledge (Chesbrough, 2003a).

Several components of KM are studied in the literature under the scope of OI term. Widely studied components are knowledge acquisition, knowledge sharing, knowledge protection and transport of internal and external knowledge (Enkel et al., 2009; Casprini et al., 2017). Ferraris et al. (2017) defined some of these components in the scope of KM process and identified these processes as acquisition, conversion and application of knowledge. Gathering knowledge and thereby expanding knowledge base through external entities and sources is referred as knowledge acquisition (Enkel et al., 2009). Transferring the gathered knowledge inside and outside of the firm is referred as knowledge transfer (Enkel et al., 2009). Disseminating the existing knowledge within and outside of the firm is referred as knowledge sharing (Enkel et al., 2009). Effective knowledge sharing processes between collaborators eases the development of core competencies required for innovation (Connell et al., 2014). Organizations with strong knowledge sharing capabilities are able to build better reputations (Ritala et al., 2015). Such reputation supports in attracting better potential collaborators and this situation provides the opportunity to enhance their innovation possibilities and alternatives. With the weak knowledge sharing capabilities, firm may miss the opportunity to share the existing useful knowledge efficiently and this might have negative impact on the achievement of potential innovation outcomes (Ritala et al., 2015).

Knowledge acquisition process consists of activities for gathering information and generating knowledge both from internal and external sources. When external knowledge sources are determined, information on these sources can be gathered and transferred within the organization. More external knowledge can be gathered when the knowledge acquisition processes works more efficiently. Efficient work of knowledge acquisition process eases the acquisition of critical knowledge and this may lead to the better adoption of inbound OI process. Knowledge acquisition is the key process in inbound OI and it focuses a firm's capability to manage knowledge by considering external knowledge acquisition outside organizational boundaries, while in outbound process focus is on knowledge sharing and managing KM activities by considering knowledge sharing across organizational boundaries.

Knowledge protection is an important component of KM and its relationship with OI process. Knowledge protection and appropriability problems in collaborative innovation activities consider patents or other IPRs and some other appropriability mechanisms like

Human Resources (HR) management, labor legislation and contracting. Such mechanisms can be used to prevent competitors from using firms' specific products and to ensure freedom of operating together with many other benefits. Because of that, the protection mechanisms are also called appropriability mechanisms. The combination of the available and effective means to protect innovations, and their potential outcomes is called the appropriability regime of the firm (Hurmelinna-Laukkanen & Puumalainen, 2007). Effective use of these protection mechanisms and control of knowledge flow is crucial to firms. Studies show that protection issues play a role in terms of both innovation performance and knowledge sharing (Hurmelinna-Laukkanen, 2011). Firms may have various knowledge protection (and appropriability) mechanisms. These can be IP right processes, contracts and labor legislation (Hurmelinna-Laukkanen & Puumalainen, 2007). Protection mechanisms promote networking and collaboration. By having such effective mechanisms, the firm will less worry about the abasement by other organizations and this will have a positive impact on the engagement in different joint operations, share of knowledge and collaborative innovation (Ritala & Hurmelinna-Laukkanen, 2009).

KM capability also is an important component of KM and it is an organization's ability in utilizing and allocating resources to enhance the management of knowledge. Alavi & Leidner (2001) define it as a summation of an organization's ability in acquiring, sharing, applying, and creating knowledge. It refers to the degree to which knowledge resources are created, shared and utilized across firm's borders. KM capability determines which knowledge is appropriate for acquisition. Acquiring external knowledge that is similar to the existing knowledge bases of the firm could reduce the positive outcomes of outside knowledge gathering (Dahlander & Gann, 2010). KM capabilities supports firms to acquire, store and properly use knowledge and by that way improves innovation outcomes. High KM capabilities brings higher degree of innovativeness and more engagement in the search of new knowledge (Ashok et al., 2016). Firm's information technology operations, effective HR practices have a positive influence on KM capability (Martinez-Conesa et al., 2017; Camelo-Ordaz et al., 2011).

As a consequence, for successful OI process KM strategies are important and sometimes crucial. Effective management of the inflows and outflows of knowledge is crucial to improve the innovation process and increase the benefits of innovation. Successful implementation of OI can be dependent on the firms' capability of managing intentional inflows and outflows of knowledge (Martinez-Conesa et al., 2017). The firm's effective processes and policies of KM is determinant in order to manage relationships among

different collaborators. As the number of partners with whom the firm collaborates grows, the complexity of the knowledge to be managed also increases, therefore KM processes become crucial.

An important aspect related to KM is absorptive capacity concept. It is a theory developed by Cohen & Levinthal (1990) and is defined as the ability of a firm to understand and identify the value of new, external knowledge, transform it and apply it. When the level of internal knowledge base is higher, firms can develop higher levels of absorptive capacity which is beneficial to identify, acquire, transform and integrate external knowledge obtained with knowledge acquisition process (Papa et al., 2018).

There are variety of knowledge sources addressed in the literature that firms may utilize through collaboration during the OI process. Each type of knowledge source provides different types of knowledge. Collaborating with competitors can improve the firm's knowledge base because competitors are likely to have similar needs related to knowledge requirements and innovation needs (Tether, 2002). Universities, research centers and academic institutions can be the sources of scientific or intensive research oriented knowledge needs. Such knowledge may require long times for application stages and may require large investments to turn them into products (Tether, 2002). On the other hand, such knowledge has high degree of novelty and due to that may provide important business opportunities (Cohen et al., 2002).

Customers also are potential and important source of knowledge. As the users of products and services, they mostly know better about the actual and practical needs. Therefore, customer information can be valuable in product improvements or in the development of new products (Tether, 2002). Moreover, information from customers can be important inputs for determining new opportunities. Customers have high level of useful knowledge about markets, the competitive environment, technological developments, and end-user needs and preferences (Garcia-Murillo & Annabi, 2002). Furthermore, suppliers have been addressed as knowledge sources. Always suppliers give knowledge as valuable inputs. However, supplier knowledge may also become easily available to competitors, which will reduce its value for innovation (Sofka & Grimpe, 2010). In addition, firms can get large amount of valuable knowledge through their partners and alliance networks (Spencer, 2003).

1.6.3. Exploration

One of the other important issues of OI process is the external exploration of innovation resources. Exploration is the main characteristic of OI and mainly refers to the search process for innovation resources. OI process is characterized by exploration and search strategy (Laursen & Salter, 2006).

Intentional knowledge acquisition and the permission of this knowledge for the exploration of new external knowledge from the sources like customers, suppliers, competitors, universities or research organizations implies the generic definition of inbound OI (Cheng & Shiu, 2015). As the generic definition of inbound OI implies, exploration is a term mostly used with inbound OI. External innovation search is related to the concept of “exploration”. The exploration concept sometimes is mentioned as exploratory search which defines the way of the search for new ideas and solutions during the innovation process (Katila & Ahuja, 2002). Search for new knowledge, technology, competencies or market is covered by the exploration term (March, 1991). In the initial stages of OI process, organizations start to explore the knowledge sources required for innovation (Roper et al., 2008). Exploration is mainly about the identifying, understanding and addressing potential novel or complementary external knowledge and possibilities of technology transfer within the scope of OI.

Benefitting the existing internal knowledge and technologies and creating means for transferring them to the external environment is the generic definition of outbound OI process. The process of OI implies making the best possible use of existing knowledge and technologies and this implication is conceptualized under the exploitation term. Thus, exploitation also is a term related to OI and used with outbound OI.

Firm's OI strategies in pursuing collaboration with different partners requires the firms to get the advantage from the collaboration and to have the capabilities to get benefit from the acquired or transferred knowledge. The ability to acquire and use of the knowledge is mostly referred to as absorptive capacity. It is defined as the ability of a firm to identify and understand the value of novel and external knowledge, acquire it and integrate it to its knowledge base (Cohen & Levinthal., 1990). Absorptive capacity is described the ability of a firm to acquire knowledge from external entities, transform and create the value from the acquired knowledge (Zahra & George, 2002). A firm culture that supports learning, flexibility, development and openness helps to develop this capacity for knowledge acquisition and usage. Organizations lacking sufficient level of absorptive capacity are may

not well-manage new knowledge acquisition, transformation and usage, which are important for both inbound and outbound innovation approaches. Knowledge and absorptive capacity concepts are closely related to each other and there is a significant relationship between a firms' absorptive capacity and the innovation capability (Chang et al., 2012).

Search for OI entails acquisition of knowledge from diverse external paths and this mostly requires diverse resources (Laursen & Salter, 2006). Excess amount of resources existing within the firms are related to organizational slack concept. Organizational slack refers to the redundant resources that are available to be readily allocated to the new, sometimes unplanned and suddenly arising activities (Tyler & Caner, 2016). They can have impact and various OI search activities (Voss et al., 2008; Tyler & Caner, 2016). High level of absorptive capacity can help a firm in recognizing and acquiring external knowledge in a proper way (Cohen & Levinthal, 1990), and thereby accelerate the firm's motive to allocate slack resources to external knowledge search. In addition, absorptive capacity can help to make sure that slack resources are effectively utilized in OI search.

One of the attributes of OI process is making use of external technology for creating economic value and is referred as external technology exploitation (Chesbrough et al., 2006; Chesbrough & Crowther, 2006). It gives the opportunity to a firm to cooperate and commercialize technological knowledge with other independent organizations (Chesbrough & Garman, 2009). It describes to a firm's willingness to chase for commercialization or outward transfer of its technological knowledge to external entities. This process covers the firm activities like searching for the commercialization of its ideas or technologies by directing them to the external market and utilizing from external use of its underutilized or unused IP or knowledge (Chesbrough & Crowther, 2006). This process helps firms to mobilize certain assets or projects towards the outside of its boundaries and utilize its technological knowledge in different markets by selling IP or other types of knowledge.

1.7. Benefits of the OI

The setup and application of OI is has many advantages and benefits. In the previous sections several of these advantages are mentioned and described. Short time to market for products and services, access to external knowledge that is not available to the firm, opportunity for lower cost of innovation, possibility of development of products and services better fitting to customer needs, commercial utilization of existing knowledge or technology and risk sharing with innovation partners in product and service development are some

examples (Wallin & Von Krogh, 2010). Possible benefits of OI have been studied by various researchers (Chesbrough & Crowther, 2006; Beije & Dittrich, 2008; Dahlander & Gann, 2010). Actually, the main purpose of OI process explains the benefits of it. Some of the most common examples are: Acquiring new knowledge and getting access to new markets, delivering in shorter times to market, More efficient utilization of internal capabilities, sharing of risk, expanding firm's network, lowering costs, having role and effect on the settings of industry standards, making use of unused internal capacities and better utilization of existing licenses (Chesbrough, 2004).

Beside these, there are several studies made on the role of OI on firm outcome. One example is the study made by Hung & Chou (2013). It explores the direct and interactive effects of inbound and outbound OI processes on firm outcome. Results show that external technology acquisition, namely Inbound OI positively affects firm performance. Inbound OI improves the relationship between external technology usage and firm outcome. There is positive relationship between both inbound OI and outbound OI and firm outcome under various conditions, environments and investment types. In addition, result of the study made by Du et al. (2014) on R&D projects' financial performance and OI showed a positive relationship.

Various studies analyzed the benefits of inbound and outbound OI. An organization that applies to outside knowledge and technology exploration and acquisition can attain entry to innovations or related capabilities that it does have internally (West & Bogers, 2014). Inbound OI process provides benefits for the firms that are in the need for shorter time to market; firms involved in OI process may achieve their goals more rapidly. Moreover, external organizations may have innovation related capabilities or technologies that are not existing in the organization. For this reason, a firm applies to suitable outsider organizations to enhance and sometimes to complement its existing knowledge base for creation of innovation possibilities for new products or services development. Thus, Inbound OI is a means for a firm to increase its know-how (Greco et al., 2019). Likewise, accumulation of knowledge external to the firm, namely inbound OI, brings benefit to the firms by improving firms' innovation performance (Katila & Ahuja., 2002).

One of the most common benefit of outbound OI is that the firm is not bounded to serve the markets which the firm is used to (Enkel et al., 2009). Firm acquires the possibility of accessing new markets where possible partner firms are operating and they are benefiting from the inside-out process (Kutvonen, 2011). As an outcome of that process, the firms'

target market is expanded with the common practices of outbound OI such as out licensing (Lichtenthaler, 2015).

The benefits of OI process can be broadened to public and social benefits. Individuals in industrialized parts of the world have become increasingly convinced of the importance of science and technology in social change and the impact of innovation on society in terms of material wealth, social welfare, and employment opportunities. There is also a significant positive relationship between organizational OI culture and organizations' innovation performance (Laursen & Salter, 2006). Through the implementation of OI, leaders can lead their organizations to develop beneficial technologies, catalyzing development and evolution. OI culture may lead to enhanced technologies that contribute to positive social change, such as clean renewable energy, effective and efficient use of recycled materials, generation of atmospheric drinking water, generation of nature friendly production techniques and products and delivery of programs that promote healthy behaviors and prevent illness.

For coupled OI, benefits and challenges may be considered as the combinations of the benefits of inbound OI and outbound OI processes.

1.8. Challenges to OI

Even though OI is the most recommended way of innovation process and has gained considerable attention in academic research area and has been implemented by organizations, there are many challenges and barriers in implementing OI strategy and having successful outcomes. Some organizations implement it successfully and results provide successful outcomes, whereas there are some implementations which provides unsuccessful outcomes. Thus, it is important to have an analysis for understanding the reasons of good and bad performance of OI outcomes for the organizations adopting OI approach.

OI process requires the knowledge inflow, outflow or exchange depending on the type adopted. This means that organizations' knowledge will be accessed to a certain degree by collaborators. Making organizations' knowledge available to collaborators to a certain degree accommodates certain risks. Organizational inertia is an important aspect and is embedded in the organizations' practices of knowledge sharing and flow process. It is the resistance of organizational entities, like employees and routines, in delivering sufficient amount of knowledge or other OI sharable items between collaborators. Most of the time,

efficient and effective implementation of OI process requires proper management and coping with organizational inertia. The “Not-Invented-Here” (NIH) syndrome is a concept related to organizational inertia and it is the tendency of the members of organization to believe that they own the unique knowledge in its area. This leads to refusing new ideas from external entities, since members think that new ideas will not be in benefit of organization’s performance, even will harm. It hinders the inflow of external ideas (Chesbrough & Crowther, 2006). Another concept related to organizational inertia is “Not-Sold-Here” (NSH) syndrome and it is resistance to outflow of knowledge. Usually it arises through the attitudes or behaviors of the firms’ employees (Lichtenthaler et al., 2010), thus blocking external commercialization of internal knowledge. Both NIH and NSH syndromes require proper management for effective and efficient operation and outcome of OI processes.

Chesbrough (2003a) and Lichtenthaler & Ernst (2006) argue that NIH and NSH syndromes are two important negative attitudes for the implementation of OI practices. Burchart et al. (2014) investigated the impact of NIH and NHS syndromes on OI and they pointed out that NIH and NSH syndromes have negative impacts on the success of both inbound and outbound OI processes.

There are many other important challenges to OI adoption that have been studied. High innovation costs are studied by Dogson et al. (2006) and Huizing (2011). Challenges in partner selection is studied by Dogson et al. (2006) and Bergman et al. (2009). NIH and NSH syndromes are studied by Chesbrough & Crowther (2006), Laursen & Salter (2006), Van de Vrande et al. (2009), Schwab et al. (2011), and Schroll & Mild (2011). The difficulties due to missing of internal commitment is studied by Van de Vrande et al. (2009). Bergman et al. (2009) studied the challenges like cultural and institutional differences between collaborators, problems related to share of responsibility between partners, insufficient resource allocation to innovation due to firms’ routine scope and lack of proper communication management between partners. KM barriers also are stated to be important challenges to OI since they hinder the proper implementation of OI strategy (Verbano et al., 2015).

Decision of OI adoption is an important change in organizations’ strategies required to recognize and efficiently make use of external opportunities (Chesbrough, 2003a). In this regards organizational culture has important impact in the success of OI process. Various studies have shown that organizational culture is important aspect to successfully implement and execute OI with desired outcomes (Chesbrough, 2006). Therefore, cultural barriers have to be overcome while managing end-to-end OI process. The protection of IPRs, finance and

KM issues are highlighted to be the important barriers to OI, as a result of study made by McCormack et al., (2015). In addition, there are important barriers related to outsourcing of R&D, in cases of outbound OI, and mostly these barriers are about proper partner management and quality of partners. Such barriers express the challenges related with identifying a collaborator with suitable capabilities for intended innovation (McCormack et al., 2015).

One of the central aspects of OI process is the partner search and partnership development. The process of partner or collaborator selection is one of the factors impacting the success of OI. Hewitt-Dundas & Roper (2018) studied the market failures in OI process and they identified three areas which may lead to failure of OI. The first one is the lack of awareness which means firm has insufficient information about the possible advantages of OI. The second one is inaccurate partner search process. This implies that the potential partner is not searched in proper and accurate way. Either missing or wrong information is gathered about the potential partner and the real and accurate capabilities of the potential partner is not recognized. This may bring collaborating with the partners which are not suitable for intended innovation. The third area which may lead to failure of OI is insufficient information about the trustworthiness and integrity of possible OI collaborator. In such a case partners' behavior is unpredictable and partner may show uncertain attitudes. This may result in self-interest behaviors, not paying enough care to the innovation project and eventually may result in poor innovation outcome.

2. LITERATURE REVIEW

In this chapter a detailed and systematic literature review is provided and results are presented. Firstly, a general literature review on OI research is conducted and results are summarized. Then, specific literature review studies on OI research and related concepts are reviewed and results are given. After that, the detailed literature review that is conducted for the aim of the study, using systematic review method is explained. Methodology for the detailed literature review is introduced. The steps of the detailed literature review are explained step by step. Finally, the findings are presented and conclusions are given with the identified gaps.

After the first introduction by Henry Chesbrough in 2003, concept of OI has drawn more and more attention from researchers over the approximately two decades. There are several benefits of usage of OI, like shorter times to market developed products or services, reach to the external knowledge, lower cost of innovation process, improved adaptability of products or services to the needs, utilizing existing and not used knowledge or technology and risk mitigation in overall innovation process. Due to such benefits, the interest of firms and research institutions in the recent years has increased considerably and this has contributed to addressing the OI practices from an academic perspective and enriching the literature. In this part, a detailed literature review has been conducted for the OI and its applications covering the last sixteen years, since the first introduction by Chesbrough in 2003. A systematic review of research on OI is conducted to have a comprehensive view on the OI drivers, OI types and the drivers that push organizations to seek for the related OI types and the basis of the decisions for collaboration structure of OI projects. For these purposes, related studies between the years 2000 to 2019 have been evaluated. Literature review contains 200 scholarly studies from 100 different publication sources starting from the year 2000. The analysis is separated into terms of “OI”, “inbound OI”, “outbound OI”, “coupled OI” and “OI collaboration types”.

Literature review is formulated to the following three conceptual areas:

- OI and the drivers behind the decision choosing OI.
- OI types and the drivers behind decision of choosing suitable OI approach for an innovation project
- Collaboration in OI and the drivers behind the seeking of collaboration types in structuring the OI projects

The literature review part is organized in three sections: In the next section, a general literature review on OI is given. Then, in the second section, specific literature review on OI is conducted which consist a review of the literature review studies on OI and its concepts. In third section a detailed lietarture review survey is given. Within the scope of the survey, firstly the methodology adopted to collect relevant studies for review based on the study aim is briefly explained. Then, the literature review is conducted by the application of the methodology described. This literature review consists of the drivers for OI adoption, the drivers for implementing OI types and the drivers for determining suitable collaboration types. Based on descriptive and content analysis respectively, each study is distinguished with regards to its focus on OI adoption, on inbound, outbound and/or coupled OI processes as well as collaboration types. Results and summaries are provided with tabular and graphical presentations. Finally, a discussion and highlight of the gaps in the literature that promote this research study and possible insights for the future research are provided.

2.1. General Literature Review on OI

OI has been studied from different perspectives over the years, after it was coined by Chesbrough in 2003. Over the last decade, firm's innovation strategies have been changed towards implementing innovation in collaboration with external partners. The idea of implementing innovation internally has changed (Appleyard & Chesbrough, 2017; Paula et al. 2018). Innovation pattern for the firms has become collaborative more and more with the involvement of different actors, such as customers, suppliers, universities, and competitors (Mention, 2011; Paula et al., 2018).

The original conceptualization of OI has been modified by scholars over the last decades. During that time frame, OI had an enormous impact on research. It has been studied by several scholars and has appeared in many academic publications. The evolution from closed innovation to OI and then the evolution of OI itself have brought changes and new ways of innovation management especially for some factors, such as type of industry, technology intensity involved in research and development, firm size, processes, firm structure, content and mechanisms for managing IP (Gassmann et al., 2010).

OI is continuing to attract attention from scholars. Studies made by Lee at al. (2020), Silva et al. (2020), Cheah & Ho (2020), Rosa et al. (2020), Ahn et al. (2020) and Oguguo et al. (2020) are some examples of recent research studies. Lee et al. (2020) explored the subject of cross-border technology collaborations and suggested a framework for setting-up

national-level strategies that helps a country to develop a collaboration strategy with another country. Silva et al. (2020) made a qualitative study to assess how science parks support OI and the role played by public policies in this process. The introduced framework integrates public policies, OI and science parks and serves to enact better public policies for science parks and thereby promoting more efficient OI. Cheah and Ho (2020) examined the impact of execution of industrial policy through public research and development funding effects the result of OI collaboration between public research institutes and firms. Rosa et al. (2020) analyzed the literature on innovation and OI performance indicators in small firms and proposed a set of indicators applicable as OI metrics for such firms. Ahn et al. (2020) examined if support policies, such as R&D funds, contributes to the foundation of a dynamic innovation ecosystem by encouraging firms' tendencies to collaborate. Oguguou et al. (2020) examined the effects national institutional environment on the benefits that a firm may acquire from R&D collaborations.

The implementation and practice of OI model can be found in various industries. Some sectors have already practiced OI and these sectors area widely studied in the research area with empirical studies. They are *high technology* (Chesbrough, 2003a ; Chesbrough & Crowther, 2006; Hung & Chou, 2013; Sisodiya et al., 2013; Naqshbandi et al., 2016; Banai, 2018), *automotive* (Huizing, 2011; Chiaroni et al., 2011), *biopharmaceutical* (Bianchi et al., 2011; Russo-Spena & Di Paola., 2019; Fu et al., 2019), *manufacturing* (Chesbrough & Crowther, 2006; Du et al., 2014; Wang et al., 2017; Lazzarotti et al., 2017) and *Information and Communication Technologies* (ICT) (Dittrich & Duysters, 2007; Carvalho & Sugano, 2016; Hong et al., 2019).

Although OI term was introduced by Chesbrough in 2003, collaborative R&D and university-industry partnerships had been widely applied in most countries before that. While OI practices have been evolved as required by free market conditions, government regulations and incentives have supported that evolution. OI policy reports that was prepared by Jong et al. (2008) is a good example. It covers different examples of OI regulations, support and incentives developed and implemented in the Netherlands, Belgium and Estonia (Jong et al., 2008). There are various successful OI practices. One of the most often assessed and cited is the Procter & Gamble case (Marcolin et al., 2017). In 2000, the firm set the aim to get 50% of its innovations outside the company (Huston & Sakkab 2006). The required organizational setup and model has been structured. In IBM, OI was implemented aiming to develop a new business model (Chesbrough, 2003c). The knowledge flow across the borders brought beneficial outcomes such as new product opinions, and these outputs helped to plan

new technologies which supported for keeping market position (Gassmann & Enkel 2004). Intel had an innovation process which allowed external collaborations and integrated external knowledge to the internal base (Chesbrough, 2003c). IBM and Intel's way of OI adoption introduced external knowledge into the organizations, namely they applied inbound OI. However, Lucent (Chesbrough, 2003c, 2004) transferred inhouse knowledge to the external world, applied outbound OI. Its way of OI adoption has led to arise of external venture firms from inhouse technologies. That resulted in new business models in commercializing internal (Chesbrough, 2003c). BMW has designed a structure applying inbound OI (Chiaroni et al., 2010). The opportunities arising from external sources have caused the requirement to found additional related organizational units.

Apart from cases stated here, there are other examples and case-studies reported by Leon (2007), Di Minin et al. (2010), Igartua-Lopez et al. (2010), Grönlund et al. (2010), Bianchi et al. (2011), Chiaroni et al. (2011), and Subtil de Oliveira et al. (2018).

OI research has gained a pace and studied by several scholars in Turkey also. Karabulut (2015) explored the impact of innovation types on the firm outcomes by an empirical research with 197 manufacturing firms in Istanbul. Result showed that financial outcome, customer performance, internal business processes performance and learning and growth performance are positively associated with product, process and organizational types of innovations. In addition, financial outcome, customer performance, and internal business processes performance have positive relationship with the marketing innovation, whereas it has negative relationship with learning and growth performance.

Findık & Beyhan (2015) investigated the innovation actions of firms in Turkey for the duration between 2006 and 2008 by using innovation survey conducted by Turkish Statistical Institute in 2009, aiming to show the effect of cooperations on innovation outcomes. The results showed that involvement in external collaborations resulted enhancement in the firms' products and markets and in the production process.

Çubukçu & Gümüş (2015) designed an OI portal using Quality Function Deployment (QFD) method. The portal was based on the results of an OI survey about the needs for OI with relevant partners and carried out with important firms in Turkey.

Kılıç & Türkmen (2019) conducted a qualitative research by using interviews with firms that apply OI practices and located in Denizli city. They attempted to investigate the awareness and the level of adoption to OI of the firms.

Satı (2019) made a study on OI for public sector by evaluating the conditions for utilizing from OI in order to make strategic management effective, to turn the decisions taken

into action, to reach the goals and to meet the needs of all collaborators with which the public interacts.

Ar et al. (2020) determined the appropriate OI model for logistics firms. According to results, outbound innovation is determined as the appropriate OI model for logistics firms. The most important three criteria in order to determine the appropriate OI model are innovation process, motivation, and market respectively.

Akın (2020) analyzed the required prerequisites for OI platforms to function successfully and OI applications in Turkey. The study highlights that OI applications and practices don't take necessary attention and importance. Study suggests some proposals for promoting OI applications, such as supporting SMEs by the chamber or public associations, developing human capital, and paying attention and implementing employees' ideas.

Ayaz & Aktaş (2020) analyzed the effect of applying innovation activities to R&D processes on the innovation performance of enterprises. Results of the study shows that setting up intensive cooperation with customers, universities, inter-inudstry companies and consultancy firms in the R&D process increases product innovation and process innovation. Also, these collaborations brought the increase in the sales of the products developed in the last one year.

Karagöz et al. (2020) made an analysis on the effcets of OI on software business in a Technology Development Zone by means of a survey and a research. Their results showed that most of the software firms in the zone are invoved in OI projects and project managers have information about OI. The level of information about OI for R&D staff is unclaer and it is proposed to increase the level of OI awareness by related trainings.

Kasalak (2020) studied the OI initiative of firms in IT sector in Turkey and analyzed the relationship between open innovation, social networks and organizational culture. Result showed that IT firms are applying OI. Te firms that are differentiated in their success on OI are the ones with more central to the social network and have stronger ties. There should be a supportive and harmonious organizational culture for the successful outcomes of OI.

Dağlı & Ezanoğlu (2020) made an analysis on OI model and studied the success of firms applying OI in Turkey. Their results showed that OI is inevitable in current business circuntances and several firms in Turkey are adopting to OI model.

In addition to above research studies, several PhD studies have been conducted in OI area in recent years in Turkey such as Erzengin (2015), Konukbay (2016), Avunduk (2017), Cubukcu (2018), Ayaz (2019), and Oran (2020). Moreover, there are recently conducted

Master of Science studies by Özkan (2017), Kılıç (2018), Ayaz (2019), Karagöz (2019), and Perçin (2019).

There are various examples of OI practices in Turkey (Özdemir & Deliormanlı, 2013). Recently many new products, technologies and services have been developed through collaborations. Various applications in mobile telecom industry are developed with the collaboration of mobile operators and small companies specialized in mobile applications. In the durable goods sector, home appliances manufacturers cooperate in R&D with design companies and other companies.

2.2. Specific Literature Review on OI

There are various literature review studies on OI. Kovács et al. (2015) conducted a bibliometric review of first 10 years of OI research to produce a more systematic and inclusive picture of the OI research scope, especially in terms of coherence and theoretical roots. They engaged in a systematic quantitative review of the existing literature on OI with the target to address the theoretical establishment of OI research and determine subjects within the OI research. Based on that, they identified various areas for further research, all built on the analysis of 358 studies published between 2003 and 2013.

Hossain et al. (2016) provided an extensive review of the development on OI literature identifying the most important topics to be studied in future research, by analyzing altogether 293 studies published from 2003 to June 2015.

Hossain & Anees-ur-Rehman (2016) explored improvements in the OI literature by performing a bibliometric analysis with the classification of 411 studies published from 2003 to June 30, 2014. They focused on the identification of extensiveness of OI literature, collaborative patterns of authorships, geographical focuses of authors and data sources, used methodologies and analytical techniques, major research streams, the areas that require further research and the collaborative pattern of authorships.

Natalicchio et al. (2017) conducted a systematic literature review to evaluate and compromise existing insights about the KM practices that support the successful adoption of OI strategies. The study showed the status of the research, addressed research gaps and eventually proposed future research areas. The study adopted the steps for systematic literature review which resulted in a final sample of 34 studies, differentiated and analyzed with respect to the three main OI approaches, i.e. inbound, outbound and coupled OI.

Subtil de Oliveira et al. (2018) conducted a systematic literature review to find critical success factors for OI application in previously published literature in a thirteen-years period, from 2003 to 2015 by selection of 156 papers. Hossain & Kauranen (2016) synthesized an extant literature on OI in SMEs ending up with the analysis of 56 articles from the year 2006 to 2013.

Le et al. (2019) conducted a study with bibliometric approach to investigate the research outputs of OI by analyzing the Social Science Citation Index (SSCI) database from 2003 to 2017. The aim was to determine potential research areas to help researches with further research. They analyzed 1.046 studies in 318 publications. Findings of the study were the research performance of countries, continents and institutions, information about related researchers and publications, most cited studies, the first studies in related subjects and study titles.

In addition to all these studies, there are several qualitative reviews also on OI research. Studies made by Gassmann et al. (2006), Elmquist et al. (2009), Dahlander & Gann (2010), Gassmann et al. (2010), Van de Vrande et al. (2010), Huizingh (2011), Lichtenthaler (2011), West & Bogers (2014), Brikerink et al. (2017), Oorschot et al. (2018), Öberg & Alexander (2019), and Loureiro et al. (2020) are some examples. All these reviews provided useful information about studied topics, explanation of related OI concepts, several important findings and the identification of potential areas for further research.

2.3. Literature Review Survey

There are studies made on the process and ways of conducting a literature review. In their study about how to conduct a literature review, Rowley & Slack (2004) aimed to find important items of the process related to the progress of literature review methodologies and explored the characteristics of the stages of performing of a literature review. Wee & Banister (2016) discussed the possible answers to the queries about the ways for writing a literature review paper (LRP). They focused on the significance adding value, rather than only producing a review. Their study also focused on presenting different types of LRPs, proposals on presenting the methodology used for the selection of studies for review, and the structure of an LRP (Wee & Banister, 2016). Rewhorn (2018) outlined the key features of a literature review and the characteristics of a successful one, giving guidance and methods for searching, reading, structuring and finally drafting for a literature review study.

There are various types of literature review methods. Some of them are systematic literature reviews, descriptive reviews, testing reviews, extending reviews and hybrid reviews. Descriptive reviews include narrative reviews, meta-summaries meta-narratives and scoping reviews. Testing reviews include reviews like meta-analysis and realist reviews. Extending reviews contain reviews like thematic synthesis, meta-studies and meta-interpretations. Hybrid reviews are mix or combination of any of these review types. One of the most widely used method for conducting a literature review is systematic one proposed by Jesson et al. (2011). Principles of their systematic literature review are scope review and addressing the subject, detailed searching, qualitative analysis, data extraction, consolidation of data and finally writing.

Xiao & Watson (2019) formulated the methodology of systematic literature review in eight steps. These steps are description of research problem, addressing the verifying the review structure, making the search, controlling the included scope, making quality assessment, taking out intended data, analyzing data and presenting the findings (Xiao & Watson., 2019).

In order to examine the related studies, the principles of systematic literature review which are being used widely in the innovation research field, are followed (Tranfield et al., 2003; Jesson et al., 2011; Xiao & Watson 2019). Based on the principles of systematic literature review, a four steps process is applied in this study. A more detailed methodology steps explaining the activities and findings for each step is given in Figure 2.1.

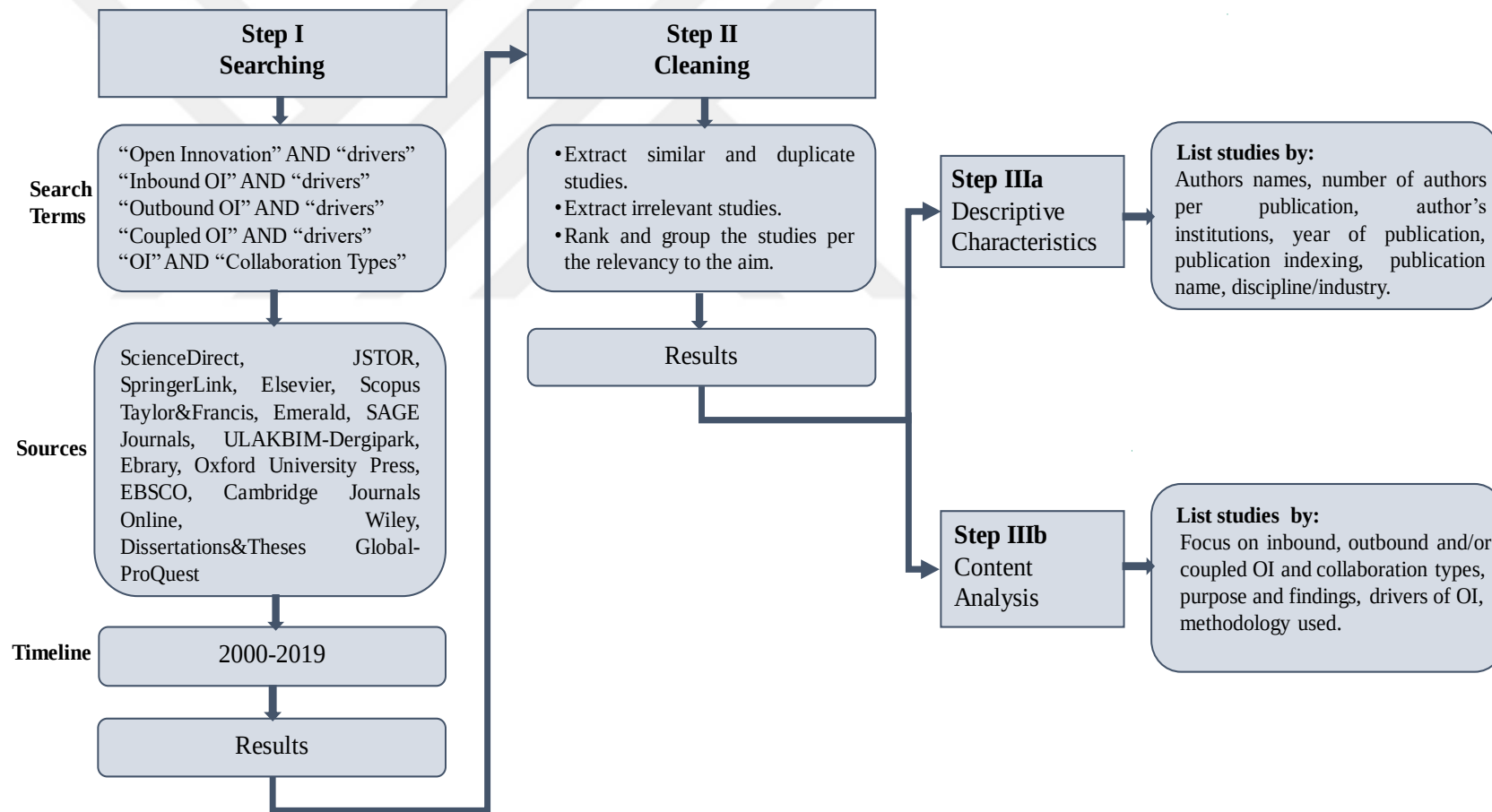


Figure 2.1. The methodology for the literature review

2.3.1. Methodology

In the first step, search criteria are determined. This covers determining search strings, identifying study databases and defining the time frame for the search. Input search strings for data sources are defined. To retrieve the studies per the focus of OI and its drivers and drivers of adopting OI practices, a three-stage search process is followed. For first stage, “OI” and “Drivers” keywords are defined, resulting with the search string of [“OI” AND “drivers”]. In second stage of the study, focus is put on the types of OI and for that the keywords “inbound OI”, “outbound OI”, “coupled OI” and “drivers” are identified and combined. Second stage has been resulted with the multiple search strings of [“inbound OI” AND “drivers”], [“outbound OI” AND “drivers”], [“coupled OI” AND “drivers”]. Lastly, for third stage of the study, the keywords of “OI” and “collaboration types” have been identified resulting with the search string of [“OI” AND “collaboration types”].

The keywords “OI”, “inbound OI”, “outbound OI”, “coupled OI” and “collaboration types” capture the focus on the OI concepts that is to be investigated. With the separate term “drivers” in the search string, it is aimed to limit the focus of this research on the studies based on the OI literature which focuses on the antecedents and the criteria for decision of adoption of OI, its types and collaboration types. By that way, including studies and papers with more general aims are tried to be avoided.

Then, the inclusion criteria for the articles is defined. In particular, it is focused on the studies that are published in peer-reviewed journals and sources that include books, book chapters, dissertations and thesis as well as conference proceedings. For that, the following types of journal databases and academic sources have been selected:

- Cambridge Journals Online, EBSCO, Ebrary, Elsevier, Emerald and SAGE Journals, JSTOR, Oxford University Press, ScienceDirect, Scopus, SpringerLink, Taylor&Francis, Wiley
- ULAKBIM-Dergipark, YÖK Dissertation Center
- Dissertations&Theses Global-ProQuest

The timeline for the search procedure is limited to the year 2000 onwards, since it includes the period of three years before the first introduction of OI construct by Chesbrough (2003a). From 2000 to 2003, there is enough period to see the studies which may include the development of innovation construct towards OI concept.

To minimize missing the studies which may include for OI and its related practices not defined under the umbrella of search string “drivers”, the keyword of “antecedents” is also

included for most of the sources resulting with the usage of search string [“OI” AND “antecedents”]. That means, the search strings of [“OI” AND “drivers”] and [“OI” AND “antecedents”] are used to retrieve the studies for OI drivers. Moreover, for most of the database sources the search strings of [“outbound OI” AND “drivers”] and [“coupled OI” AND “drivers”] resulted with very low quantities. In such cases, the string “drivers” has been removed from these strings and the strings of [“outbound OI”] and [“coupled OI”] have been applied not to miss the relevant studies.

In the second step, a cleaning process was applied to filter the search results with the aim of eliminating duplicate and unrelated studies and determine the final list of studies to analyze for the aim of this research study. The articles and studies were selected by analyzing their specific content and checking whether all the inclusion criteria are relevant. Firstly, duplicate studies, same studies published in multiple sources, are extracted. That has resulted a sample of 388 studies. Then, the publications with different languages rather than English languages are extracted and this process has resulted a sample of 17 studies. Finally, the studies were grouped and ranked per the relevancy to the aim of the study. The ranking was done by reviewing the article name and the abstract for some specific cases, where a more detailed info is needed for relevancy grouping. Accordingly, studies were grouped to five ranks. Rank 1 category was grouped as the most relevant to the aim of the study. The studies with this category was expected and thought to contain anyone of the drivers or decision criteria for adoption of either OI or its related typees. Additionally, any of the studies that is considered or expected to contain any of the criteria or drivers for the collaboration types or partner selection decisions for OI adoption is grouped under this category. Rank 2 category studies contain OI and its types and also collaboration types or anyone of these constructs, not necessarily including the criteria or drivers. Rank 3 category studies contain innovation related constructs, not necessarily OI. OI may exist in these studies but its relevancy degree to the aim of the study was considered to be low. Rank 4 and rank 5 category studies may contain innovation, but main focus of the studies is not innovation or totally irrelevant to OI. Social media related and crowdsourcing types of OI practices were also considered under these categories, since these types of OI practices has low relevancy degree to the aim of this study. From the categorization of the studies, it was concluded that rank1 and rank 2 categories will provide enough literature review inputs for the research aim. Thus, it has been decided to analyze rank 1 and rank 2 category studies in detail.

The third step was divided into two parts: a) descriptive characteristics and b) content analysis. In first part (step IIIa), the study outcome was structured by making a descriptive

analysis of the selected studies and descriptive characteristics are extracted. Descriptive analysis was done making a detailed analysis of the publication info. Analysis consist of extraction of the characteristics like authors names, authors locations by countries, number of authors per publication, author's institutions, year of publication, journal or publication abstracting and indexing and journal or publication name. As a result of this analysis, articles and studies were listed by publications year, published journals and publications, journal or publication index, country of location of first author and number of authors per study. The results are shown in findings section of this study.

In the second part for third step (step IIIb), the included studies were further analyzed and grouped according to the framework proposed in this study. In other words, based on a content analysis, each study was classified with regards to its focus on inbound, outbound and coupled OI processes as well as collaboration types.

2.3.2. Findings

Findings on the literature review is presented in this section. The result of the detailed literature review is demonstrated as the *drivers of OI*, *descriptive statistics* and *content analysis*.

2.3.2.1. Studies on Drivers of OI and Applications

The application of the search criteria and process defined in methodology section has resulted an initial sample of 1475 studies, of which 181 are book chapters and rest is mostly journal articles. The results of each search strings and related sources is summarized in Table 2.1.

Table 2.1. The results of step I

Search Terms	Sources												TOTAL
	Science Direct	JSTOR	Springer Link	Taylor& Francis	Emerald	SAGE Journals	Cambirdge Journals	Wiley	Dissertations& Theses-ProQuest	YÖK Dissertation Center	Scopus	Ulakbim-Dergipark	
“Open Innovation” AND “drivers”	85	14	96	53	41	25	4	27	25	2	62	19	453
“Open Innovation” AND “antecedents”	29	4	31	28	19	13	-	5	16	-	20	-	165
“Inbound Open Innovation” AND “drivers”	8	8	12	20	6	6	-	1	12	-	55	-	128
“Outbound Open Innovation” AND “drivers”	9	7	34	20	5	5	-	4	10	-	35	-	129
“Coupled Open Innovation” AND “drivers”	1	-	23	9	3	4	-	9	5	-	14	-	68
“Open Innovation” AND “Collaboration Types”	-	-	-	-	2	-	-	-	-	-	-	-	2
“Open Innovation” AND “Collaboration”	39	39	-	46	35	31	141	24	57	-	110	8	530
TOTAL	171	72	196	176	111	84	145	70	125	2	296	27	1475

Then, after the cleaning process applied in step II of methodology, 365 studies out of the initial 1475 studies were selected in the sample for detailed analysis. Specifically, 388 studies were duplicated, 17 studies not written in English and 705 studies were categorized as rank3, rank4 and rank5, which were considered not actually dealing with drivers of OI, its approaches as well as types of collaborations. Summary of the results of categorizations per related sources is given in Table 2.2.

Table 2.2. The results of step II

Study Category	Sources												TOTAL
	Science Direct	JSTOR	Springer Link	Taylor& Francis	Emerald	SAGE Journals	Cambirdge Journals	Wiley	Dissertations& Theses-ProQuest	YÖK Dissertation Center	Scopus	Ulakbim-Dergipark	
Rank1&Rank2	51	17	31	48	38	29	2	13	43	1	83	9	365
Duplicates	48	23	66	37	20	15	-	12	37	-	123	7	388
Rank3	42	10	61	48	30	17	-	18	17	1	59	5	308
Rank4&Rank5	30	21	27	43	23	23	143	27	23	0	31	6	397
Different Language	1	11	-	-	-	-	-	-	5	-	-	-	17
TOTAL	51	17	31	48	38	29	2	13	43	1	83	9	365

2.3.2.2. Descriptive Characteristics

Studies retrieved using this methodology were published from the year 2000 onwards. Among 365 selected studies as an outcome of cleaning stage, 200 studies have been analyzed in detail. Figure 2.2 shows the number of studies per year. From the results, it can be seen that 18% of the studies have been published in 2017. This is followed by the years 2016 and 2018 with 13% respectively. With these figures, it can be concluded that almost half of the studies are published between the years 2016 and 2018.

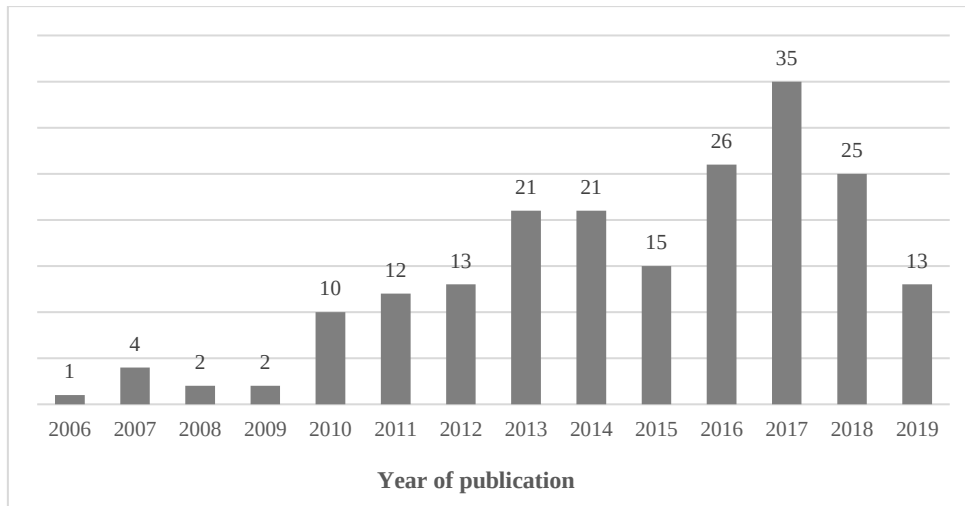


Figure 2.2. The number of the studies by year

Figure 2.3 shows a detailed view of journals and sources on which selected studies are published. It is observed that there are high number of theses on OI, with 14 studies published in ProQuest Dissertations&Theses Global. 13 studies are retrieved from book chapters. Moreover, California Management Review is in the top of the list among the journals. There are 73 publications containing only one study which is not shown in Figure 2.3.

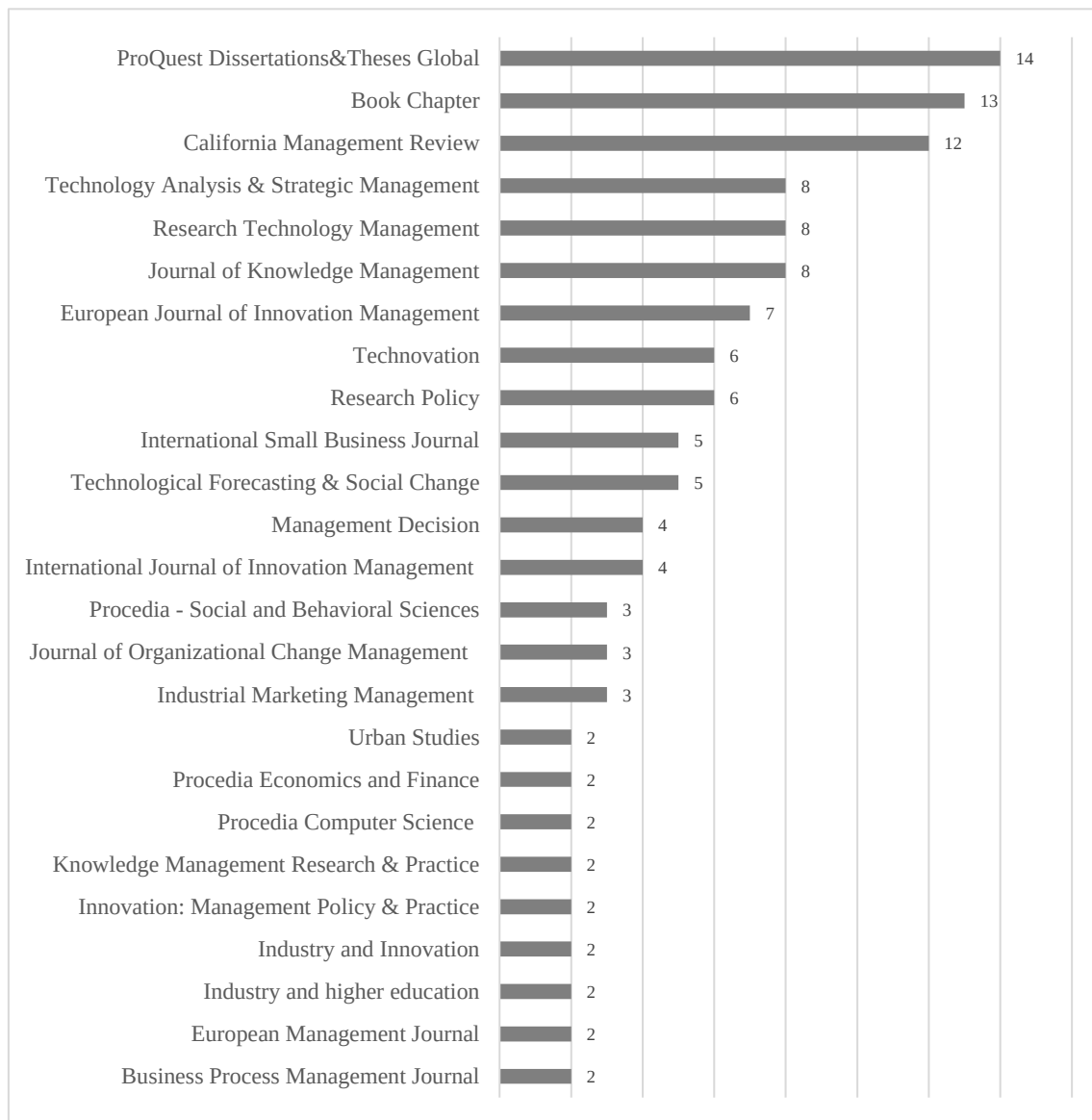


Figure 2.3. The number of the studies per publication

Figure 2.4 shows the number of the studies by the location of the authors (country). According to that figure, USA is at the top of the list (36 studies, 18%). Next on the list are European countries: Italy (30), the UK (18), Finland and Germany (9). China as an Asian country is among the fourth on the list with 9 studies.

In Figure 2.5, the authors of OI studies have been grouped into the following geographical regions as Asia, Europe, North America, Oceania, and South America. According to it, European authors have contributed with a significant proportion of the studies (63%). The number of North American authors, with the highest number of authors

from the USA, is also remarkable (18%). Asian authors represent approximately 12% of the total.

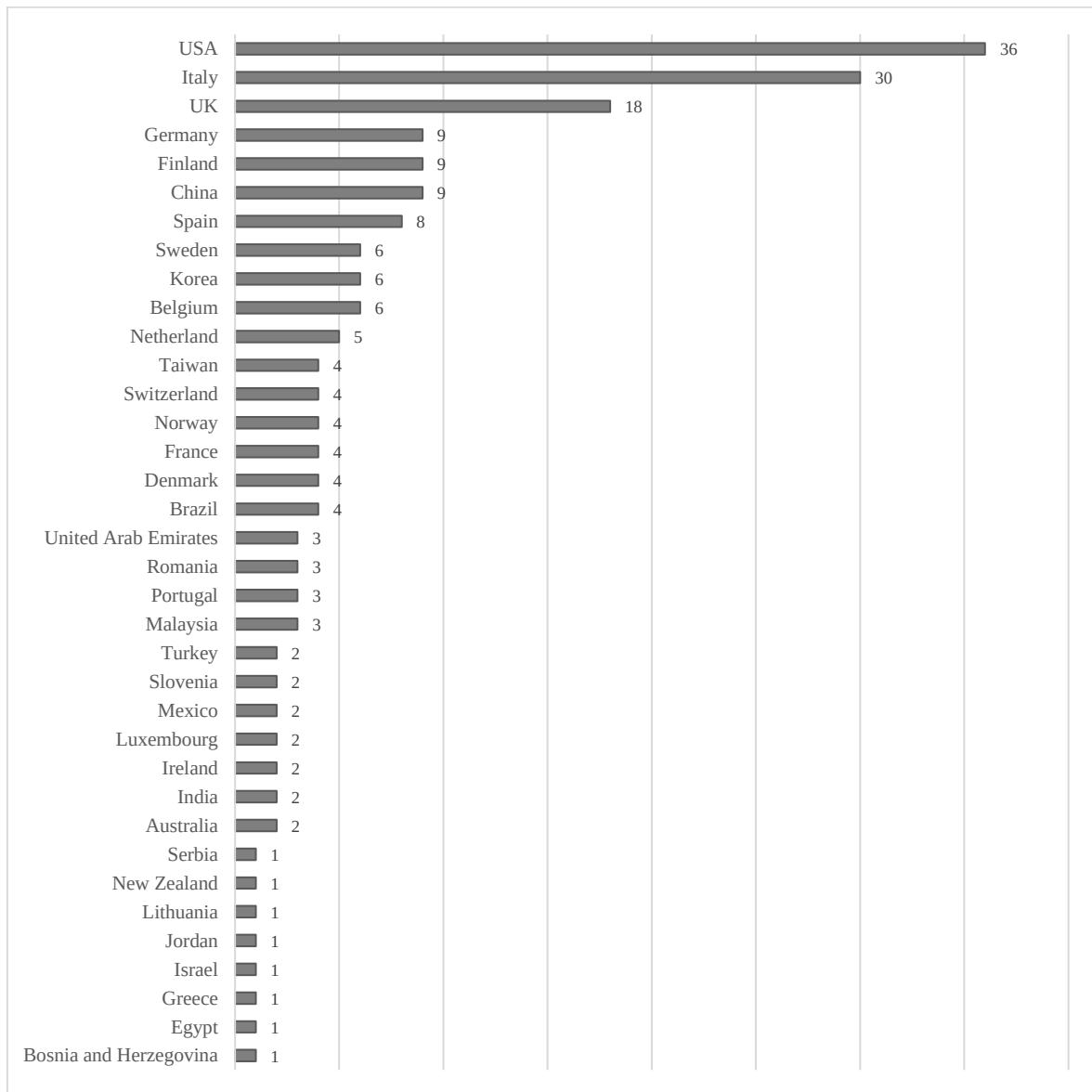


Figure 2.4. The number of the studies by location of the authors (country)

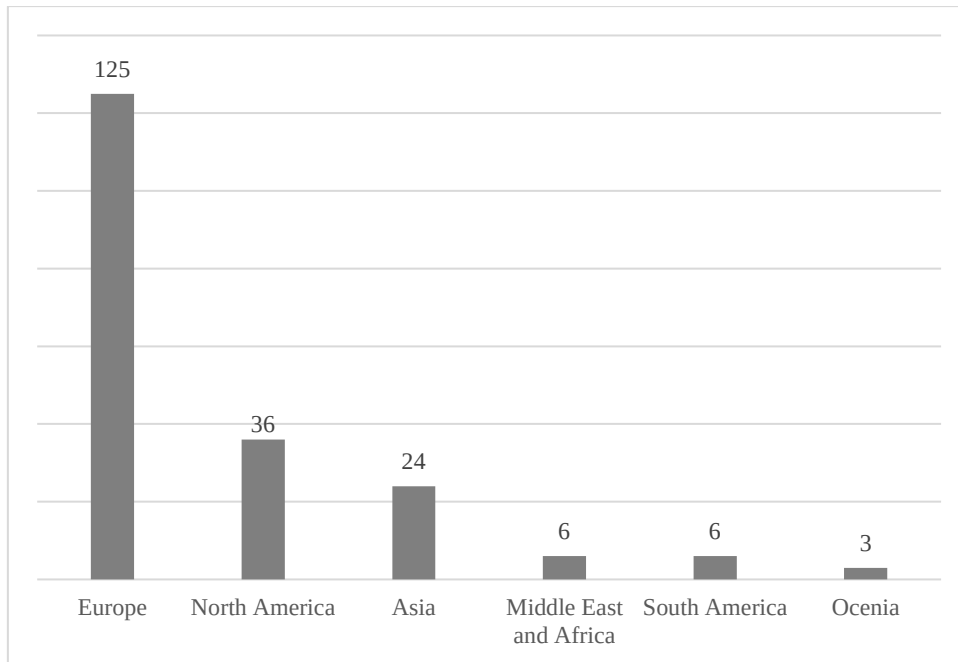


Figure 2.5. The number of the studies by location of the authors (region)

Figure 2.6 shows the number of publications that have been abstracted/indexed in major citations indexes. Four major citation indexes have been taken as reference. These are Emerging Sources Citation Index (ESCI), Social Science Citation Index (SSCI), Science Citation Index (SCI) and Science Citation Index Extended (SCIE). There are 26 publications which are not indexed by any one of these citation indexes and these are grouped as "Not Indexed". Moreover, since indexing/abstracting is not applicable to book chapters and dissertations&theses, such studies are not shown. 96 publications are indexed in SSCI only, 25 publications are indexed in ESCI only, 8 publications are indexed in both SCI and SSCI. In addition, 8 publications are indexed in both SSCI and SCIE. 6 publications are indexed in SCI only and 4 publications are indexed in SCIE only.

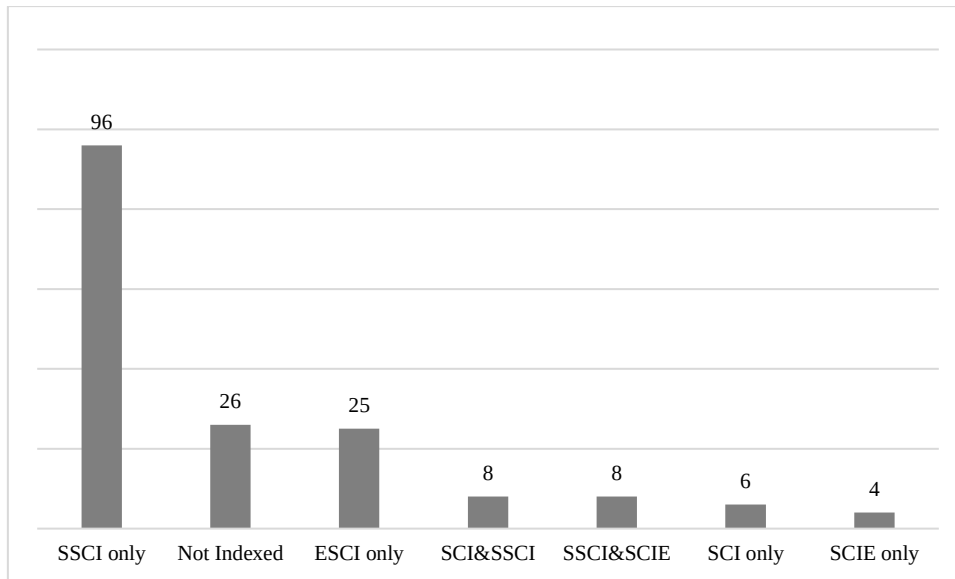


Figure 2.6. The number of the studies by abstracting/indexing of the publications

2.3.2.3. Content Analysis

OI and its related terms that are in the objective of this research have been assessed with the focus of division and percentage among the retrieved studies. Figure 2.7 indicates the study division among OI and its terms. It can be seen that most of the attention has been devoted to the OI itself (104 studies and 52% of the contributions) without directly addressing its types and inbound OI process (21% of the contributions). This is followed by the outbound OI process (13%). Only 3% of the contributions focused on the coupled OI. Focus on collaboration is 36% with 72 studies.

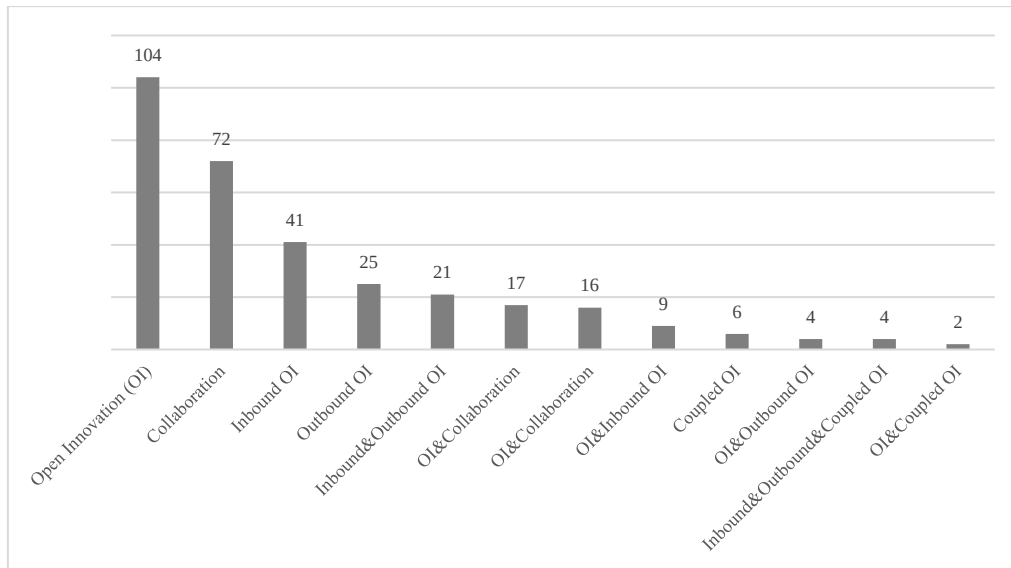


Figure 2.7. The number of the studies per OI process and types

Finally, out of the total of 72 studies focusing on collaboration 13 studies (18%) are focused on science-based, 9 studies (13%) focused on market-based and 9 studies (13%) focused both types of collaboration. In 41 studies collaboration has not been specifically mentioned by name, meaning that the collaboration is analyzed as a general construct and may apply to suitable type depending on the purpose. The summary of the studies on collaboration types is shown in Figure 2.8.

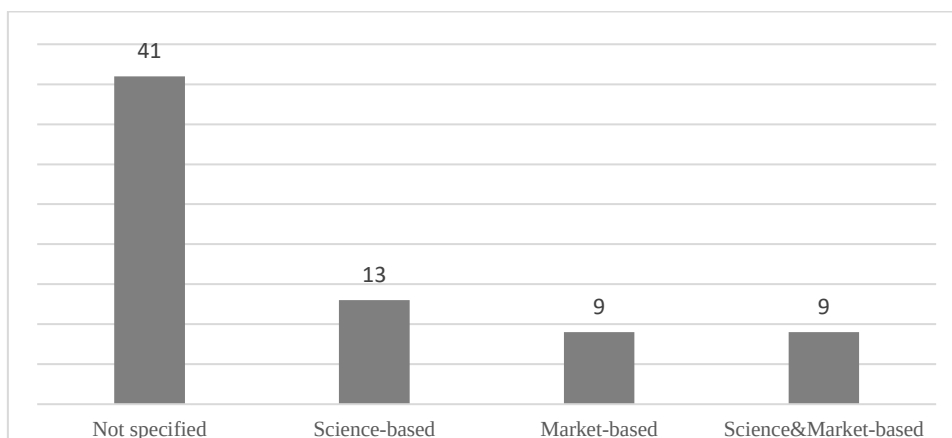


Figure 2.8. The number of the studies per collaboration types

Among the 210 studies, 176 studies have clear statements and illustrations of their methodology. These studies were investigated to find the patterns of the use of analytical techniques (Figure 2.9). Regression was the most commonly used technique (55 studies with

26 per cent). Analytical techniques such as regression (tobit), regression (probit), regression (logit), regression (binomial) and regression (logistic) were used. Case studies (22%), qualitative analysis (15%) and literature review (11%) were also widely used techniques. Some studies used simple calculation techniques like descriptive analysis and basic calculation techniques to show quantitative results. Techniques like ANOVA, cluster analysis, relational vs. transactional channel ranking, thematic analysis, bibliographic coupling analysis, fuzzy set theory and multi criteria decision making were used in very few studies and these techniques are grouped under “others” (8%). Among 200 selected studies for analysis, 10 studies used more than one technique. Thus, total number of studies per used analytical techniques are 210.

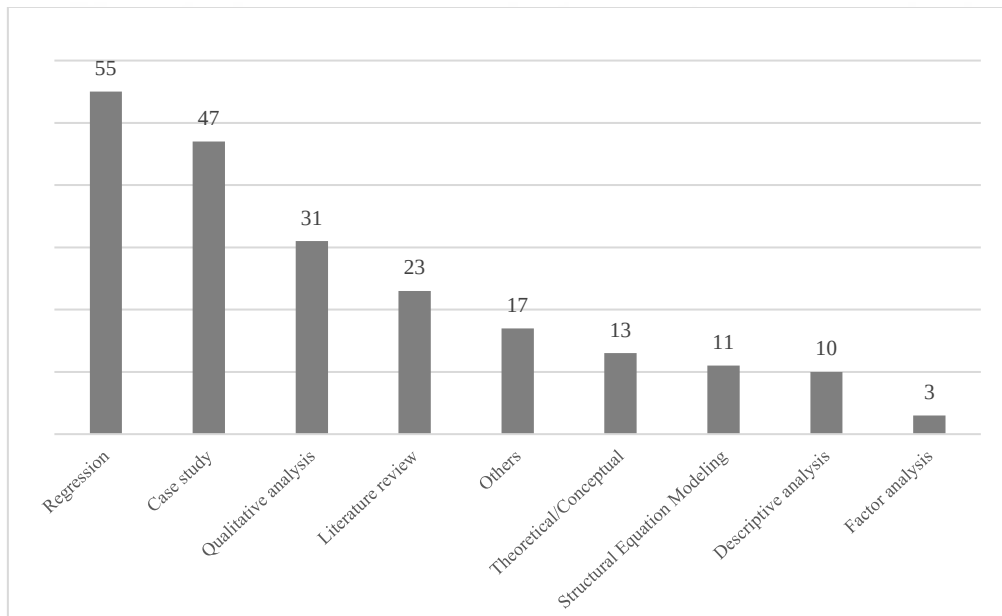


Figure 2.9. The number of the studies by the methodology used

2.3.3. Discussion

All these various literature review studies on OI give useful insights and help in building an understanding of theoretical concepts and terminology of OI as well as addressing of some research gaps. Some of them include OI and its constructs of OI types and collaboration types. However, there is lack of a comprehensive literature review study which make analysis on OI, its types and applications and linking them to each other in an end-to-end perspective. In other words; there is a gap of a thorough literature review in terms of analysis on OI by its approaches of inbound, outbound, coupled OI's and the type of

collaborations adopted in OI projects. The fact that a set of criteria and an end-to-end decision making model has not been developed, which allows the analysis of all aspects of OI by analyzing the proposed factors in different studies causes uncertainty in the evaluation of the potential of OI projects. This has impacts on various areas ranging from resource allocation to OI projects to the development of inter-institutional cooperation in innovation studies. Therefore, the development of a comprehensive scale of criteria for evaluating the potential of OI is an important area of study. As a result, this study contributes to fill the gap in this area and is unique in providing an analysis on OI and its related constructs and linking these constructs to each other in an end-to-end perspective.

Considering the adoption of OI, the most commonly used OI type in the literature is inbound OI. Overall, this literature review reveals that 104 studies address general OI process, without directly addressing its types, within the vast literature on innovation. Among them, studies on inbound OI process are dominant and most of the attention has been paid to it. Coupled OI process, has not been interested too much and the amount of the studies about it are limited. In addition, the most studied collaboration type is science-based partnership. There is an interesting finding about the coupled OI type. Researchers paid much less attention to this OI type. This can be a possible research area and in building a preferred OI model adoption, balancing between disadvantages of outbound OI and advantages of inbound OI. Overall, these results show that coupled OI approach needs be studies more in the future research studies

As seen from the literature studies, the most of studies in the OI literature are at organizational level and empirical studies are based on case studies. Enablers, motives and drivers that are determinant for organizations for structuring their OI projects are studied mainly on organizational level. Project level drivers are rarely studied. There are studies for the constructs of enablers and antecedents of OI and its types and the project structure for OI projects but these constructs; antecedents of OI, OI types and OI collaboration types, have been studied mostly independently. There is lack of an end-to-end comprehensive view on project level for OI by linking these constructs and an end-to-end process for addressing an end-to- end path for determining best suitable structure for OI cases.

With this argument in mind, it can be concluded that there is important focus on the drivers and antecedents of OI constructs which form the basis of this study. From all these studies, the drivers and antecedents, namely the criteria for adoption of IO, selecting its types and selecting best collaboration method for OI projects are extracted.

3. RESEARCH DESIGN and METHODS

In this part, the research design and the used methodology are explained in detail. Firstly, research design which includes stages are presented. Then, the used decision techniques, Delphi technique and Fuzzy Multi Criteria Decision Making (FMCDM), are expressed within the scope of the methodology.

3.1. Research Design

Selecting the suitable innovation type, OI type and partners are complex decision processes, especially at the beginning of an innovation project. This study divides these process into three stages. In the first stage, *Stage I*, it is aimed to determine and decide which innovation type (Open, Closed) will be used to build the structure of an innovation project. In the second stage, *Stage II*, it is assumed that an OI type will be used for an innovation project and the aim is to determine which OI type (Inbound, Outbound, Coupled) to implement. In the third stage, *Stage III*, the aim is to determine the most suitable type of collaboration type (science-based, market-based).

The process of setting up the most appropriate structure for "OI" projects requires selecting the appropriate innovation type, better OI approach and suitable partners. Usually, decision makers work in environments that require group decisions with the need to consider multiple, complex and sophisticated criteria. Most of the time the decision making environment is accompanied by high uncertainty and high fuzziness, suitable for the decision making with the multi criteria decision making approaches. Both qualitative and quantitative criteria have to be engaged with different and sometimes various approaches. To cope with all these complexities, this study proposes the use of FMCDM method. Detailed design and steps of research are shown in Figure 3.1. There are three phases for each stage. In phase 1, criteria are determined using extensive literature review and Delphi technique. In phase 2, the criteria relationships are determined by the evaluation of a group of experts. In phase 3, FANP method is used to weight the criteria and rank the alternatives.

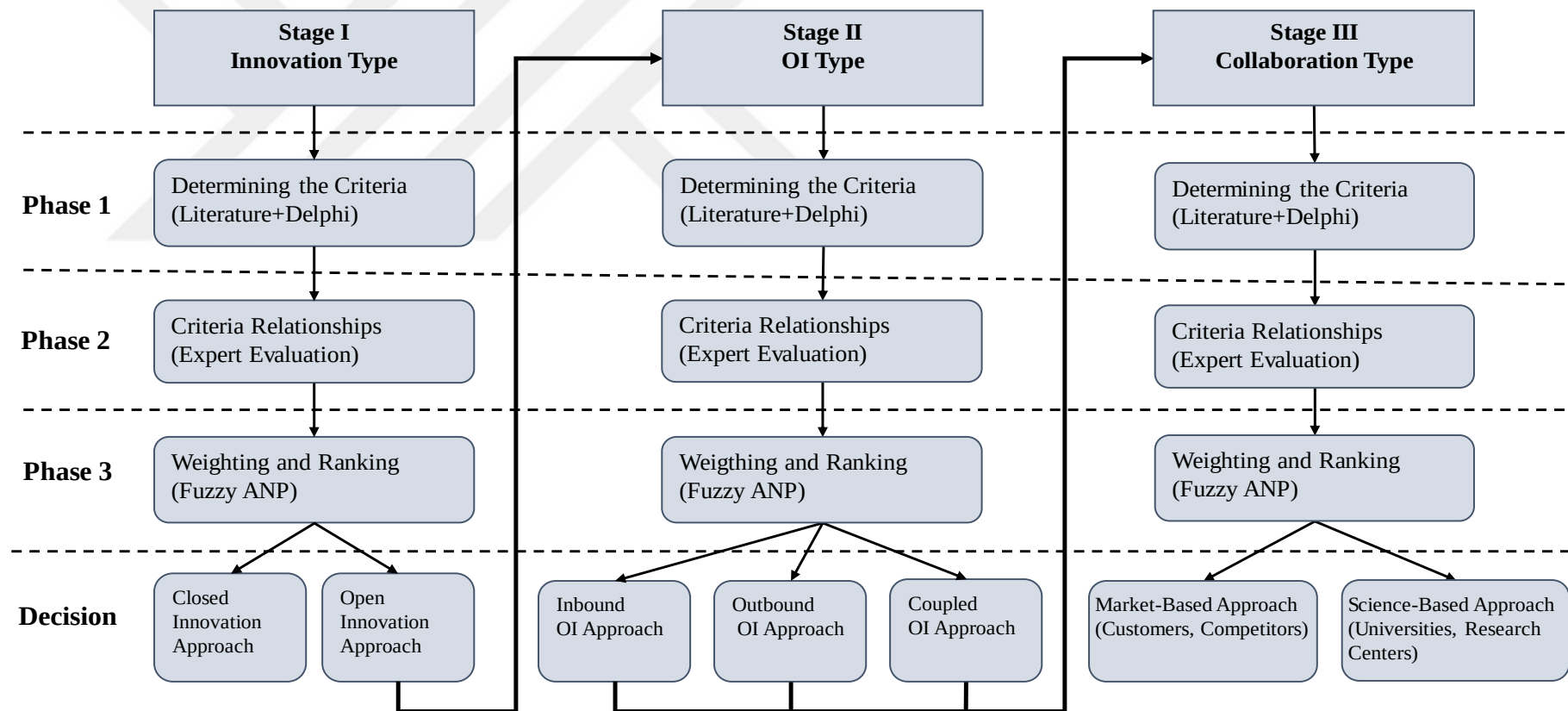


Figure 3.1. Research methodology

The initial criteria determining for each stage is done during the process of the detailed systematic literature review conducted and that is summarized in part 2 of this study. The criteria extraction from the literature is based on the drivers that are determinants for firms to adopt OI (*Stage I*), selecting OI type (*Stage II*) and applying the best suitable collaboration type (*Stage III*). These criteria give a comprehensive view on the OI antecedents, OI types and the drivers that push organizations to seek for the related OI types and the basis of the decisions for collaboration structure of OI projects.

3.1.1. Stage I: Innovation Type

This is the stage for determining the general innovation type. For an organization having an innovation project and intending to reach the desired outcomes and targets from this project, firstly organization has to make a decision whether to build a structure for this innovation project based OI or closed innovation approaches. Drivers and motives for an organization to select the appropriate innovation type is forming the criteria for that stage. After extraction and determination of related criteria from literature, a three step Delphi technique is used to finalize the criteria. This is followed by determination of the criteria relationships. Then, Multi Criteria Decision Making (MCDM) technique FANP is used for weighting the criteria and ranking the alternatives. It is expected to select the best approach of innovation after the ranking process.

3.1.2. Stage II: OI Type

This is the stage for determining the OI type. Once it is decided to proceed with the OI approach for an innovation project, the decision process starts for choosing the most suitable OI type to build the suitable structure either applying inbound, outbound or coupled OI approaches. Drivers for making this decision are based on organizational, environmental or project specific characteristics. These drivers form the criteria for that stage. After extraction and determination of related criteria from literature, a three step Delphi technique is used to finalize the criteria. Then, like in *Stage I*, expert evaluation for criteria relationships and FANP methods are used consecutively for weighting the criteria and ranking the alternatives. After ranking process decision makers are provided with sufficient data to select the best approach of OI type.

3.1.3. Stage III: Collaboration Type

This is the stage for determining the collaboration type and constitutes the process of choosing the best collaboration type. Drivers of choosing the type of collaboration will form the criteria. These criteria will be both organizational, environmental and project specific characteristics. After extraction and determination of related criteria from literature, a three step Delphi technique is used to finalize the criteria. Then, expert evaluation and FANP method is used consecutively for determining criteria relationships, weighting the criteria and ranking the alternatives. Based on the ranking results decision makers can choose the best suitable collaborators and build the suitable OI project structure accordingly. These collaborators may be chosen among either universities, research centers, competitors or customers etc. depending on the ranking results.

3.2. Fuzzy Set Theory

Most of the time MCDM implementation in decision making process brings the necessity of handling vast amount of data which is characterized by indefinite, uncertainty, fuzziness and intangibility. One of the most effective methodologies in dealing and structuring such complexities is to utilize from fuzzy set theory. Fuzzy set theory gives the opportunity to model and process the uncertainty and vagueness due to insufficient data. Fuzzy logic was introduced in 1965 by Zadeh (1965). In fuzzy logic the results of evaluations can take not only solid and single values corresponding to the conceptions like “true/false”, “high/low”, “yes/no” etc., but also intermediate values of conceptions between these solid values like “very high”, “very low”, “rather true” etc. (Dalalah et al., 2011). With fuzzy logic, the intermediate conceptions like “rather true” or “very slow” can be expressed mathematically and processed by computers (Dalalah et al., 2011).

3.2.1. Fuzzy Sets

By using fuzzy set, it is possible to make analysis by converting linguistic variables to fuzzy numbers. This provides convenience for situations that are difficult to express quantitatively. A fuzzy set is a group of items with ratings or gradings of membership. The ratings are continuous functions. A fuzzy set is represented by a membership or characteristic function. This membership function assigns a grade or rate to each element of the set. The grade of membership is a value between zero and one.

Direct implementation of arithmetic operators on fuzzy numbers is computationally complex. To overcome this difficulty, fuzzy numbers are expressed in certain ways, usually triangular or trapezoidal. A triangular fuzzy number (TFN), is shown in Figure 3.2. A tilde ‘ $\sim$ ’ is placed above a symbol which is representing a fuzzy set. In that figure the fuzzy number is a set defined by $\tilde{Z} = x \in R | \mu_{\tilde{Z}}(x)$. A TFN is shown as (l, m, u) . The parameters l , m and u , respectively, show the smallest possible value, the most promising value and the largest possible value that describe a fuzzy event (Yuksel & Dagdeviren, 2010).

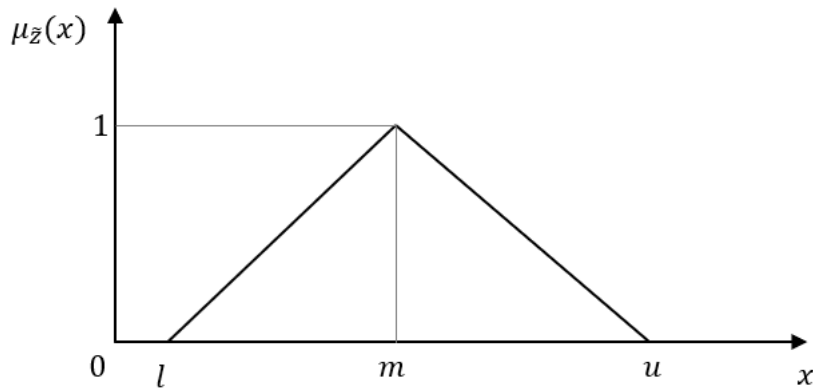


Figure 3.2. A triangular fuzzy number (Chen & Chen, 2010)

The left and right of a TFN is represented by a linear function. The membership function is described with the following Equation (1) :

$$\mu_{\tilde{Z}}(x) = \begin{cases} = 0 & x < l \text{ or } x > u \\ = \frac{x-l}{m-l} & l \leq x \leq m \\ = \frac{x-u}{m-u} & m \leq x \leq u \end{cases} \quad (1)$$

For a fuzzy number defined with the set $\tilde{Z} = (l, m, u)$, l denotes the lower value, u denotes the upper value and m denotes the middle value. Addition, extraction, multiplication, extraction, division and inverse of two fuzzy numbers, $\tilde{z}_1 = (l_1, m_1, u_1)$ and $\tilde{z}_2 = (l_2, m_2, u_2)$ are done with the following Equations (2-6) (Chen & Chen, 2010; Yuksel & Dagdeviren, 2010; Chou et al., 2006, 2008).

$$\tilde{z}_1 \oplus \tilde{z}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (2)$$

$$\tilde{z}_1 \ominus \tilde{z}_2 = (l_1 - l_2, m_1 - m_2, u_1 - u_2) \quad (3)$$

$$\tilde{z}_1 \otimes \tilde{z}_2 = (l_1 \cdot l_2, m_1 \cdot m_2, u_1 \cdot u_2) \quad (4)$$

$$\tilde{z}_1 \otimes \tilde{z}_2 = (l_1/l_2, m_1/m_2, u_1/u_2) \quad l_2, m_2, u_2 > 0 \quad (5)$$

$$\tilde{z}^{-1} = (1/l, 1/m, 1/u) \quad l, m, u > 0 \quad (6)$$

3.2.2. Fuzzy Multi Criteria Decision Making

MCDM is a set of analytical processes for finding or ranking the best option among multiple alternatives. It helps decision makers in carrying out qualitative and quantitative evaluations to find the weights of alternatives with respect to every criteria, as well as the relative importance of each criteria with respect to the entire aim of the decision process (Dalalah et al., 2011). MCDM often occurs in a fuzzy context, and in such cases is called FMCDM. In FMCDM context the existing data is not exact and this situation may misguide the decision makers in their decisions. Both MCDM and FMCDM procedures consist of identification of alternatives, determining criteria, assessment of alternatives, evaluations of criteria weights and finally implementation of a ranking process (Vincke, 1992; Opricovic, 2011). The alternatives are evaluated based on various diverse criteria depending on the purpose of the decision making. Mostly, alternative evaluations are done taking each criterion from the groups of determined criteria as reference. There are several studies making the analysis of MCDM and FMCDM methods separately and evaluating the advantages and contributions that each bring (Opricovic & Tzeng, 2007; Triantaphyllou, 2000).

There are many studies where innovation project selection is addressed as the MCDM and FMCDM problem. Chou et al. (2008) suggested a model using the FANP and fuzzy VIKOR (“Viekriterijumsko KOMPromisno Rangiranje” term for multi criteria optimization and compromise solution) methods based on a scale of 26 criteria for the selection of IT projects. Jeng & Huang (2015) proposed a mixed MCDM method based on Delphi, Decision Making Trial and Evaluation Laboratory (DEMATEL) and ANP processes for the selection of projects to be carried out by the National Research Institute to differentiate products and services. Using MCDM and hesitant fuzzy sets, Öztaysi et al. (2017) developed a decision model for selection of innovation projects. Özdemir (2018) developed a scale and a model in determining social innovation potential using MCDM methods based on Delphi technique, fuzzy DEMATEL, FANP, fuzzy VIKOR and fuzzy TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) methods. Kashyab & Garg (2019) proposed an MCDM method called Euclidean Distance Based Approach (EDBA) for the

assessment and selection of R&D projects, yielding an overarching ranking of the projects and helping the decision makers to select the best one.

Beside all these examples, the selection of innovation approaches (closed vs. open, inbound vs. outbound or coupled) and suitable collaboration types are rarely studied with MCDM and FMCDM methodologies. In that respect, this study will be one of the first in applying FMCDM methods in innovation projects, determining innovation type and collaboration structures

3.3. Decision Techniques Used in the Research

The techniques used in the study are carried out in three stages: Delphi Technique in criteria finalization, expert evaluation in determining criteria relationship and FANP in alternative ranking.

The study involves a decision making process and requires handling large amount of a criteria set. Most of the criteria is characterized by uncertainty, fuzziness and intangibility. Since one of the most effective methodologies in dealing and structuring such complexities is to utilize from fuzzy set theory, it is decided to use FANP technique in weighting and ranking process of the study. This gives the opportunity to model and process the uncertainty and vagueness in the criteria set and in decision making process.

Criteria for each stage is determined and extracted from literature with detailed literature review, then further verified, checked and finalized by applying Delphi Technique. After that, for each stage, criteria are weighed, and alternatives are ranked using FANP. In this chapter, theoretical information about each method is given.

3.3.1. Delphi Technique

Delphi technique is developed by RAND Corporation, a research organization in USA, in 1950's. The commonly used definition is done by the RAND. According to that definition Delphi technique is simply a method for revealing and refining group decisions (Dalkey & Brown, 1969). Delphi method is for supporting and easing structured group communication in order to obtain consensus of expert opinions for providing solutions in cases of complex problems, complex decision makings and agreement requirements in uncertain contexts (Crawford et al., 2016). Anonymously, a series of questions are given to the experts for the relevant subject of the study and numerical responses are requested. An accumulation of the

answers is then composed and sent back to the expert group, sometimes requesting the reasons and explanations for their answers. By that way the opportunity of revision of the responses are given to the experts. Based on the feedback received experts or can revise their answers. This iterative and controlled feedback process continue until a consensus point is achieved. Several rounds of iteration may be conducted depending on the nature of the problem. Some studies state that three rounds are commonly agreed number of enough rounds and can be thought as sufficient for achieving a desired level of consensus (Delbecg et al., 1975; Linstone & Turoff, 1975).

The main purpose of using Delphi Technique is to get benefit from collective and subjective expert judgements and decisions (Crawford et al., 2016). Due to that, in the Delphi panel, a sample is selected with experts who have the competence to answer research questions in the related field (Skulmoski et al., 2007, Hatcher & Colton, 2007). Depending on the aim of the research, number of experts to be included in the panel can vary from a few to hundreds (Hatcher & Colton, 2007; Hung et al., 2008; Gill et al, 2013). Skulmoski et al. (2007) presented how Delphi method has evolved into a flexible research method by analyzing a wide variety of information system Delphi research projects. The analysis presents that sample size in IS research studies varies between 9 to 104, whereas in non-IS studies it varies from 3 to 177. Rowe & Wright (2001) recommend sample size to be between 5 and 20. Key principles of Delphi technique are as follows (Rowe & Wright, 2001; Skulmoski et al., 2007; Gill et al., 2013) :

- Experts and responses are anonymous: Their identities and responses are kept confidential.
- It is ensured that the questionnaires are applied sequentially in tours.
- Group responses are analyzed with the statistical methods and controlled feedback is provided to participants.
- Participants are given the opportunity to reconsider their opinions each round and this is continued until a consensus to a certain degree is reached.

Some important advantages of Delphi technique are: the possibility of getting geographically distributed panel experts together (Hung et al., 2008; Gill et al., 2013; Crawford et al., 2016), avoiding face to face or direct discussions and evaluations of experts with one another (promoting fair evaluation, free from group bias), being cost effective, flexible and adaptable (Hung et al., 2008; Crawford et al., 2016) and providing expert consensus (Hung et al., 2008).

The disadvantages and weaknesses also are highlighted by some scholars, such as long times between rounds, drop-outs of experts (Hung et al., 2008), Missing of empirical evidence in achieving consensus (Delbecq et al., 1975). Anonymity also may be a drawback sometimes, since it can cause insufficient accountability in replying and providing the opinion about the queries, in addition to causing fast responses (Sackman, 1975). Time delays and expert drop-outs can be overcome by sending reminder to experts attending the panel and encouraging them to participate effectively (Hsu & Sandford, 2007).

Delphi technique process can be summarized in the following steps (Hatcher & Colton, 2007; Skulmoski et al., 2007; Hung, 2008; Crowford & Wright, 2013; Özdemir, 2018).

Step 1- Determination of panel experts: Experts should be selected among the people who have knowledge and expertise related to research subject.

Step 2- Design of the first round questionnaire and distribution to experts: The aim of the research study and the questionnaire is clearly expressed. The experts are requested to rate the importance and maturity level of each item determined for the research problem on a 1-7-point Likert scale. They are also requested to provide their own proposals for new questions which are not existing in the questionnaire. Distribution of the questionnaire to the experts can be done via various ways. Most commonly used ways are through e-mails or web.

Step 3- Analysis of first Delphi questionnaire: The importance level of each question is calculated with the following statistical methods related to Delphi technique.

Median (Md): Median is the middle number in a list of numbers. It is the point where 50% of the answers located to right and 50% located to left of it.

First Quartile (Q1): It is the median of the lower half of the data set. This means that it is the point that takes 25% of the answers to the left and 75% to the right.

Third Quartile (Q3): It is the median of the upper half of the data set. This means that is the point that takes 75% of the answers to the left and 25% to the right.

Interquartile Range (R): It is the difference between the first and third quartiles ($R=Q3-Q1$). Low value shows the high level of consensus, whereas high R value shows low level of consensus.

Step 4- Preparation of second round questionnaire and distribution to the experts: Delphi statistics of each question of the first round and the expert's response in the previous round are reported under the relevant question. Moreover, additional questions suggested by experts in the first round are added to the questionnaire. The experts are asked to re-answer

the related question. In case the expert is thinking different than the group view, it is requested to justify it.

Step 5- Analysis of second round questionnaire: Median, First Quartile, Third Quartile and Range is calculated for the expert answers in the second round. If there are specific comments from experts, it is consolidated in a different form.

Step 6- Preparation of third round questionnaire and distribution to the experts: This questionnaire is the same with the second round questionnaire. For each question, statistics of the second round and the participants' answer to the related question is added.

Step 7- Analysis of third Delphi round and results: The statistics of second round are used for the analysis of third round. It is checked whether the range between quartiles are decreased or not. Decrease in range means higher level of consensus. The decision for criteria is made by looking at the median and range values related to their importance and impact levels.

For the questionnaire at each round, a seven-point Likert scale was used, and response choices ranged from 1 (should never be used) to 7 (should be used). Seven rather than five points are selected for greater data granularity and to support analysis of responses.

3.3.2. Fuzzy Analytical Network Process

ANP (Analytical Network Process) was developed by Saaty (1996) and is built on the general structure of Analytical Hierarchy Process (AHP). AHP is a theory for decision making. It is built by setting up a hierarchical model having a goal, criteria and alternatives. Elements of the model, criteria, are classified by the hierarchical level that they belong to and pairwise comparisons are made with respect to the element in an upper level in the hierarchy. Based on the comparisons, decisions are made on the importance and weights of the elements, mostly criteria. In the majority of real-life problems, there are complex dependencies, interactions or feedback between criteria. Feedback and mutual interactions or dependencies cannot be fully modeled with AHP hierarchical structure (Saaty & Vargas, 2006). Therefore, ANP is proposed for such complex dependencies, feedback and interactions. In ANP, elements or criteria are grouped into clusters of related factors rather than into hierarchical levels. ANP includes dependencies and feedback between criteria and analyzes the relationships between criteria by establishing a network model (Saaty & Vargas, 2006). The clusters, criteria in each cluster and the links between criteria and clusters form a network. Thus, in cases when there are relationships between the elements of the problems,

ANP is a useful method to overcome uncertainty and ambiguity in pairwise comparisons and providing solution to the overall decision making problem.

Mostly elements are grouped under clusters or dimensions based on their similarities and the elements of the clusters are modeled in a matrix structure for building the relationship structure between them. Saaty (1980) proposed a scale of 1–9 to for the quantification and rating the preferences of decision makers. This scale is used in comparisons of the elements. Usually comparisons are done for a component i (column element in the matrix) with component j (row element in the matrix). Rating with a value of 1 means completely two different elements and implies that is not any relationship between the two compared elements. Rating with a value of 3 means weakly preferred, a value of 5 shows a strong preference, a value 7 shows a very strong preference and value 9 shows the absolute preference of i over j . Similar to the scale of 1–9 proposed by Saaty (1980), a scale of 1 to 9 can be defined for triangular fuzzy numbers (Mohanty et al., 2005). These numbers are fuzzy linguistic variables that reflect different aspects of human language and are divided into linguistic evaluation. The preferences associated with the ratings of these linguistic variables can be expressed as equally important, moderately important, strongly important, very strongly important, and extremely important. In FANP, such an evaluation scale consisting of fuzzy linguistic variables is used (Mohanty et al., 2005). Linguistic variables in the scale are converted into fuzzy triangular numbers.

Derived originally from Saaty's scale (Saaty, 1980, 1996), fuzzy linguistic terms and corresponding TFNs which are used for pairwise comparisons are given in Table 3.1 (Chiou & Tzeng, 2001; Lee et al., 2008; Lin et al., 2009). The criteria between two adjacent judgements defined in Table 3.1 are referred as intermediate values and are used in pairwise comparisons for the corresponding related linguistic terms (Lamata, 2004; Lin et al., 2009).

Table 3.1. The linguistic variables and triangular fuzzy numbers for importance

<i>Linguistic variable</i>	<i>Fuzzy number</i>	<i>Triangular fuzzy number</i>	<i>Triangular fuzzy reciprocal number</i>
Equally important (EI)	1	(1; 1; 1)	(1; 1; 1)
Intermediate value (IV1)	2	(1; 2; 3)	(1/3; 1/2; 1)
Moderately more important (MI)	3	(2; 3; 4)	(1/4; 1/3; 1/2)
Intermediate value (IV2)	4	(3; 4; 5)	(1/5; 1/4; 1/3)
Strongly more important (SI)	5	(4; 5; 6)	(1/6; 1/5; 1/4)
Intermediate value (IV3)	6	(5; 6; 7)	(1/7; 1/6; 1/5)
Very strong more important (VSI)	7	(6; 7; 8)	(1/8; 1/7; 1/6)
Intermediate value (IV4)	8	(7; 8; 9)	(1/9; 1/8; 1/7)
Extremely more important (EMI)	9	(9; 9; 9)	(1/9; 1/9; 1/9)

There are many studies in the literature using FANP method. When some of these studies are analyzed, FANP process can be summarized in the following steps (Cebeci, 2009; Chen & Chen, 2010; Uygun et al., 2014):

Step 1- Pairwise comparisons: Considering the interactions in the network structure and criteria relationships, relative importance of each cluster and criteria in each cluster are compared by a number of decision makers. The relative importance of pairwise comparisons are categorized from 1 to 9. Category (1) represents pairs of equal importance and (9) represents extreme inequality in importance (Saaty, 1980). For the inverse comparisons, a reciprocal value is assigned, that is, $a_{ij} = 1/a_{ji}$ where a_{ij} denotes the relative dominance of the i^{th} criterion compared to the j^{th} criterion. As a result of that step, for k number of decision makers, k number TFN's of $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ are obtained.

Step 2- Aggregation of group decisions: Decisions from K decisions makers are aggregated by geometric mean calculation of pairwise comparisons. as given in Equation (7) (Chang et al., 2009; Meixner, 2009; Özdemir, 2018).

$$l_{ij} = \min(l_{ijk}), m_{ij} = (\prod_k^K m_{ijk})^{1/K}, u_{ij} = \max(u_{ijk}) \quad (7)$$

However, min and max operations are not appropriate if individual decisions from group members have wide range of upper and lower values, in other words, if evaluations are inhomogeneous (Mikhailov, 2003; Meixner, 2009). This is the case for most applications including this study. Therefore, it is decided to use the geometric mean, also for l_{ij} and u_{ij} , as stated in Equation (8). Using geometric means for all, gives satisfying fuzzy group weightings (Meixner, 2009).

$$l_{ij} = (\prod_k^K l_{ijk})^{1/K}, m_{ij} = (\prod_k^K m_{ijk})^{1/K}, u_{ij} = (\prod_k^K u_{ijk})^{1/K} \quad (8)$$

Step 3- Generation of fuzzy pairwise comparison matrices: After aggregation of pairwise comparisons in step 2, fuzzy pairwise comparison matrices are formed. This is done to break the main problem into the sub-problems as suggested by AHP method (Ar et al., 2014).

Step 4- Calculation of local weights vectors: Based on the fuzzy pairwise comparison matrices, the fuzzy weights of each element of synthetic pairwise comparison matrices are obtained with the geometric mean method of Buckley (1985) (Cebeci, 2009; Meixner, 2009;

Chen & Chen, 2010). For n number of elements, the geometric mean of fuzzy comparison value of fuzzy element i to each element can be found with the Equation (9):

$$\tilde{r}_i = (\prod_1^n z_{ij})^{1/n}, \quad i=1,2,\dots,n \quad (9)$$

Then, the fuzzy weight of the i^{th} element indicated by a triangular fuzzy is obtained with the following Equation (10):

$$\begin{aligned} \tilde{w}_i &= \tilde{r}_i \otimes (\sum_1^n l_i, \sum_1^n m_i, \sum_1^n u_i)^{-1} \\ &= \tilde{r}_i \otimes \left(\frac{1}{\sum_1^n u_i}, \frac{1}{\sum_1^n m_i}, \frac{1}{\sum_1^n l_i} \right), \quad i=1,2,\dots,n \end{aligned} \quad (10)$$

The fuzzy weight vectors can be defuzzified. There are many methods in the literature for the defuzzification of the fuzzy numbers. One of the most used ones is Centre of Area method (Hsieh et al., 2004; Cebeci, 2009; Chan & Wang, 2009). It is described by the Equation (11) and is used for the defuzzification of weight vectors.

$$w_i = \frac{(m_i - l_i) + (u_i - l_i)}{3} \quad \text{or} \quad w_i = \frac{l_i + m_i + u_i}{3}, \quad i=1,2,\dots,n \quad (11)$$

Step 5- Construction of supermatrix: The general form of supermatrix is shown in Equation (12) (Liou et al., 2007; Chen & Chen, 2010). C_m shows the m^{th} cluster, e_{mn} shows the n^{th} element in the m^{th} cluster. W_{ij} is the principal eigenvector of the influence of the elements compared in the j^{th} cluster to the i^{th} cluster. If the j^{th} cluster has no influence on the i^{th} cluster, then $W_{ij}=0$.

$$W = \begin{matrix} & \begin{matrix} C_1 & C_2 & \dots & C_m \end{matrix} \\ \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_m \end{matrix} & \begin{bmatrix} \begin{matrix} e_{11} & \dots & e_{1n_1} & e_{21} & \dots & e_{2n_2} & \dots & e_{m1} & \dots & e_{mn_m} \end{matrix} \\ \begin{matrix} e_{11} \\ e_{12} \\ \vdots \\ e_{1n_1} \end{matrix} & W_{11} & W_{12} & \dots & W_{1m} \\ \begin{matrix} e_{21} \\ e_{22} \\ \vdots \\ e_{2n_2} \end{matrix} & W_{21} & W_{22} & \dots & W_{2m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \begin{matrix} e_{m1} \\ e_{m2} \\ \vdots \\ e_{mn_m} \end{matrix} & W_{m1} & W_{m2} & \dots & W_{mm} \end{bmatrix} \end{matrix} \quad (12)$$

Step 6- Calculation of weighted supermatrix: The calculated weight of each element in each cluster in step-4 is multiplied by related cluster weight and results are used for calculation of weighted supermatrix. Then, normalization of the resulting matrix is done by summing up the columns and dividing each element to the column sum.

Step 7- Calculation of limit supermatrix: Using the expression $\lim_{k \rightarrow \infty} W^k$, the powers of weighted supermatrix is taken and the limit supermatrix is calculated. The process of taking powers of supermatrix is continued to a large enough value, until the weights have been converged and remain stable. As a result of this process, the global weights of the sub criteria and alternatives are obtained.



4. APPLICATION of THE PROPOSED DECISION MAKING MODEL

In this part, an application of the decision making model is presented. Firstly, purpose of the research is described. Then, research questions are given and explained. This is followed by a detailed expression about the stages and phases of the research. Finally, the carried application process and steps are described in detail and results of the stages and phases of the appalication are presented.

4.1. Purpose

There are several studies for the drivers of OI and its types and the project structure for OI projects. These studies give useful insights and help in building an understanding of theoretical concepts and terminology of OI. Drivers of OI, OI typees and OI collaboration types have been studied mostly independently. A scale of criteria and an end-to-end model has not been developed and has not been studied. The end-to-end analysis and decision making model will help to minimize uncertainty in the evaluation of the potential OI projects by having impacts on various areas ranging from resource allocation to OI projects to the development of inter-institutional cooperation in innovation studies.

The aim of this study is to make an end-to-end analysis, from the selection of innovation type (closed vs. open) to the selection of collaboration type (science-based vs. market-based) and develop a decision making model by linking OI, OI types and collaboration types in three stages for determining best suitable structure of OI projects.

4.2. Research Questions

In this study the arguments are that; an organization is having an innovation project and wants to reach the desired outcomes. Firstly, organization has to make a decision whether to build a structure for this innovation project based OI or closed innovation approach. The process of this initial decision constitutes the first stage of the decision making. Criteria and drivers for making this decision will guide firm's decision makers to choose the best approach. Based on that, the aim for the first stage is determining the general innovation type for building the innovation structure, either with open or closed innovation approaches. The research question (*RQ1*) for this stage is:

*RQ1: What are the organizational, environmental or project related drivers (criteria) to determine the *innovation type* for suitable innovation project structure?*

If organization has decided to proceed with OI approach, then a decision process starts whether to build the structure with Inbound, Outbound or Coupled OI approaches. This process constitutes second stage of decision making. Criteria and drivers for making this decision will guide firm's decision makers to choose the best suited approach to their organizations.

Based on that the aim for the second stage is determination of OI type for building the OI structure either with Inbound, Outbound or Coupled OI approaches. The research question for this stage is:

*RQ2: What are the organizational, environmental or project related drivers (criteria) to determine the suitable *OI type* of an OI project structure?*

Third stage of the decision making is the process of choosing the best suitable collaboration type. Criteria and drivers for that the organization will choose the best suitable collaborators and build the suitable OI project structure accordingly; either with universities, research centers, competitors or customers etc. The research question for this stage is:

*RQ3: What are the organizational, environmental or project related drivers (criteria) to determine the suitable *collaboration type* of an OI project structure?*

A summary of the questions is given in Figure 4.1.

4.3. Research Methodology

As explained in detail in part 3.1 of the study and shown in Figure 3.1, the study is composed of three stages and each stage has three consecutive phases. Three phases are criteria determining, criteria relationships and criteria weighting and ranking the alternatives as shown in Figure 4.2. In phase 1, criteria are determined using extensive literature review and Delphi technique. In phase 2, the criteria relationships are determined by expert evaluation with a group of experts composed of three academicians. In phase 3 of each stage FANP method will be used to rank the criteria. After these three phases at each stage, there is decision process which is based on the ranking of the alternatives.

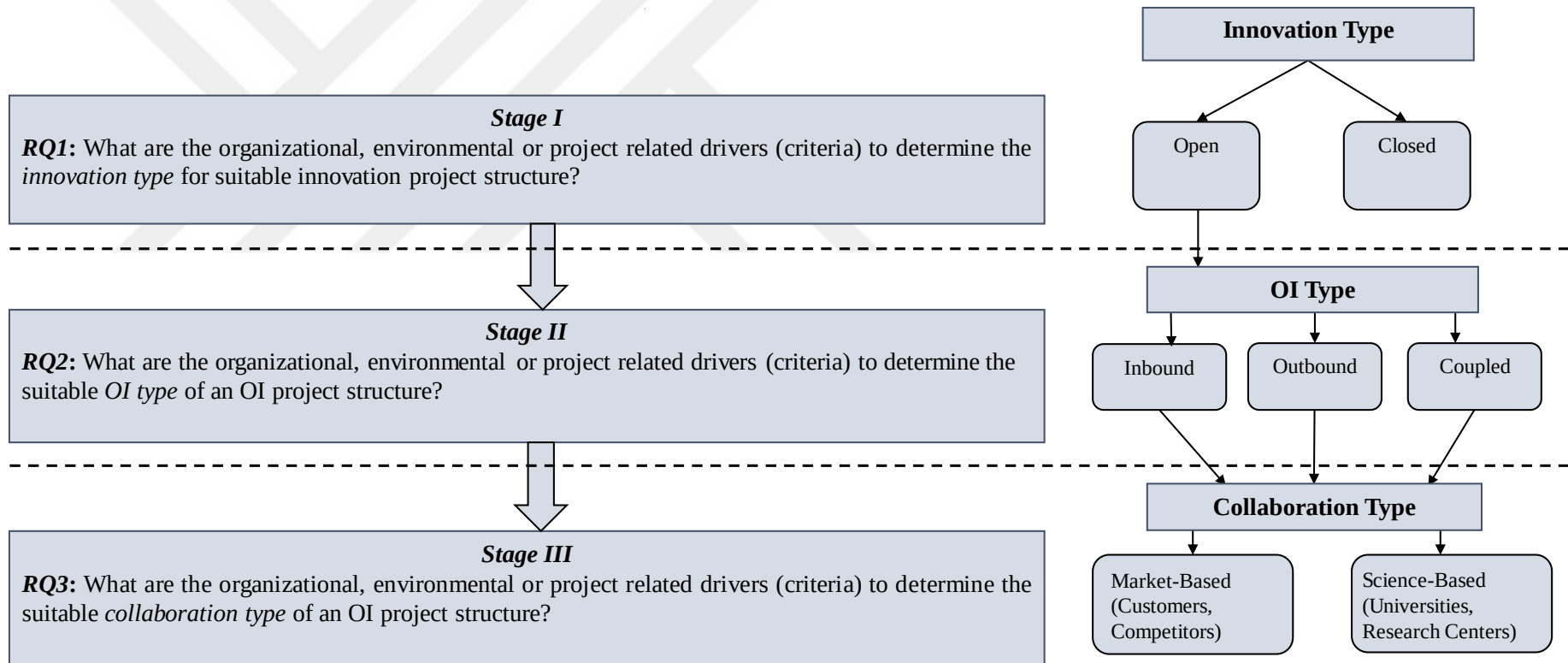


Figure 4.1. Research questions

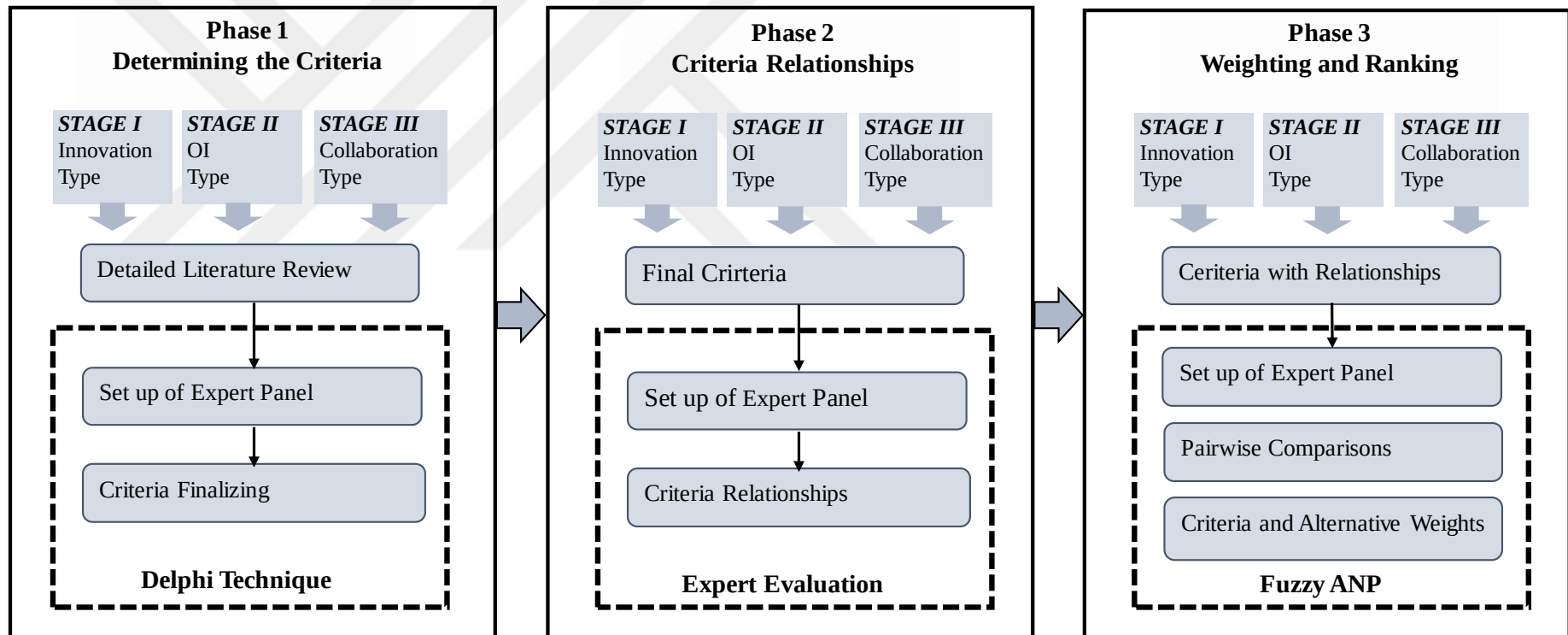


Figure 4.2. Phases of the each stage in the study

4.4. Limitations of the Research

The criteria determined as the drivers and antecedents of OI, OI types and collaboration types are initially extracted from the literature. This is done by extensive search of the literature as stated in part II of the study. One of the limitations can be the restriction the search to the selected sources and databases. With that restriction, this study may not have complete coverage of all articles and studies in the field of OI. Additional types of publications, such as conference articles, magazine and newspaper articles, policy papers, working papers and professional and expert reports, may be explored in future studies. Secondly, focus of search strings and content analysis was on the OI and its types. With that focus some important studies on OI may have been missed. In future studies, a broader range of keywords could be used for identifying suitable studies

Another limitation may be in the criteria harmonization process, as explained in detail in section 4.5.1.2. After the criteria determination from the literature, a total of 246 criteria were identified. The process of criteria harmonization and combination applied, explained in detail in section 4.5.1.2, may have caused the missing of important criteria which might have effect on the OI stages and decision making model proposed. Moreover, there may be criteria which is not stated in the searched literature, such as the ones dependent on the environment, national conditions and other factors not stated here. Such criteria may have impact on the stages of OI process.

4.5. The Phases of the Research

This decision making model application constitutes three consecutive phases for each stage as explained in Figure 3.1 and Figure 4.2. Each phase consists the steps for all three stages in parallel. Namely, in phase 1 criteria determining is made for all three stages. In phase 2, criteria relationships are determined for all three stages and finally in phase 3, criteria weightings and alternative rankings are done for all the three stages.

4.5.1. Phase 1: Determining the Criteria

The criteria for each stage have been determined in two steps. First step was extraction of criteria as a result of extensive literature review based on drivers of OI, OI types and collaboration types. This step is explained in detail in Part II of the thesis. Second step was

application Delphi technique as shown in Figure 4.2 to get expert opinion and finalize the list of criteria for each stage.

4.5.1.1. Literature Review

During the process of detailed literature review, stated in part 2 of this study, much focus was given to determine and extract the criteria that are drivers for OI, OI types and collaboration types. Based on the systematic literature review, detailed information about the related studies and the criteria for drivers of OI, OI types and collaboration types are summarized in the rest of this section.

The information about the studies which the main focus was innovation type and the drivers of OI is given below. Reviewed studies are summarized and main findings are presented.

Leon (2007) analyzed the cooperation models used highlighting the need to develop open cooperative technology transfer models. The result of the analysis proposed open collaboration when the innovation project requires multidisciplinary approach, innovation outcome (product) need fast time-to-market and entry barriers to innovation in related industry are low. Moreover, analysis proposed collaboration with university when technology needed for innovation project needs complementing with other technologies.

Lazzarotti & Manzini (2009) identified some organizational and managerial characteristics for the application of innovation mode. The result of the empirical study suggested that a company is proposed to go with OI mode if it has high organizational and managerial complexity, can afford high transaction costs, want to share risk and has high level of managerial competencies.

Flores et al. (2009) developed a metric to measure the results of collaborative research. The empirical study showed that majority of collaborative research projects with universities aims to create new technology, get intellectual capital and develop knowledge relationships. Additionally, majority of collaborative research projects with universities aims to develop a new product.

Greenwood (2010) studied conditions and factors of OI. In his study he developed the Innovative Capacity Index for effectiveness of OI based on the four items. These were social capital, network ties, boundary spanning and absorptive capacity. The result of the study showed that absorptive capacity is very important for knowledge transfer and to increase

innovative business firms must develop capacities that gives them opportunity to develop and keep absorptive capacity.

Hurmelinna-Laukkanen (2011) studied to clarify the role of knowledge protection related with collaborative innovation efforts. The results of the study suggested that there are positive relationship between protection subjects and innovation performance and knowledge sharing. Positive relationship between strong protection and appropriability mechanism and knowledge sharing shows that a strong appropriability process helps a firm to share knowledge both in terms of getting and transferring it out, namely both inbound and outbound OI approaches.

Abouzeedan et al. (2013) stated that the difficulties that SMEs encounter for innovation are shortage of resources, complexity of scientific field and issues in reaching up-to-date scientific knowledge. OI helps SMEs to manage these difficulties and access external knowledge and extend their technical capabilities.

Huang et al. (2013) performed a study with empirical analysis to investigate OI from the organizational change point of view. Results of the study showed that there is negative relationship between organizational inertia and OI. For successful OI adoption, firms should sense and adopt porous borders instead of solid borders to support and ease the flow of innovative inputs and OI. Mostly employees are behaving against such flows and processes and such behaviors are associated with inertia.

Felin & Zenger (2014) proposed a comparative framework for innovation management. The study argued that some types of innovation problems are best identified by innovation management methods: more complex problems require OI. Simple problems require closed innovation.

Pervan et al. (2015) examined some factors like government supports, financial resources, UICs and market dynamics for the support of innovation activities in SMEs. The result of the study highlighted that; there should be a link between innovation and the local economic development and innovation should be assisted by specific policies and programs. At the policymaker's level, the governments are required to support for institutional level settlement of cooperation by means of academic and industry forums and build systems to promote for research collaborations.

McCormack et al. (2015) made an empirical study to address the degree of OI applications in the clusters and the motives and challenges with respect to the adoption of OI. Results showed that the primary motive of OI in clusters was knowledge. Cost was also

was encountered with the same importance as compared to knowledge. I was also identified that capacity, control and market were with the equal importance levels.

Yawson (2017) examined the effect of internal innovation climate and strategic partnerships with suppliers on OI success in SME's. The study found a significant positive relationship between internal innovation climate and strategic partnership with suppliers in SMEs.

Carvalho & Sugano (2016) explored the relationship between OI and entrepreneurship and identified four dimension of entrepreneurship orientation: autonomy, risk taking, proactiveness and network. Their analysis with five case studies showed that: Autonomy has a positive effect on OI and is positively related to outbound OI; risk taking has a positive impact on OI; there is a positive and significant relationship between proactiveness and OI as well as inbound OI; network dimension has a positive effect on OI.

Popa et al. (2017) empirically assessed relationship between organizational antecedents and innovation climate, including the effect of these items on firm outcome in SMEs. The assessment showed a positive relationship between innovation climate and organizational aspects like commitment based HR applications, inter-departmental connectedness and decentralized decision making process. With regards to that positive relationship, innovation climate has positive effect on both inbound and outbound OI.

Pustovrh et al. (2017) analyzed the influence of two important OI applications, namely knowledge exchange and collaboration, on the commercialization capabilities of high-tech SMEs. The analysis showed that external factors like support by institutional environment and network with other firms and knowledge centers bring a positive influence on the innovativeness of high-tech SMEs. Moreover, internal factors like top management support and suitable leadership, project management and specific technology supporting policies will have a positive influence on the innovativeness of high-tech SMEs.

Casprini et al. (2017) examined the ways of OI strategy implementation of family firms. The focus was the way of family firm' handling of information flows. They developed capability concept named as fraternization, which means the firm's capability to develop stable and long term relations with internal staff and with outside parties. Their case study showed that fraternization helps the firm to deal with the challenges to knowledge gathering and transferring, which are important for the success of OI.

Wang et al. (2017) explored the relationship between various types of organizational slack on firms' open search processes, including the moderating role of absorptive capacity. Result of the study showed that for the firms with relatively high unabsorbed slack the degree

of openness for the search is expected to be more. Additionally, the degree of openness will be weakened by absorbed slack. High level of unabsorbed slack refers to the high amount of the readily available resources to allocate (Tyler & Caner, 2016).

Martinez-Conesa et al. (2017) assessed the impact of internal aspects on KM capability. The results of the study revealed that there is positive relationship between improvement of KM capability and firms' IT operations and CHR practices. IT tools support for faster and more efficient searches and make it easier to reach the knowledge. IT tools may help also for more efficient knowledge distribution and better cooperation between organizational members. Moreover, the existing knowledge assets of organizations can fastly turn into obsolete knowledge in highly dynamic environments. To overcome this situation and keep a stable competitive position in such environments, organizations implement OI applications by utilizing from knowledge and technologies of outside collaborators (Cheng & Shiu, 2015). The advantages of high level of KM capabilities are considered to be higher in dynamic environments (Lichtenthaler & Lichtenthaler, 2009). Thus, environmental dynamism and OI are positively related to each other (Martinez-Conesa et al., 2017).

Abdul Razak & Murray (2017) performed an empirical study to investigate if innovation strategies that are operationalized by OI, have positive relationships with commercialization in public universities. Results of the study showed that OI strategy has a positive and significant relationship with commercialization success, which means success in introducing innovation outcomes into the market for application and generating economic value.

Grimaldi et al. (2017) examined the role of intangible assets in OI applications through a systematic literature review. The analysis showed that the firms applying a relatively higher degree of openness, with higher level of social capital and networking and with higher level of commitment to innovation are having high potential and possibility to collaborate with research centers and universities. Innovation drivers are heavily dependent of the type of collaborator engaged in the joint efforts. Product knowledge about new market opportunities is a very high potential driver to setup partnership with customers, whereas knowledge on novel technological improvements has more potential to be encountered as a driver for the collaboration within the same industry. As facilitator of OI, network relationships provide the possibility of the external acquisition of beneficial knowledge and technologies, at the same time supporting for decreasing risks reducing costs.

Papa et al. (2018) studied the impact of knowledge acquisition on innovation outcome and the moderating role of two HR management applications, which are employee retention and HR management practices. The study found that HR management practices can improve a reliable and strong organizational climate and flexibility. Moreover, employee retention develops the effect of knowledge acquisition on innovation outcome since it increases commitment and trust among employees, supporting knowledge specialization and innovation culture.

Banai (2018) explored effective strategies that high-technology organizations use to develop a sustainable OI culture and highlighted primary drivers and motives for organizations to pursue OI. According to the study, the main motives for OI for organizations are to gain needed skills, technologies, assets and other resources from outside the organization, as well as to enhance the firm's capabilities while reducing the firm's cost and risk. Study also found that there is a significant link between organizational OI culture and an organization's innovation performance. The shortening of product life cycles, resource needs for innovation and desire to increase competitiveness are among the identified primary motivations for OI.

Subtil de Oliveira et al. (2018) identified 22 critical success factors for OI application at the organizational level by means of a comprehensive systematic literature review on OI. Study classified success factors into six categories, which are leadership, internal innovation capability, network and relationships, strategy, technology management and culture. They argued that addressed critical success factors can be applied by managers and decision makers as a guideline for examining a firm's readiness level for adopting OI process.

Bogers et al. (2018) theorized the impact of employee diversity on the openness to outside knowledge sources at the firm level, namely inbound OI. Results of the study showed a positive relationship between the degree to which employees have diverse educational backgrounds and the firm's use of external knowledge sources, namely firms' inbound OI.

Hewitt-Dundas & Roper (2018) examined levels of OI in micro-businesses and analyzed if market failures may be the reason for the failure of the implementation of OI. Empirical analysis showed that market failures are related to lack of awareness about OI and its potential benefits of OI, to lack of knowledge about possible collaborators and to lack of knowledge about the trustworthiness of partners.

Valente (2019) explored biopharmaceutical firms' innovation-related knowledge sourcing decisions and associated performance measurements. The results indicated the firm's core competencies and resources were key influencers on the selection of open versus

closed innovation strategies. The analysis also indicated that the internal and external operating environment factors such as national innovation systems related to pricing and collaborations, firm culture, cross-cultural communication and national culture heavily influenced open versus closed innovation decisions.

Sivam et al. (2019) analyzed and revealed the factors influencing the foundation of a suitable area for implementing OI. They tried to describe how a firm can create an influential area to acquire access to external knowledge. The study found that culture, leadership and strategy are the main motives for OI area. These motives are followed by firm resources which consist of human capital, organizational competencies, external relationships and organizational forms supporting to the innovation activities.

Hungund & Mani (2019) investigated firm level and external factors impacting application of innovation processes for SMEs. Result of the empirical analysis showed that the level of the application of OI processes for younger firms is higher as compared to the elder firms. In addition, the experience of decision makers and existence of rewarding mechanisms for suggesting new ideas have positive impacts on the implementation of OI. Moreover, firms having a culture of not penalizing the employees, if the suggested idea of the employee does not produce useful outcomes, are most likely to adopt OI.

The information about the studies which the main focus was OI types and the drivers for suitable OI approach is given below. Reviewed studies are summarized and main findings are presented.

Grönlund et al. (2010) explored the way that firms can utilize from new product development process by implementing OI, namely integrating the principles of OI with the Stage-Gate process. The alignment between the OI project and the existing business model and core capabilities is analyzed. Study found that full alignment leads to inbound OI and the situation of no alignment pushes firm to consider export options only, namely outbound OI. Partial may either lead to inbound OI or outbound OI depending the firm's decision and ability to redefine existing core capabilities and business model.

Spithoven et al. (2011) investigated how organizations in traditional industries deal with the lack of absorptive capacity needed to be effective in setting up of inbound OI. The study founded that absorptive capacity is taken through certain factors such as the ability to address and track the market for technology and to transform this technology. The results of empirical study demonstrated that the OI process helps organizations lacking absorptive capacity to look for alternative ways to involve in inbound OI.

Kutvonen (2011) examined the dimensions of outbound OI with a focus on addressing strategic aims for utilizing knowledge externally by reviewing literature and focusing on the empirical results of former researches. The study found that purpose of outbound OI are classified in the dimensions of reaching to new knowledge, multiplication of internal technologies, learning from knowledge flows, having control over the technological trajectories and environment.

Bucic & Ngo (2012) examined the degree to which inbound OI applications contribute to collaborative innovation. The results of their empirical study showed that collaborative creativity, learning and knowledge stock are important inputs for collaborative innovation, with the help of formal coordination processes and internal search methods, such as structural centralization, formality and absorptive capacity.

Sisodiya et al. (2013) identified key factors that enable inbound OI and increase its efficiency. The result of the study showed that high performance can be driven from OI, but firms must have the ability to enact it, specifically through their relational capability.

Hung & Chou (2013) explored effects of internal R&D and environmental dynamism on the relationship between inbound and outbound approaches of OI and firm outcome. The result of the study showed that inbound OI and outbound OI have positive effect on firm outcome under high internal R&D investment conditions and a dynamic market environment.

Burcharth et al. (2014) empirically assessed the theoretical arguments about the negative relationship between NIH and NSH syndromes application of inbound and outbound OI. Their study revealed that high negative attitude to external knowledge acquisition (i.e., NIH-syndrome) results in low level of inbound OI. Likewise, high level of negative attitude to external knowledge sharing (i.e., NSH syndrome) results in low level of outbound OI.

Cheng et al. (2016) showed that firms with high knowledge acquisition capabilities promotes inbound OI while high knowledge sharing capabilities promotes firms outbound OI.

Lee et al. (2016) studied the impact of the decision making setup on both inbound and outbound OI at the project level. The outcomes of the empirical study revealed that the decentralization of decision making supports both inbound and outbound OI. However, as the level of decentralization increases, the relationship becomes concave between inbound OI and convex between outbound OI. This indicates that as decentralization level increases,

the effect of the relationship between inbound OI and decentralization decreases, where the effect increases between outbound OI and decentralization.

Naqshbandi et al. (2016), examined the role of Organizational Citizenship Behaviors (OCB) in two types of OI, inbound and outbound. Result of the empirical study showed that, when taken as aggregate (OCB as a whole) OCBs have positive impact on both inbound and outbound OI. However, when looked at the isolated mode taking each dimension of OCB into consideration separately, OCBs still have positive impact on outbound OI while only one dimension, sportsmanship, has significant positive impact on inbound OI.

Greco et al. (2016) analyzed the relationship between OI strategies with innovation outcomes in European firms. The result of the study suggested that the relatively higher degree of the collaborations through different external channels (coupled OI) is curvilinearly related with innovation outcome. Firms may utilize and get benefit from OI process by collaborating with other organizations rather than only importing knowledge, competences and innovations and such collaborations favor the exchange of tacit and explicit knowledge. Moreover, coupled OI has a stronger potential than inbound OI to improve the development and commercialization of new products.

Naqshbandi & Kamel (2017) studied the relationship of highly integrative and hierarchy cultures with inbound and outbound OI. The empirical results showed that a highly integrative culture is positively related with both inbound and outbound OI, whereas a hierarchy organizational culture is negatively associated with both types of OI. Their study included investigation of the relationship between absorptive capacity and inbound and outbound OI. The result of empirical study showed that a firm's realized absorptive capacity is positively associated with both inbound and outbound OI.

Freel & Robson (2017) analyzed the relationship between OI processes and appropriation mechanisms of SMEs. The result of empirical study showed that SME's focusing on informal, strategic mechanisms of IP protection shows higher rates of both coupled and inbound OI. On the other hand, the application of formal protection processes has restricted relationship with the degree of openness of both inbound or coupled OI. Additionally, the empirical results showed that there is a negative relationship between increasing usage of both informal and formal appropriation mechanisms and the 'closedness' of innovation; meaning that OI is recommended in such cases.

Usman & Vanhaverbeke (2017) illustrated the ways that startups successfully setup and manage OI with large organizations. They highlighted the main difficulties and barriers that startups encounter during the adopting of OI practices. The analysis showed that start-

ups seek for inbound OI to save on R&D costs and have a quick entry to market. Moreover, they seek for outbound OI for commercialization and to reduce the need for funds for development or commercialization.

Burcharth et al. (2017) analyzed the impact of employee autonomy on both inbound and outbound OI. Employee autonomy is an organizational activity that formally provides employees with work autonomy, namely the autonomy to do innovation activities without the need for managerial approval. The result of the study showed that inbound and outbound OI are positively and significantly related to employee autonomy. The benefits of OI are acquired if firms apply some of the internal organizational practices that provide employees with time, freedom and independence to carry out their tasks.

Aquilani et al. (2017) analyzed the intermediaries which help to cope with the challenges to successfully implement OI practices. The study determined that for inbound OI process absorptive capacity is a crucial intermediary. For outbound OI process multiplicative capability, the ability of a firm to multiply and to transfer its knowledge externally to the firm's borders (Gassman & Enkel, 2004) is important intermediary. For coupled OI process relational capability, the capability of developing and keeping long-term relationships with partners, is argued to be important (Aquilani et al., 2017).

Greul et al. (2018) analyzed the nature and drivers of knowledge flows for start-up firms, including the interdependence of inbound and outbound processes. The result of the study showed that the more technical capabilities a startup firm has, the less inbound knowledge flows it will benefit. Moreover, the more proprietary IP a start-up firm has, the less inbound knowledge flows it will use.

Behnam et al. (2018) determined OI capabilities when innovations are aimed for sustainable development. They analyzed the capabilities to attract external actors in innovation process. The review of the literature on external exploration (inbound OI) showed that firms should have absorptive capacity, networking capability and competence mapping capability for external exploration (inbound OI). The review of the literature on the required capabilities revealed that, for outbound OI, firms should have connective capacity (Lichtenthaler & Lichtenthaler, 2009), alliance capability (Kale & Singh, 2007), relational capability (Capaldo, 2007) and desorbtive capacity (Lichtenthaler, 2007).

Russo-Spena & Di Paola (2019) explored the drivers of the internal sources of absorptive capacity. Their analysis revealed that a firm's human capital knowledge consistency, entrepreneurial knowledge relatedness and business knowledge diversity have influence on its inbound OI.

Greco et al. (2019) presented a new theoretical framework consisting of twelve propositions defining the main benefits and costs of inbound and outbound OI processes. Results showed that inbound OI brings shorter time-to-market and outbound OI extends the firm's target market. Moreover, both inbound and outbound OI increase the know how of the firm.

Naqshbandi et al. (2019) argued that empowering leaders create an organizational climate that motivates and engages followers to be involved in knowledge acquisition and sourcing. Leaders also can make knowledge sources reachable to their followers to promote free knowledge flows that supports knowledge sourcing and acquisition. The result of the empirical study showed that empowering leadership has positive relationship with both inbound and outbound OI.

The information about the studies which the main focus was collaboration types and the drivers for suitable collaboration types are given below. Reviewed studies are summarized and main findings are presented.

Faems et al. (2007) highlighted the importance of collaboration when firms need information exchange. Study states that collaborations can improve the exchange of tacit and explicit knowledge.

Mention (2011) analyzed the impact of different types of cooperation and utilization of knowledge sources on the degree of innovation novelty. The analysis in the study revealed that firms that gather knowledge from market sources (customers and suppliers) and firms engaged in science-based collaboration for product innovations are more likely to produce more novel innovation, whereas knowledge taken from competitors is possibly having a negative impact on the degree of novelty of innovation.

Aslesen & Freel (2012) examined the ways that industrial knowledge bases impact the recombination of knowledge by analyzing the different extents, forms and geography of inbound OI. According to the developed analytical framework, firms with the analytical knowledge base are significantly more likely to collaborate with universities and research institutions in their innovation related cooperative arrangements. Firms with synthetic and symbolic knowledge bases are more likely to cooperate with the actors along with the value chain, like customers, suppliers and competitors (Aslesen & Freel, 2012).

Theyel (2013) assessed the implementation of OI practices during different value chain activities and measured their impacts on product and process innovation. The empirical research in the study revealed that firms are more innovative when they involve in

technology development collaborations with their suppliers. Likewise, firms are more innovative when they engage in product development collaborations with their customers.

Ritala et al. (2013) sought to address firms' strategic orientations that determine the use of certain open knowledge search processes, namely partner search strategies for OI, in large R&D-intensive firms. They identified three firm-specific strategic orientations: Customer relationship orientation, entrepreneurial orientation and technology orientation. They analyzed the impact of these orientations on the open knowledge search strategies, namely search for OI partners. Customer relationship-oriented firms accommodate an organizational culture that emphasize and promote the value and priority of long-term customer relationships and are likely to implement a market-driven search strategy and collaborate with market-related partners such as customers, competitors, and alliance partners. Technology-oriented firms have the capability and desire to get important technological knowledge and use it in the development of new products. Such firms are likely to focus on science-driven external knowledge sources and having a tendency to collaborate with science-based partners such as public and private research institutes, universities and polytechnics. Entrepreneurial orientation implies the firm's strategic orientation that mainly consists the dimensions of innovativeness, proactiveness, and risk taking. Firms that are proactive in their strategic behaviors (i.e. entrepreneurially oriented) can collaborate with a broad types of collaborators including customers, competitors, consulting agencies, public and private research institutes, universities and polytechnics.

Du et al. (2014) examined the relationship between inbound OI and the financial outcome of R&D projects by focusing on science-based and market-based collaborations. Results of the study showed that market-based collaborations are positively correlated with project outcome if a formal project management process is used. Science-based collaborations are associated with higher project outcome for projects managed with less formal project management processes. Therefore, market-based partnerships are recommended for the organizations adopting high level of formal project management methodologies, whereas science-based partnerships are recommended for the firms adopting a low level of formal project management methodologies.

Jackson (2014) studied the density, the perceived benefits and risks and the key factors that motivate leaders to collaborate with their competitors in management consulting industry. The result of the study revealed that fear of missing out on current and future opportunities and the willingness to develop stronger relationships in both vertical and

horizontal networks are the main motivations for leaders who prefer to collaborate with competitors.

Draghici et al. (2015) proposed an interdisciplinary approach of the collaboration between universities and industry based on the studies conducted by consulting references. The aim of the study was to identify the role that university has in the knowledge society and discuss the elements that leads to the development of a new conceptual model for UIC with the inputs of experts and specialists from industry and academia. The study described UIC framework and motivation factors. The identified motivation factors for UIC are: industrial partner has no expertise in R&D, industrial partner has no resources for the R&D activities in the field, university IP right need, incomes increasing (UIC can facilitate OI process between partners), cost reduction and partners reputation.

Saebi & Foss (2015) examined the ways that firms need to align business models with different OI strategies. They argued in their study that firms are having more probability to seek for a market-based strategy in order to benefit from market-ready innovations, complementary resources or technological capabilities of external parties and thus to have shorter development time and shorter time to market. If the intended innovation project requires need for joint development of knowledge and innovation co-creation, a collaborative or a network-based innovation strategy should be pursued which requires collaboration with knowledge-intensive organizations like research centers and/or universities.

Lefebvre et al. (2015) examined the impact of different external sources of knowledge on product, process, market and organizational innovations in SMEs. The study found a positive relationship between product innovations and collaboration with customers. Likewise, they found a positive relationship between organizational innovations collaboration with competitors.

Guertler et al. (2016) developed a methodological approach for selecting OI partners by developing an integrated methodology in cooperation with three German small and SEMs. Their study pointed out suitable collaboration strategies and methods for OI-partners as well as the preceding ranking and selecting of OI-partners. Potential OI-partners are ranked according to different dimensions, such as strategic relevance, operative potential, structural and political influence and technical potential.

A thorough literature review conducted by Aloini et al. (2016) showed that the criteria discussed in the literature for partner selection on OI are focused on six factors. These are

technological focus, technological alignment, strategic alignment, relational alignment, financial focus and supplier's co-design efforts.

Lazzarotti et al. (2017) analyzed whether internal social capital mediates the relationship between OI applications and innovation ambidexterity. Results showed that the intensity of collaboration with scientific and business partners (partners in supply chain such as customers and suppliers), is positively related to the innovation ambidexterity. Moreover, the level of internal relational social capital mediates the impact of collaborations with both business partners and scientific partners on innovation ambidexterity.

In their study of systematic literature review in analyzing role of intangible assets in OI practices, Grimaldi et al. (2017) concluded that private research organizations, public research centers, and universities have more potential for collaborations with firms which apply more open approaches to innovation, have high levels of absorptive capacity, have greater social capital and networking capabilities and have deeper commitments to innovation. Such science-based parties are called specialist knowledge providers and by collaborating with such parties, firms try to complement their internal innovation activities and reach other external sources of knowledge (Tether & Tajar, 2008).

4.5.1.2. The Criteria

Selected 200 studies from the search results, stated in Part II of this study and in 1.5.1 section of this part, are analyzed in detail for criteria extraction. Extraction was based on the criteria which are drivers and determinants for firms to decide for innovation type (*Stage I*), selecting OI type (*Stage II*) and applying the best suitable collaboration type (*Stage III*). During the analysis of the studies for criteria extraction, each criterion is grouped according to the applicable stage. The applicability to the related stage was based on the related source study in which criterion was studied or defined. Moreover, the definition of each criterion was extracted from the related source study and from the literature, in case not defined in the source. The number of criteria that initially extracted was 246, covering all the stages. Some of the criteria was applicable to more than one stage. Among initial 246 criteria, 109 were applicable to *Stage I*, 83 to *Stage II* and 84 to *Stage III*.

To combine the similar criteria and eliminate the less related ones, a four steps criteria harmonization process was applied. In the first step, the aim was to eliminate the very less related criteria to the aim of study. With the analysis in first step, 5 criteria are extracted, resulting in 241 total criteria. In the second step, filtering process was done by the analysis

of each stage separately. The aim was to eliminate the duplicate and combine the similar criteria for each stage. After that step, *Stage I* resulted with 77, *Stage II* resulted with 73 and *Stage III* resulted with 75 criteria. To finalize the criteria with the best level of degree of relevancy and select the most appropriate ones, in third step all the criteria are re-analyzed one by one with the detailed re-analysis of the related source studies. After that process criteria that are less relevant are extracted. That resulted in 48 criteria for *Stage I*, 47 criteria for *Stage II* and 42 criteria for *Stage III*.

Finally, in fourth step, a detailed source study analysis for each criteria were carried by analyzing the definition and purpose of criteria usage in the source study. With that analysis it was identified that each criteria can be classified in common organizational, environmental and project related dimensions. For each criteria, the study resulted in classification according to the 12 organizational, environmental and project related dimensions, given in Table 4.1. Each criteria were grouped under best suited dimension. Dimensioning and classification process and re-analysis of the criteria in the source studies provided another opportunity for a further harmonization and combination process for similar and less relevant criteria. With that combination and harmonization process *Stage I* finalized with 29, *Stage II* with 21 and *Stage III* with 26 criteria.

Table 4.1. Criteria dimensions

No	Criteria Dimensions
1	Firm Characteristics
2	Industry Characteristics
3	Innovation Approach
4	KM Capability
5	Knowledge Management
6	Organizational Culture
7	Project Characteristics
8	Commercialization
9	IP Rights Management
10	Network Management
11	HR Management
12	Resource Capability

4.5.1.2.1. Stage I: The Criteria for Innovation Type

In *Stage I*, decision will be made whether the project will be structured based on open or closed innovation approaches. The main focus is on the firm resources, firm characteristics, firm's culture, firm's organizational structure, firm capabilities, innovation

approach and industry characteristics. The criteria classification and grouping are done accordingly. Criteria for that stage is given in Table 4.2.

4.5.1.2.2. Stage II: The Criteria for OI Type

In *Stage II* the main target is to decide the suitable OI type. It will be decided which OI type, namely inbound, outbound or coupled, to implement. Main focus is on KM, innovation approach, firm's network management, organizational culture, project characteristics and HR management and dimensioning is done based on that. Criteria for that stage is given in Table 4.3.

4.5.1.2.3. Stage III: The Criteria for Collaboration Type

In *Stage III*, suitable collaboration type will be determined. Firm needs to decide whether to proceed with science-based collaboration or market-based collaboration. Main focus will be on firm's network management, IP rights management, commercialization, firm's innovation approach and KM. The criteria in each stage is grouped under the related dimensions accordingly. The criteria for that stage is given in Table 4.4.

Table 4.2. The initial criteria list for *Stage I*

Criteria Dimension	Criteria Name	Study
Firm Characteristics	Firm Age	Hungund & Mani (2019)
	Firm Competencies	Valente (2019), Sivam et al. (2019)
	Firm's Business Diversity	Russo-Spena & Di Paola (2019)
	ICT Infrastructure and Usage	Martinez-Conesa et al. (2017)
	Project Management Structure	Pustovrh et al. (2017)
	Relationship Development	Kale & Singh (2007), Bucic & Ngo (2012), Kazadi et al. (2016), Casprini et al. (2017), Grimaldi et al. (2017), Behnam et al. (2018)
	Capability	
Industry Characteristics	Collaboration Policies	Pervan et al. (2015), Pustovrh et al. (2017), Valente (2019)
	Competitiveness	Banai (2018), Hungund & Mani (2019)
	Market and Environmental Dynamism	Hung & Chou (2013), Martinez-Conesa et al. (2017)
	Industry Characteristics (low entry barriers)	Leon (2007), Usman & Vanhaverbeke (2016), Banai (2018), Greco et al. (2019)
	Knowledge on New Market Opportunities	Grimaldi et al. (2017)
Innovation Approach	Innovation Ambidexterity	Lazzarotti et al. (2017)
	Innovation Strategy	Ritala et al. (2013), Subtil de Oliveira et al. (2018), Sivam et al. (2019)
	Internal Innovation Capability	Subtil de Oliveira et al. (2018)
	Open Innovation Awareness	Hewitt-Dundas & Roper (2018)
KM Capability	Absorptive Capacity	Greenwood (2010)
	Inter-Departmental Connectedness	Popa et al. (2017)
	Knowledge Acquisition	Felin & Zenger (2014), McCormack et al. (2015), Banai (2018)
HR Management	Employee Retention	Papa et al. (2018)
	Firm's Human Capital	Pustovrh et al. (2017), Sivam et al. (2019)
	HR Management Policies and Practices	Popa et al. (2017), Martinez-Conesa et al. (2017), Papa et al. (2018)
Organizational Culture	De-centralized Decision Making	Popa et al. (2017)
	Organizational Inertia	Huang et al. (2013)
	Organizational Structure	Sivam et al. (2019)
	Top Management Support	Pustovrh et al. (2017), Subtil de Oliveira et al. (2018), Sivam et al. (2019)
Resource Capability	Cost Reduction/Sharing	McCormack et al. (2015), Usman & Vanhaverbeke (2016), Banai et al. (2018)
	Financial Limitations	Valente (2019)
	Internal R&D as an Enabler	Aquilani et al. (2017)
	Firm Resources	Abouzeedan et al. (2013), Sisodiya et al. (2013), Wang et al. (2017), Valente (2019), Banai (2018)

Table 4.3. The initial criteria list for Stage II

Criteria Dimension	Criteria Name	Study
HR Management	Diverse Educational Backgrounds of Employees	Bogers et al. (2018)
	Employee Autonomy	Burcharth et al. (2017)
	Empowering Leadership	Naqshbandi et al. (2019)
Knowledge Management	Absorptive Capacity	Spithoven et al. (2011), Naqshbandi & Kamel (2017), Aquilani et al. (2017), Behnam et al. (2018)
	Access to Scientific Knowledge	Abouzeedan et al. (2013)
	Desorptive Capability	Lichtenthaler (2007), Behnam et al. (2018)
	Knowledge Multiplication Capability	Aquilani et al. (2017)
	Knowledge Acquisition	Flores et al.(2009), Bucic & Ngo (2012), Cheng et al. (2016), Banai (2018), Greco et al. (2019)
	Knowledge Exchange Knowledge Sharing	Greco et al. (2016) Cheng et al. (2016)
Organizational Culture	De-centralized Decision Making	Lee et al. (2016), Popa et al. (2017)
	Firm's Entrepreneurship Orientation	Carvalho & Sugano (2016)
	NIH (Not Invented Here) Syndrome	Burcharth et al. (2014)
	NSH (Not Sold Here) Syndrome	Burcharth et al. (2014)
	OCB	Naqshbandi et al. (2016)
	Organizational Inertia	Huang et al. (2013)
Project Characteristics	Access to New Markets/New Market Opportunities	Kutvonen (2011), Grimaldi et al. (2017), Greco et al. (2019)
	Firm's Business Model Alignment	Grönlund et al. (2010)
	Novelty of Innovation Technology	Mention (2011) Leon (2007)
	Complementarity	
	Type of Innovation- (Technology, Product, Process or Organizational)	Theyel (2013), Lefebvre et al. (2015), Paula et al. (2018)

Table 4.4. The initial criteria list for *Stage III*

Criteria Dimension	Criteria Name	Study
Commercialization	Commercialization Capabilities and Success	Lazzarotti et al. (2009), Kutvonen (2011), Usman & Vanhaverbeke (2016), Abdul Razak & Murray (2017), Valente (2019)
	Development and Commercialization of Radically New Product	Greco et al. (2016)
	Financial Performance-Income Increase	Draghici et al. (2015), Greco et al. (2019), Sivam et al. (2019)
	Reduced Development and Time to Market	Leon (2007), McCormack et al. (2015), Usman & Vanhaverbeke (2016), Banai (2018), Greco et al. (2019)
Innovation Approach	Firm's Strategic Orientation-Entrepreneurial	Ritala et al. (2013)
	Firm's Strategic Orientation-Technology and R&D Emphasis	Ritala et al. (2013)
	High Commitment to Innovation	Grimaldi et al. (2017)
	Innovation Ambidexterity	Lazzarotti et al. (2017)
	Strategy Relevance and Partnership	Guertler et al. (2016), Aloini et al. (2016), Yawson (2017)
IP Rights Management	Access to New Knowledge Assets	Kutvonen (2011)
	Amount of Proprietary IP's Control Over the Market and Technology	Greul et al. (2018) Kutvonen (2011)
	Intellectual Capital	Flores et al. (2009), Cheng et al. (2016)
	Firm's IP Rights Protection	Draghici et al. (2015), Greco et al. (2019), Sivam et al. (2019)
	Processes on Innovation Results	Hurmelinna-Laukkanen (2011), Freel & Robson (2017), Sivam et al. (2019).
Knowledge Management	Absorptive Capacity	Grimaldi et al. (2017)
	Access to Scientific Knowledge	Abouzeedan et al.(2013), Lefebvre et al. (2015)
	Firm's Knowledge Base Capital and Type	Flores et al. (2009), Bucic & Ngo (2012), Aslesen & Freel (2012)
	High Innovation Complexity (Multidisciplinary Requirement)	Abouzeedan et al. (2013), Draghici et al. (2015)
	Knowledge Co-Creation Capability	Saebi & Foss (2015)
Network Management	Fraternization	Kale & Singh (2007), Behnam et al. (2018), Casprini et al. (2017)
	Horizontal and Vertical Network Relationships	Jackson (2014)
	Network Building	Kazadi et al. (2016), Behnam et al. (2018), Grimaldi et al. (2017)
	Partner's Information	Hewitt-Dundas & Roper (2018)
	Relationship Building and Management	Capaldo (2007), Sisodiya et al. (2013), Carvalho & Sugano (2016), Pustovrh et al. (2017), Behnam et al. (2018), Subtil de Oliveira et al. (2018), Sivam et al. (2019)
Organizational Culture	Firm's Strategic Orientation-Customer Relationship	Ritala et al. (2013)

4.5.1.3. The Criteria Finalization with Delphi Technique

After the criteria extraction from extensive literature review, Delphi method is initiated to take the opinion of experts and finalize the criteria. Process explained in detail in section 3.3.1 of this study is applied.

4.5.1.3.1. Expert Panel

For Delphi process, an expert group sample of 8 respondents was setup. Group consisted of 6 experts from academia, 1 expert from private sector and 1 expert from state agency (IT and Telecommunication Authority). The average work experience of the respondents were more than 18 years. Academics in the sample were active researchers in innovation and OI and were mostly university professors. Practitioners were in consulting and senior project management positions and involved in the management of high technology projects. Table 4.5 presents respondent information and profiles.

Table 4.5. Expert group information for Delphi process

Number	Academic/ Practitioner	Position	Organization/ Department	Year of Work Experience/Research
1	Academic	Professor	Business School	20
2	Academic	Professor	Business School	25
3	Academic	Professor	Business School	20
4	Academic	Associate Professor	Business School	15
5	Academic	Associate Professor	Business School	20
6	Academic and Practitioner	Professor	Business School	18
7	Researcher and Practitioner	IT Expert	IT Authority	10
8	Researcher and Practitioner	Project Manager	IT Equipment Supplier	20

4.5.1.3.2. Delphi Analysis

A three round Delphi process was applied as described in in Part 3.3.1. Questionnaires have been prepared and distributed to experts in an online platform, mainly due to the difficulties in bringing up the expert groups together and also to avoid the group members affecting each other. The experts are requested to rate the importance level of each criteria determined from the literature for all stages on a 1-7-point Likert scale. The median, first quartile, third quartile and range statistics were calculated for the answers given in the first round. Then, the questionnaire to be used in the second round was prepared. In the second round the questionnaires were prepared specific to each specialist, since the surveys included

the expert's answer to the question in the previous round. Sample questions of the first and second round surveys are presented in appendix 1 and appendix 2, respectively. In the third round, the second round of questionnaires were sent back to the same experts by adding median, first quartile, third quartile and range statistics of the answers in the second round. As in the second round, in the third round also the questionnaires were prepared for each specialist separately, since the surveys included the expert's answer to the question in the previous round. With the third round and with the statistical information of the second round of survey, experts were informed about the general tendency of opinion and are given the opportunity to re-evaluate their answers. Common points were tried to be found between the different opinions. The criteria determining was completed by analyzing the results of the third round of surveys.

4.5.1.3.3. Delphi Results

With the application of Delphi technique, the total of 76 criteria obtained from literature are evaluated and revised by a group experts. By three round Delphi technique and the distribution of the statistical data related to the group decision for the second and third rounds, the convergence of different opinions about each criteria are obtained by the revision of the answers at these rounds. The interquartile range, R value, which is the difference between the first and third quartiles, is the main indicator of consensus. Low value shows the high level of consensus, whereas high R value shows low level of consensus. The statistics about R values are given in Table 4.6. From the data provided in the table, it can be seen that second-round answers consist more level of consensus than first round answers. Likewise, third round answers contain more level of consensus than first and second round answers.

Table 4.6. The count of Interquartile range values

Round	0	0.25	0.5	0.75	1	1.25	1.5	2	2.25	2.5	2.75
Round 1	4	6	7	0	20	20	8	4	5	1	1
Round 2	12	17	4	1	26	12	1	2	1	0	0
Round 3	14	30	4	0	20	5	1	2	0	0	0

Another important statistic about Delphi analysis is the median value. Median (Md.) is the middle number in a list of number and it is the point where 50% of the answers located

to right and 50% located to left of it. It is also a measure of group consensus for each criterion. The statistics about Md values given in Table 4.7 show that second round answers consist more level of consensus than first round answers. Likewise, third round answers contain more level of consensus than second round answers.

Table 4.7. The count of Median values

Round	4	4,5	5	5,5	6	6,5	7
Round 1	2	4	12	11	40	4	3
Round 2	1	5	17	8	39	4	2
Round 3	2	3	17	7	44	1	2

The answers of Delphi third round and the analysis results for each stage are shown in Appendix 3, Table 7.1, Table 7.2 and Table 7.3. In the literature there are studies suggesting the consensus level based on the median and interquartile range values. Green (1981) suggests that at least 70% of Delphi subjects need to rate three or higher on a four-point Likert scale. Hsu & Stanford (2007) suggest that the median values have to be at 3,25 or higher (Hsu & Stanford, 2007). Norizan (2003) used three formulas for describing the level of importance and level of consensus. Ab Latif et al. (2017) used this formula and method in their study. According to the developed formula for a five-point Likert scale, Median value greater or equal to 4 and interquartile range value less than or equal to 1 represent a high level of both consensus and importance. For the same Likert scale (1-5), Median values equal to or less than 3.5 and the interquartile range values between 1 and 2 represent moderate level of consensus and low level of importance. Interquartile range values greater than or equal to 2 represent either very low or no consensus (Norizan, 2003; Ab Latif et al., 2017). Özdemir (2018) eliminated the criteria for social innovation with median values less than 6 and interquartile range values greater 2. Since in this study 1-7 Likert scale is used, a mapping process from 1-4 and 1-5 Likert scales to 1-7 Likert scale has been done to make a comparison between the suggestions made by Hsu & Stanford (2007), Norizan (2003) and Ab Latif et al. (2017). Accordingly, mapping between median and interquartile range values of 1-4 and 1-5 Likert scales with those of 1-7 Likert scale was done. Upon the result of the mapping process and the suggestions, median values greater or equal to 6 and interquartile range values less than 1.5 gives both high level of consensus and high level of importance. This has been applied to the Delphi round 3 analysis results and criteria which does not meet this consensus and importance requirements are extracted. With that elimination and extraction process criteria finalization has been completed. Final

number of criteria for *Stage I*, *Stage II* and *Stage III* are reduced to 13, 11 and 20 respectively, with a total of 44 criteria for all stages. For each stage final list of criteria and numbering for each criteria are shown in Table 4.8, Table 4.9 and Table 4.10 respectively.

4.5.1.4. Results of Phase 1

As a result of Delphi technique application in previous part, the final list of criteria and criteria dimensions for each stage is formed. Numbering and identification with letters for the criteria dimensions and criteria are done with same lettering order for each stage. Same dimension and criteria can be seen with different letters and id's at different stages. This identification has not caused any complexity, since all the processes and evaluations for each stage are independent from each other. In the eventual steps, the comments and conclusions will be done with criteria names. In some stages same criteria are grouped under different dimension. This is the case for the “Absorptive Capacity” and “Access to Scientific Knowledge” criteria. In *Stage I* these criteria are evaluated in terms of “KM Capability” while in *Stage II* they are evaluated in terms of “KM”. After criteria finalization as a result of Delphi process the criteria under the dimensions of “HR Management” and “Resource Capability” dimensions are either eliminated or extracted. Therefore, these two dimensions will not be taken into calculations in the further steps of this study; namely in criteria relationship determination and in ANP process.

Table 4.8. Final criteria list and dimensions for *Stage I*

<i>Dimension</i>	<i>Criteria</i>	
	<i>ID</i>	<i>Name</i>
A-Firm Characteristics	A ₁	Firm Competencies
	A ₂	Firm's Business Diversity
	A ₃	ICT Infrastructure and Usage
	A ₄	Project Management Structure
	A ₅	Relationship Development Capability
B- Industry Characteristics	B ₁	Collaboration Policies
	B ₂	Competitiveness
	B ₃	Knowledge on New Market Opportunities
C- Innovation Approach	C ₁	Innovation Strategy
	C ₂	Internal Innovation Capability
	C ₃	Open Innovation Awareness
D- KM Capability	D ₁	Absorptive Capacity
	D ₂	Knowledge Acquisition

Table 4.9. Final criteria list and dimensions for *Stage II*

<i>Dimension</i>	<i>Criteria</i>	
	<i>ID</i>	<i>Name</i>
A- Knowledge Management	A ₁	Absorptive Capacity
	A ₂	Access to Scientific Knowledge
	A ₃	Knowledge Multiplication Capability
	A ₄	Knowledge Acquisition
	A ₅	Knowledge Exchange
	A ₆	Knowledge Sharing
B- Organizational Culture	B ₁	Firm's Entrepreneurship Orientation
	B ₂	NIH (Not Invented Here) Syndrome
C- Project Characteristics	C ₁	Access to New Markets/New Market Opportunities
	C ₂	Firm's Business Model Alignment
	C ₃	Type of Innovation-(Technology, Product, Process or Organizational)

Table 4.10. Final criteria list and dimensions for *Stage III*

<i>Dimension</i>	<i>Criteria</i>	
	<i>ID</i>	<i>Name</i>
A-Commercialization	A ₁	Commercialization Capabilities and Success
	A ₂	Development and Commercialization of Radically New Product
	A ₃	Reduced Development and Time to Market
B- Innovation Approach	B ₁	Firm's Strategic Orientation-Entrepreneurial
	B ₂	Firm's Strategic Orientation-Technology and R&D Emphasis
	B ₃	Strategy Relevance and Partnership
C- IP Rights Management	C ₁	Access to New Knowledge Assets
	C ₂	Control Over the Market and Technology
	C ₃	Intellectual Capital
	C ₄	Firm's IP Rights Protection
	C ₅	Processes on Innovation Results
D- Knowledge Management	D ₁	Absorptive Capacity
	D ₂	Access to Scientific Knowledge
	D ₃	Firm's Knowledge Base Capital and Type
	D ₄	High Innovation Complexity (Multidisciplinary Requirement)
	D ₅	Knowledge Co-Creation Capability
E- Network Management	E ₁	Horizontal and Vertical Network Relationships
	E ₂	Network Building
	E ₃	Partner's Information
	E ₄	Relationship Building and Management

4.5.2. Phase 2: Criteria Relationships

The criteria relationships are determined by expert evaluation. The expert group consisted of the panelists who had expertise on innovation and OI research field. More detail on the group the process of the evaluation for the relationship determining is given in the following section.

To evaluate and determine the pairwise relationship of criteria in each stage, an expert group has been setup. Group has been formed with three experts from academia, each of them having experience on innovation studies and highly involved in OI research. The average work experience of the respondents were more than 20 years. All experts were active researchers in OI and application of MCDM techniques and were university professors. Table 4.11 presents expert group information and profiles.

Table 4.11. Expert group information for criteria relationship

Number	Academic/ Practitioner	Position	Organization /Department	Year of Work Experience/Research
1	Academic	Professor	Business School	20
2	Academic	Associate Professor	Business School	15
3	Academic and Practitioner	Professor	Business School	18

The relationship determination has been done in two rounds. In the first round, the criteria are sent to the experts separately and experts are asked to answer the relationships. The answers are collected and consolidated. Then, a group meeting has been conducted to evaluate the consolidated answers and discuss for a common agreement. As a result of the first round, the relationships are taken for the criteria for which all the experts had consensus. The relationships that are found only by one expert (i.e., criteria for which other two experts did not find any relationship) are extracted from the whole evaluation.

The relationships that only two experts had consensus on, are decided to be evaluated by the expert group with a second round. The relationship matrix that only 2 experts had consensus in the first round, is resent to the group for a second evaluation. In the second round, two experts have replied the evaluation. Third expert has not changed his opinion of first round. As a result of that, the relationships in the second round are taken for the criteria which two experts had the consensus on.

With the combination of the results in first and second rounds, the direct relationship matrix is generated.

The process of expert evaluation in two rounds has resulted in the direct relationship matrices for each stage. Direct relationship matrices for each stage are shown in Appendix 4, Table 7.4, Table 7.5 and Table 7.6 respectively.

4.5.3. Phase 3: Weighting and Ranking

Determining the weight of the criteria and alternatives for each stage in the evaluation of structuring setup of OI projects constitutes the main purpose of the weighting process. This process consists of three steps (Figure 4.2): setup of expert panels, creation of paired comparisons, and calculation of criteria weights. Detailed information regarding this process is presented in this part of the study.

4.5.3.1. Expert Panel

Experts in innovation studies and MCDM techniques were invited to participate in this study for answering the questionnaires about pairwise comparisons. For that, an expert group sample of 5 respondents was setup. Sample group consisted of 4 experts from academy and 1 expert from private sector. The average work experience of the respondents were more than 18 years. Academics in the sample were active researchers in innovation, OI and application of MCDM techniques and all were university professors. Practitioners were in consulting and senior project management positions and involved in the management of high technology projects. Table 4.12 presents expert group information and profiles.

Table 4.12. Expert panel information for pairwise comparisons

Number	Academic/ Practitioner	Position	Organization/ Department	Year of Work Experince/Research
1	Academic	Professor	Business School	20
2	Academic	Associate Professor	Business School	15
3	Academic	Associate Professor	Business School	20
4	Academic and Practitioner	Professor	Business School	18
5	Researcher and Practitioner	Project Manager	IT Equipment Supplier	20

4.5.3.2. Pairwise Comparisons

In this step, the importance of the criteria and alternatives were determined by performing pairwise comparisons. In line with the relationships and interactions determined

in the previous step, separate questionnaires for each stage have been prepared and sent to experts. To quantify the preferences of decision makers, scale of 1–9 is used as explained in Section 3.3.2. Questions for paired comparisons were prepared, considering the determined relationships. Questionnaire for each stage consisted three parts. First part is the pairwise comparisons with respect to criteria, second part is the comparisons of alternatives with respect to criteria and third part is the comparisons of criteria dimensions. Sample pairwise comparison questions for each stage are given in Appendix 5.

4.5.3.3. The Calculation of The Criteria and Alternatives Weights

Pairwise comparison data from the answers of questionnaires from experts was analyzed in accordance with the FANP method steps explained in Section 3.3.2 to determine the weights of criteria and alternatives. For the FANP process, to determine the weight of the criteria, relationships between criteria were taken as a basis in pairwise criteria comparisons. During the analysis, fuzzy linguistic terms and corresponding TFNs given in Table 3.1 are used. As a result of this analysis, the global weights of the sub criteria and the weights of alternatives were obtained. Analysis at the weighing stage were carried out using the tables and macros written in the excel program.

4.5.3.4. Results of Phase 3

The evaluations of 5 experts on pairwise comparisons were aggregated using equation (8) and then fuzzy pairwise comparison matrices were created. For the calculation of the local weights of criteria, weights of alternatives and dimensions, the geometric mean method of Buckley (1985) has been used, using the equations (9) and (10). The local weight of each criterion is multiplied by weight of the related criteria dimension to obtain global weights for the related criterion. This process is repeated for each criterion and for each stage. Using the calculated global weights of criteria and alternatives, the weighted supermatrix has been constructed. The process of weight calculation and supermatrix formation is repeated for each stage separately. Weighted supermatrices for *Stage I*, *Stage II* and *Stage III* are given in Appendix 6, Table 7.7, Table 7.8 and Table 7.9 respectively. After normalization of the resulting weighted supermatrices are done, limit supermatrices for each stage are calculated by taking the powers of supermatrices. The convergence and stability of limit matrix entries were achieved by taking until 37th power of matrix for *Stage I*, 35th power for *Stage II* and

38th power for *Stage III*. Such large powers for matrices are calculated by writing a special function in excel program. The limit supermatrices for each stage are shown in Appendix 6, Table 7.10, Table 7.11 and Table 7.12 for each stage. The column entries of limit supermatrix are the same and these values give the weights of the related column head, namely criteria or alternatives.

The weights of criteria and alternatives are given in the Table 4.13 for *Stage I*. According to the criteria weights, the two most important criteria for *Stage I* are “C₃-OI Awareness” and “C₁-Innovation Strategy”. However, weights of both criteria are close to each other, one with 13.9% share and another with 13% share. The level of importance between criteria are presented in Figure 4.3. As seen on the figure also, the distance between the third most important criteria “C₂-Internal Innovation Capability” is high and between two most important criteria is relatively high. Thus, the first two most important criteria have much higher importance in terms of selecting innovation type. The less important criterion is “A₄-Project Management Structure”, with a share of 5.5% among all criteria. However, as seen in the Figure 4.3, the importance level of A₂, D₁, A₁, B₁, B₃, B₂, A₃, D₂, A₄ are close to each other. In terms of alternatives, OI is preferred with a much higher priority, with 80% share. These results show that; the first four criteria are determinant in terms of selection OI approach for innovation setup.

For *Stage II*, the weights of criteria and alternatives are given in the Table 4.14. “A₄-Knowledge Acquisition” and “C₁- Access to New Markets/New Market Opportunities” are two most important criteria. The weights of these criteria are close to each other, one with 12% and another with 11.6% share. The level of importance between criteria are presented in Figure 4.4. The importance level of the criteria A₁, A₅, C₃, A₆, A₂, C₂ and A₃ are close to each other. The less important two criteria are “B₁- Firm's Entrepreneurship Orientation” and “NIH (Not Invented Here) Syndrome” with an equal share of 6% among all criteria. In terms of alternatives in *Stage II*, the most priority one is coupled OI, with 54% among three. The priorities for other 2 alternatives are close to each other with 26% for inbound OI and 20% outbound OI. Outbound OI is the less preferred OI type. These results show that, the first two criteria are determinant in terms of selection coupled OI approach for innovation setup.

The weights of criteria and alternatives for *Stage III* are given in the Table 4.15. The most preferred criterion is “E₂- Network Building” with a weight share of 6%. The criteria weights and priorities for the rest of the criteria are close to each other. The level of importance between criteria are presented in Figure 4.5. The less important criterion is “C₂-

Firm's Business Model Alignment” with the 4.1% weight share. The difference between the most important and the less important criteria is only 1,9%. In terms of alternatives also, the difference is not much. Even though Science-Based collaboration is mostly chosen with a 52% weight share, Market-Based collaboration wight share is close to that, with a value 48% weight share.



Table 4.13. Weight and priorities for *Stage I*

Criteria/ Alternative	Weight	Priority (%)
C ₃	0,0854	13.9
C ₁	0,0795	13.0
C ₂	0,0556	9.1
A ₅	0,0516	8.4
A ₂	0,0426	6.9
D ₁	0,0411	6.7
A ₁	0,0406	6.6
B ₁	0,0403	6.6
B ₃	0,0367	6.0
B ₂	0,0358	5.8
A ₃	0,0355	5.8
D ₂	0,0350	5.7
A ₄	0,0339	5.5
Open	0,3069	80
Closed	0,0789	20

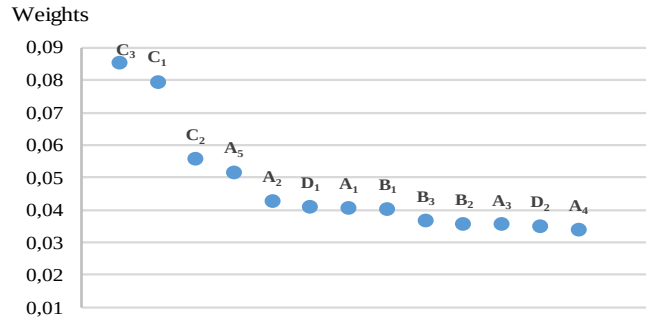


Figure 4.3. The level of the criteria weights for *Stage I*

Table 4.14. Weight and priorities for *Stage II*

Criteria/ Alternative	Weight	Priority (%)
A ₄	0,0726	12.0
C ₁	0,0698	11.6
A ₁	0,0621	10.3
A ₅	0,0585	9.7
C ₃	0,0568	9.4
A ₆	0,0551	9.1
A ₂	0,0526	8.7
C ₂	0,0519	8.6
A ₃	0,0513	8.5
B ₂	0,0361	6.0
B ₁	0,0360	6.0
Coupled	0,2128	54
Inbound	0,1042	26
Outbound	0,0797	20

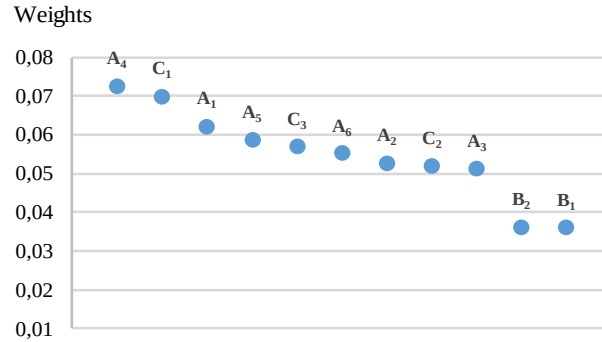


Figure 4.4. The level of the criteria weights for *Stage II*

Table 4.15. Weight and priorities for *Stage III*

Criteria/ Alternative	Weight	Priority (%)
E ₂	0,0347	6.0
A ₂	0,0328	5.7
E ₁	0,0325	5.6
E ₄	0,0319	5.5
A ₃	0,0318	5.5
C ₄	0,0315	5.4
A ₁	0,0312	5.4
D ₅	0,0299	5.2
D ₃	0,0298	5.1
E ₃	0,0292	5.0
B ₂	0,0290	5.0
C ₁	0,0289	5.0
B ₃	0,0280	4.8
D ₄	0,0278	4.8
C ₃	0,0270	4.7
D ₁	0,0263	4.5
B ₁	0,0258	4.5
C ₅	0,0241	4.2
D ₂	0,0236	4.1
C ₂	0,0235	4.1
Science-Based	0,2181	52
Market-Based	0,2018	48

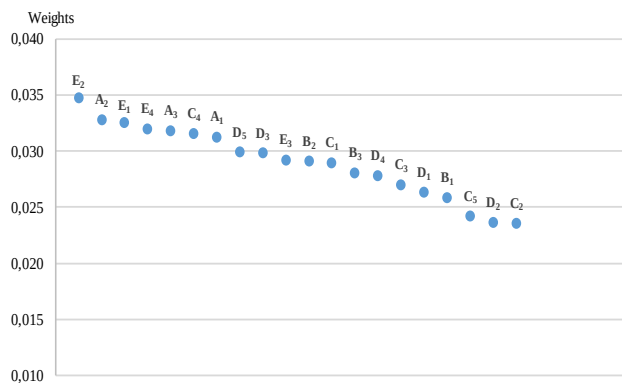


Figure 4.5. The level of the criteria weights for *Stage III*

5. CONCLUSIONS and IMPLICATIONS

The aim of this study is to make an end-to-end analysis, from the selection of innovation type (closed vs. open) to the selection of collaboration type (science-based vs. market-based) and develop a decision making model by linking OI, OI types and collaboration types consecutively in three stages for determining best suitable structure of OI projects. In the first stage, *Stage I*, it is aimed to determine and decide which innovation type (Open, Closed) will be used to build the structure of an innovation project. In the second stage, *Stage II*, it is assumed that OI approach will be used for an innovation project and the aim is to determine which type of OI (Inbound, Outbound, Coupled) to implement. In the third stage, *Stage III*, the aim is to determine the most suitable type of collaboration model (science-based, market-based).

There are three phases for each stage. In phase 1, the criteria were determined. Determining criteria was done in two steps. First step was extraction of criteria as a result of extensive literature review based on drivers of OI, OI types and collaboration types. Second step was application Delphi technique to get expert opinion and finalize the list of criteria for each stage. The criteria determined from literature was finalized with the Delphi analysis, conducted in three rounds with the participation of 8-person expert group through the related questionnaires for each stage.

After determining the final criteria list for each stage as a result of phase 1, in phase 2 the criteria relationships for each stage were determined. This process was done by expert evaluation, with the formation of a sample group consisting 3 academics and the detailed evaluation in two rounds. Then, in phase 3, pairwise comparisons were made by an expert group of 5 people through the separate pairwise questionnaires for each stage, analysis was performed using the FANP method and the weights of criteria and alternatives were calculated.

As a result of the analysis in the study, a decision making model is developed for innovation type, OI type and collaboration type, with the weights and priorities. Decision making model consists of two alternatives (open, closed) and 13 criteria for innovation type (*Stage I*), three alternatives (inbound, outbound, coupled) and 10 criteria for OI type (*Stage II*) and two alternatives (science-based, market-based) and 20 criteria for collaboration type (*Stage III*).

The analysis of the study contains important findings about the OI concept and processes. The criteria and weights in the developed model provide important information about the concepts associated with OI and the degree of these relationships.

The most important three criteria determined in *Stage I* are “C₃-Open Innovation Awareness “, “C₁-Innovation Strategy” and “C₂-Internal Innovation Capability”. These criteria were dimensioned under the cluster “C-Innovation Approach”. This shows that the innovation approach for a firm is the most important dimension for successful setup of an innovation project with OI approach. In terms of the innovation type, OI is rated with a very high value compared to the closed innovation. That shows, implementing OI is the most preferred way for setup of innovation projects. As the criterion C₃ implies, awareness about the potential benefits of OI is the most important factor for firms to implement OI approach. This is followed by firm’s strategy about sourcing of the innovation, development and exploration processes. Firm’s structure and resources for an effective innovation process, including innovation proposal generation, prioritization of the proposals, decision of selection and execution, IP management, technical competences for R&D, project and KM capabilities are important requirements. “OI awareness”, “innovation strategy” and “internal innovation capability” are studied in the literature as important criteria affecting OI. Empirical study made by Hewitt-Dundas & Roper (2018) with micro-businesses firms found important relationship between lack of awareness of the potential benefits of OI and market failures. Subtil de Oliveira et al. (2018) identified innovation strategy and internal innovation capability as important success factors for OI. Sivam et al. (2019) showed that strategy is one of the main drivers to OI. Similarly, Ritala et al. (2013) identified that firm’s strategic orientations determined suitable OI strategies in large R&D intensive firms. These studies show that the results of *Stage I* are compatible with the literature. With these results it can be commented that, firms with high OI awareness, having a clear and solid OI strategy and having innovation capability will be better to setup their innovation projects with a OI based approach.

The result of analysis for *Stage II* shows that the most important three criteria for determining OI type are “A₄- Knowledge Acquisition “, “C₁- Access to New Markets/New Market Opportunities” and “A₁- Absorptive Capacity”. Moreover, coupled OI is the most preferred OI approach. These results show that gathering knowledge and valuable learning assets is the most important factor for realizing the required type of OI approach. The knowledge gathering is not one way, it is bidirectional as coupled OI is the preferred OI approach. The motive behind this is the access to new market opportunities as the results

verifies with the importance of criteria “C₁- Access to New Markets/New Market Opportunities”. “Knowledge Acquisition” is studied in the literature as important criterion affecting the OI type. The study made by Flores et al. (2009) on UIC, the study made by Bucic & Ngo with medium to large firms (2012), the research conducted by Cheng et al. (2016), the study made by Banai (2018) on high technology organizations and the study made by Greco et al. (2019) with SEMs are important example researches. Similarly, “Absorptive Capacity” is studied by many scholars (Spithoven et al., 2011; Aquilani et al., 2017; Naqshbandi & Kamel, 2017; Behnam et al., 2018). Likewise, some example studies for “Access to New Markets/New Market Opportunities” are studies done by Greco et al. (2019), Kutvonen (2011), and Grimaldi et al. (2017). These studies show that the results of *Stage II* are compatible with the literature. With these results it can be concluded that the firms with high knowledge acquisition and absorptive capacity and aiming a better understanding of the new market opportunities for the product or service offered by innovation as well as targeting to expand to new markets, will be better to setup their OI projects with a coupled OI based approach.

The analysis result for *Stage III* shows that the most important three criteria for selection of collaboration type are “E₂- Network Building”, “A₂- Development and Commercialization of Radically New Product” and “E₁-Horizontal and Vertical Network Relationships”. However, the difference between these criteria is not much. The difference between the weights of the first and second is only 0.3% and second and third is only 0.1%. Even, the weights of the most important fourth criteria (“E₄- Relationship Building and Management”) and fifth criteria (“A₃-Reduced Development and Time to Market”) are almost equal and very close to the third most important criteria. Moreover, the difference between the weights of the alternatives are also not much, only 2% between science-based and market-based choices, science-based alternative being 2% more. These results show that, if the intended innovation product is a radically new product, the collaboration is better to be science-based (with universities, research centers etc.). With the “Development and Commercialization of Radically New Product” it is meant the innovation aiming a product or service that supplants or transforms an existing business model and bringing this product or services to the market. To commercialize this product, market-based collaboration can be chosen. Both product development and commercialization require good network building and relationships, namely the criteria “E₁- Network Building” (ability to attract external actors to be engaged in an innovation project and manage and gain benefits from external relationships), “E₁-Horizontal and Vertical Network Relationships” and “E₅- Relationship

Building and Management”. Moreover, from the results it can be commented that the firms having good “Horizontal and Vertical Network Relationships” (interactions between organizations within the same value chain (Vertical) and interactions across firms within the same industry, including interactions between competitors (Horizontal)) are better to choose market-based collaboration. Overall, the result of this stage shows that the collaboration type will be mostly based on the intended innovation product and the requirements for its commercialization.

There are studies in the literature about the important criteria in *Stage III*. Some studies about the “E₂-Network Building” are the ones done by Kazadi et al. (2016), Behnam et al. (2018), and Grimaldi et al. (2017). “A₂-Development and Commercialization of Radically New Product” criterion is studied by Greco et al. (2016). “E₁-Horizontal and Vertical Network Relationships” criterion is studied by Jackson (2014). “E₄-Relationship Building and Management” criterion is researched by Subtil de Oliveira et al. (2018), Carvalho & Sugano (2016), Pustovrh et al. (2017), Sivam et al. (2019), Capaldo (2007), Behnam et al. (2018), and Sisodiya et al. (2013). “A₃-Reduced Time to Market” criterion is examined by Greco et al. (2019), Usman & Vanhaverbeke (2016), Banai (2018), Léon (2007), and McCormack et al. (2015). All these examples show that the results of *Stage III* are compatible with the literature.

Looking at the results of *Stage I*, *Stage II* and *Stage III* as a whole and combining the results, several combinations of the innovation project setup can be recommended. For example, taking the most important criteria into account for each stage, it can be concluded that firms that are well aware of the potential benefits of OI and have good knowledge acquisition capability can setup their innovation projects with OI and coupled approaches and with either science-based or market-based collaboration approaches. The first two or three most important criteria also can be combined to make certain setups. Taking the second most important criteria into account, it can be concluded that firms with a clear innovation strategy and with a strategy to access new market opportunities can setup their innovation structure with OI and coupled OI based approach and can choose market-based collaboration. The combinations can be broadened and different combinations can be selected by different organizations.

5.1. Theoretical Implications

As a result of developing a decision making model by linking OI, OI types and collaboration types in three stages for determining best suitable structure of OI projects, it is

aimed to contribute to literature in terms of application area and the methods used. It is considered that the developed model as a result of comprehensive analysis will fill an important gap in the literature for evaluating decision processes in innovation projects.

There are many studies on OI and its applications of OI types and collaboration types. However, there is lack of a comprehensive study which makes analysis on OI and stages of implementing OI and links these stages to each other in an end-to-end perspective. Analysis of drivers and end-to-end decision making process based on these drivers have not been studied. There is lack of analysis of the criteria for the entire OI process to evaluate the potential of OI for projects and organizations. Moreover, there are not much studies on Coupled OI. This study contributes to fill the gap in these areas and is unique in providing an analysis on OI and its related concepts and linking OI processes to each other in an end-to-end perspective.

In addition, handling this subject with analytical methods, especially with MCDM and FMCDM methods, draws attention as a big gap in the literature. At this point, for the solution of the complex decision problem caused by the uncertainty in the OI setup and the impact of many criteria in the OI process, it was decided to use FMCDM methods. Analyzing OI stages with an end-to-end perspective and by using the combination of Delphi technique and FANP methods, it was aimed to have an integrated solution and bring a differentiation with the studies existing in the literature. With the proposed decision making model, it is contributed to the evaluation phases of OI project stages and project setup before starting the implementation.

Such an end-to-end perspective about OI stages with the usage of FMCDM techniques is not found in the related literature. For that reason, the developed decision making model can be considered as a first effective and objective study which uses the FMCDM methods in evaluation of OI stages and accordingly determine OI project setup in an end-to-end perspective.

5.2. Practical Contributions

It is thought that the approach and the decision making model presented in the study will contribute to the development of suitable setup of innovation projects. It will have a contribution on guiding public, private sector, universities, public and private research centers and non-governmental organizations who are proposed to work together on innovation, for the suitable cooperation and innovation setup. The approach will act as a

decision support system for such organizations in the selection of suitable innovation type, OI innovation type and collaboration type. Moreover, public or private institutions that grant to the innovation projects through financial support programs will be able to evaluate the potential OI setup for the projects by adding the developed model to their evaluation process.

5.3. Further Research

The criteria determined as the drivers and antecedents of innovation types, OI types and collaboration types are initially extracted from the literature, then harmonized and finally finalized with a three round Delphi technique. In that respect, the criteria taken as input to decision making model may not reflect all the aspects impacting the decision of innovation type, OI type and collaboration types. For example, type of industry can be an important aspect to consider if the criteria determined all applicable to all industries types or not. Another aspect can be size of the organizations. The criteria taken as inputs may show different impacts depending on the size of the organizations. Moreover, age of the organizations may have impact on the effect and weights of the criteria determined. Such aspects can be the main limitations of the study. Also, there may be criteria which is not stated in the searched literature, such as the ones dependent on the environmental conditions such as national conditions and policies and other factors not stated here. With that possible limitations, future research can be done by considering some control variables such as industry type, firm size and firm age. The research can be done on a smaller samples like only large firms, only SMEs, only high-tech firms etc. Also, the research can be done based on the age of firms, like only startups, only mid age firms or firms with high age. This, the results of the study and the proposed model may show differences depending on the industry type and firm age.

In the future research the developed decision making model can be widened with a larger antecedent and/or criteria domain. Moreover, the barriers and challenges to OI can be studied further and the criteria related to the reduction the impacts of the barriers to OI can added. Dased on that addition the proposed model can be developed to further application areas.

Using the developed decision making model, a software program can be developed that helps organizations in the decision making in choosing the suitable innovation setup. In addition, further research can be done on the evaluation of OI capacity of the organizations using the developed decision making model. Likewise, OI setup models can be developed

for the institutions by evaluating their strategies and internal processes. Finally, the decision making model presented in the study can be adapted to different application areas to increase the effectiveness of the decision making process.

Another area for future research is the requirement of further studies for coupled OI approach. As shown in the result of the FANP analysis in Part 4, coupled OI is the most preferred alternative of OI approaches. Moreover, as shown in the result of the detailed literature review in Part 2, there is not much research studies on coupled OI, especially as compared to inbound OI. Thus, coupled OI approach and processes need to be studied more in the future.



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7. APPENDICES

APPENDIX 1. Delphi Technique Example Questions (First Round)

Please rate each of the following 29 questions in terms of the impact on determining the innovation type (Open, Closed) for setup of an innovation project. 1-7-point Likert scale is used for rating (1-Absolutely not effective, 7-Absolutely effective)

FIRM CHARACTERISTICS *

	1	2	3	4	5	6	7
1. Firm Age	☐	☐	☐	☐	☐	☐	☐
2. Firm Competencies	☐	☐	☐	☐	☐	☐	☐
3. Firm's Business Diversity	☐	☐	☐	☐	☐	☐	☐
4. ICT Infrastructure and Usage	☐	☐	☐	☐	☐	☐	☐
5. Project Management Structure	☐	☐	☐	☐	☐	☐	☐
6. Relationship Development Capability	☐	☐	☐	☐	☐	☐	☐

APPENDIX 2. Delphi Technique Example Questions (Second and Third Rounds)

Please rate each of the following 29 questions in terms of the impact on determining the innovation type (Open, Closed) for setup of an innovation project. 1-7-point Likert scale is used for rating (1-Absolutely not effective, 7-Absolutely effective)

FIRM CHARACTERISTICS *

	1	2	3	4	5	6	7
1. Firm Age (Q1=2.75, Q3=5, Md=4, R=2.25 , Your Answer: 6)	☐	☐	☐	☐	☐	☐	☐
2. Firm Competencies (Q1=6, Q3=6, Md=6, R=0, Your Answer: 6)	☐	☐	☐	☐	☐	☐	☐
3. Firm's Business Diversity (Q1=5.5, Q3=6, Md=6, R=0.5 , Your Answer:6)	☐	☐	☐	☐	☐	☐	☐
4. ICT Infrastructure and Usage (Q1=5, Q3=6, Md=6, R=1, Your Answer:	☐	☐	☐	☐	☐	☐	☐

APPENDIX 3. Delphi Analysis Results

Table 7.1. Delphi analysis results for *Stage I*

Criteria Dimension	Criteria Name	Participant Answers-Round 3								Round 3 Statistics			
		P1	P2	P3	P4	P5	P6	P7	P8	Q1	Q3	Median	Range
Firm Characteristics	Firm Age	4	5	4	3	3	5	2	5	3	5	4	2
	Firm Competencies	6	6	6	7	7	6	6	6	6	6,3	6	0,25
	Firm's Business Diversity	6	6	5	5	6	6	6	6	5,8	6	6	0,25
	ICT Infrastructure and Usage	6	5	6	5	7	6	6	5	5	6	6	1
	Project Management Structure	6	6	6	6	7	5	4	6	5,8	6	6	0,25
	Relationship Development Capability	6	6	6	5	7	6	6	7	6	6,3	6	0,25
Industry Characteristics	Collaboration Policies	6	6	6	7	6	6	6	6	6	6	6	0
	Competitiveness	6	6	6	4	7	7	6	5	5,8	6,3	6	0,5
	Market and Environmental Dynamism	5	6	6	5	4	5	6	5	5	6	5	1
	Industry Characteristics (low entry barriers)	5	5	5	5	1	6	6	5	5	5,3	5	0,25
	Knowledge on New Market Opportunities	5	5	6	6	7	5	6	6	5	6	6	1
Innovation Approach	Innovation Ambidexterity	6	5	5	6	5	6	6	5	5	6	5,5	1
	Innovation Strategy	6	7	7	7	7	5	6	7	6	7	7	1
	Internal Innovation Capability	5	6	6	6	7	6	6	5	5,8	6	6	0,25
	Open Innovation Awareness	6	6	6	6	7	7	6	5	6	6,3	6	0,25
KM Capability	Absorptive Capacity	6	7	5	6	7	6	6	5	5,8	6,3	6	0,5
	Inter-Departmental Connectedness	5	5	5	5	6	5	5	5	5	5	5	0
	Knowledge Acquisition	6	7	7	6	7	6	6	6	6	7	6	1
HR Management	Employee Retention	5	5	4	4	7	5	3	4	4	5	4,5	1
	Firm's Human Capital	5	5	4	4	6	7	4	4	4	5,3	4,5	1,25
	HR Management Policies and Practices	4	5	4	6	6	6	3	4	4	6	4,5	2
Organizational Culture	De-centralized Decision Making	5	6	5	4	3	5	6	5	4,8	5,3	5	0,5
	Organizational Inertia	6	5	5	5	5	6	5	4	5	5,3	5	0,25
	Organizational Structure	5	6	5	6	3	7	5	4	4,8	6	5	1,25
	Top Management Support	6	6	6	7	7	5	7	7	6	7	6,5	1
Resource Capability	Cost Reduction/Sharing	5	5	6	6	6	5	6	5	5	6	5,5	1
	Financial Limitations	4	5	6	5	5	7	6	4	4,8	6	5	1,25
	Internal R&D as an Enabler	6	6	6	6	6	7	6	5	6	6	6	0
	Firm Resources	5	6	6	5	5	7	6	5	5	6	5,5	1

Table 7.2. Delphi analysis results for *Stage II*

Criteria Dimension	Criteria Name	Participant Answers-Round 3								Round 3 Statistics			
		P1	P2	P3	P4	P5	P6	P7	P8	Q1	Q3	Median	Range
HR Management	Diverse Educational Backgrounds of Employees	4	5	5	4	6	2	4	4	4	5	4	1
	Employee Autonomy	5	5	5	6	5	5	5	5	5	5	5	0
	Empowering Leadership	5	6	5	6	7	5	5	6	5	6	5,5	1
Knowledge Management	Absorptive Capacity	5	6	7	6	7	6	6	5	5,8	6,3	6	0,5
	Access to Scientific Knowledge	6	6	6	6	7	5	6	5	5,8	6	6	0,25
	Desorptive Capability	5	6	5	6	5	6	5	4	5	6	5	1
	Knowledge	6	6	6	5	6	6	6	5	5,8	6	6	0,25
	Multiplication Capability												
	Knowledge Acquisition	6	6	6	6	7	5	6	6	6	6	6	0
	Knowledge Exchange	6	6	6	7	7	6	6	6	6	6,3	6	0,25
	Knowledge Sharing	6	6	6	6	7	6	7	6	6	6,3	6	0,25
Organizational Culture	De-centralized Decision Making	5	5	5	5	5	6	6	5	5	5,3	5	0,25
	Firm's Entrepreneurship Orientation	6	6	6	6	7	5	7	6	6	6,3	6	0,25
	NIH (Not Invented Here) Syndrome	6	6	6	6	7	5	6	5	5,8	6	6	0,25
	NSH (Not Sold Here) Syndrome	5	6	5	6	7	5	6	5	5	6	5,5	1
	OCB	5	5	5	4	6	4	5	5	4,8	5	5	0,25
	Organizational Inertia	5	5	5	5	6	4	5	5	5	5	5	0
Project Characteristics	Access to New Markets/New Market Opportunities	6	6	6	6	7	7	6	6	6	6,3	6	0,25
	Firm's Business Model Alignment	6	6	6	5	6	6	6	6	6	6	6	0
	Novelty of Innovation	5	5	5	6	3	5	6	5	5	5,3	5	0,25
	Technology	6	6	5	5	5	6	5	4	5	6	5	1
	Complementarity												
	Type of Innovation-(Technology, Product, Process or Organizational)	6	6	7	5	1	7	6	4	4,8	6,3	6	1,5

Table 7.3. Delphi analysis results for *Stage III*

Criteria Dimension	Criteria Name	Participant Answers-Round 3								Round 3 Statistics			
		P1	P2	P3	P4	P5	P6	P7	P8	Q1	Q3	Median	Range
Commercialization	Commercialization Capabilities and Success	6	7	6	7	6	6	6	5	6	6,25	6	0,25
	Development and Commercialization of Radically New Product	6	6	6	6	6	6	6	5	6	6	6	0
	Financial Performance-Income Increase	4	5	5	4	3	5	5	5	4	5	5	1
	Reduced Development and Time to Market	6	6	5	6	4	6	6	6	5,75	6	6	0,25
Innovation Approach	Firm's Strategic Orientation-Entrepreneurial	6	6	6	6	5	5	6	6	5,75	6	6	0,25
	Firm's Strategic Orientation-Technology and R&D Emphasis	7	7	7	6	7	6	7	7	6,75	7	7	0,25
	High Commitment to Innovation	5	5	5	5	7	6	7	5	5	6,25	5	1,25
	Innovation Ambidexterity	6	6	5	5	4	6	7	5	5	6	5,5	1
	Strategy Relevance and Partnership	6	6	6	6	7	5	6	6	6	6	6	0
IP Rights Management	Access to New Knowledge Assets	6	6	6	7	7	6	6	6	6	6,25	6	0,25
	Amount of Proprietary IP's	5	6	5	6	6	6	5	3	5	6	5,5	1
	Control Over the Market and Technology	6	6	6	6	5	4	6	6	5,75	6	6	0,25
	Intellectual Capital	6	6	6	6	7	5	6	5	5,75	6	6	0,25
	Firm's IP Rights Protection	6	6	7	6	7	6	6	6	6	6,25	6	0,25
	Processes on Innovation Results	6	6	6	6	5	5	6	6	5,75	6	6	0,25
Knowledge Management	Absorptive Capacity	6	6	6	6	7	5	6	5	5,75	6	6	0,25
	Access to Scientific Knowledge	6	6	6	6	6	6	6	5	6	6	6	0
	Firm's Knowledge Base Capital and Type	6	6	6	6	5	6	6	5	5,75	6	6	0,25
	High Innovation Complexity (Multidisciplinary Requirement)	6	7	6	7	5	7	6	5	5,75	7	6	1,25
	Knowledge Co-Creation Capability	6	6	6	6	6	6	5	6	6	6	6	0
Network Management	Fraternization	5	6	5	5	1	6	5	5	5	5,25	5	0,25
	Horizontal and Vertical Network Relationships	6	7	6	5	6	6	7	7	6	7	6	1
	Network Building	6	6	6	6	7	5	7	7	6	7	6	1
	Partner's Information	6	6	6	6	7	6	6	6	6	6	6	0
	Relationship Building and Management	6	6	6	6	7	6	6	6	6	6	6	0
Organizational Culture	Firm's Strategic Orientation-Customer Relationship	6	6	6	6	7	6	5	6	6	6	6	0

APPENDIX 4. Criteria Relationships

Table 7.4. Relationship matrix for *Stage I*

	A ₁	A ₂	A ₃	A ₄	A ₅	B ₁	B ₂	B ₃	C ₁	C ₂	C ₃	D ₁	D ₂
A ₁		x	x	x		x	x		x	x		x	
A ₂					x	x	x		x		x		x
A ₃							x						x
A ₄						x							
A ₅						x			x		x	x	
B ₁									x	x	x	x	x
B ₂								x	x				
B ₃									x		x		x
C ₁										x	x	x	
C ₂											x		
C ₃												x	x
D ₁													x
D ₂													

x: Existence of relationship

Table 7.5. Relationship matrix for *Stage II*

	A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	B ₁	B ₂	C ₁	C ₂	C ₃
A ₁				x				x			
A ₂				x							x
A ₃				x	x	x					
A ₄					x	x			x		x
A ₅							x		x		x
A ₆									x		x
B ₁									x		
B ₂											
C ₁											
C ₂											
C ₃											

x: Existence of relationship

Table 7.6. Relationship matrix for *Stage III*

	A ₁	A ₂	A ₃	B ₁	B ₂	B ₃	C ₁	C ₂	C ₃	C ₄	C ₅	D ₁	D ₂	D ₃	D ₄	D ₅	E ₁	E ₂	E ₃	E ₄
A ₁		x		x										x		x				
A ₂					x						x	x	x	x	x		x		x	
A ₃																	x		x	
B ₁						x								x						
B ₂									x					x		x		x	x	
B ₃										x						x	x	x	x	
C ₁								x	x		x	x								x
C ₂											x									
C ₃												x			x					
C ₄													x					x		x
C ₅														x						
D ₁													x	x		x				x
D ₂														x	x	x				
D ₃																x		x	x	
D ₄																		x	x	x
D ₅																		x		x
E ₁																			x	x
E ₂																			x	x
E ₃																				x
E ₄																				

x: Existence of relationship

APPENDIX 5. FANP Process Sample Questions for Pairwise Comparisons

Sample Questions for Stage I

Data Form – I: Rating With Respect to the Criteria

1. Compare the importance of the two criteria in each line with respect to the reference criterion (A₁-Firm Competencies).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more

Criterion 1																		Criterion 2
A ₂ -Firm's Business Diversity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A ₃ -ICT Infrastructure and Usage
A ₂ -Firm's Business Diversity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A ₄ -Project Management Structure
A ₃ -ICT Infrastructure and Usage	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A ₄ -Project Management Structure
A ₂ -Firm's Business Diversity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A ₅ -Relationship Development Capability
A ₃ -ICT Infrastructure and Usage	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A ₅ -Relationship Development Capability
A ₄ -Project Management Structure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A ₅ -Relationship Development Capability
B ₁ -Collaboration Policies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	B ₂ -Competitiveness
C ₁ -Innovation Strategy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C ₂ -Internal Innovation Capability

2. Compare the importance of the two criteria in each line with respect to the reference criterion (A₂-Firm's Business Diversity).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more

Criterion 1																		Criterion 2
A ₁ -Firm Competencies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A ₅ -Relationship Development Capability
A ₁ -Firm Competencies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A ₃ -ICT Infrastructure and Usage
A ₁ -Firm Competencies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A ₄ -Project Management Structure
A ₃ -ICT Infrastructure and Usage	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A ₄ -Project Management Structure
A ₃ -ICT Infrastructure and Usage	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A ₅ -Relationship Development Capability
A ₄ -Project Management Structure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A ₅ -Relationship Development Capability
B ₁ -Collaboration Policies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	B ₂ -Competitiveness
C ₁ -Innovation Strategy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C ₃ -Open Innovation Awareness

Data Form – II: Rating With Respect to the Alternatives

3. Compare the importance of the two innovation types (alternatives) in each line with respect to the reference criterion (A₁-Firm Competencies).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more

Closed Innovation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Open Innovation
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4. Compare the importance of the two innovation types (alternatives) in each line with respect to the reference criterion (A₂-Firm's Business Diversity).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more

Closed Innovation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Open Innovation
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5. Compare the importance of the two innovation types (alternatives) in each line with respect to the reference criterion (A₃-ICT Infrastructure and Usage).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more

Closed Innovation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Open Innovation
-------------------	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	-----------------

6. Compare the importance of the two innovation types (alternatives) in each line with respect to the reference criterion (A₄-Project Management Structure).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more

Closed Innovation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Open Innovation
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Data Form – III: Rating With Respect to the Criteria Dimensions

7. Compare the importance of the two dimensions in each line with respect to the reference dimension (A-Firm Characteristics).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more																		
Dimension 1																		Dimension 2
B- Industry Characteristics	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C- Innovation Approach
B- Industry Characteristics	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D- KM Capability
C- Innovation Approach	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D- KM Capability

8. Compare the importance of the two dimensions in each line with respect to the reference dimension (B-Industry Characteristics).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more																			
Dimension 1																		Dimension 2	
A-Firm Characteristics		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C- Innovation Approach
A-Firm Characteristics		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D- KM Capability
C- Innovation Approach		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D- KM Capability

9. Compare the importance of the two dimensions in each line with respect to the reference dimension Alternatives (Open or Closed innovation types).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more																			
Dimension 1																		Dimension 2	
A-Firm Characteristics	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	B- Industry Characteristics	
A-Firm Characteristics	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C- Innovation Approach	
A-Firm Characteristics	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D- KM Capability	
B- Industry Characteristics	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C- Innovation Approach	
B- Industry Characteristics	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D- KM Capability	
C- Innovation Approach	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D- KM Capability	

Sample Questions for Stage II

Data Form – I: Rating With Respect to the Criteria

1. Compare the importance of the two criteria in each line with respect to the reference criterion (A₁-Absorptive Capacity).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more

Criterion 1																			Criterion 2
A2-Access to Scientific Knowledge	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A3-Knowledge Multiplication Capability	
A2-Access to Scientific Knowledge	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A4-Knowledge Acquisition	
A2-Access to Scientific Knowledge	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A5-Knowledge Exchange	
A2-Access to Scientific Knowledge	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A6-Knowledge Sharing	
A3-Knowledge Multiplication Capability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A4-Knowledge Acquisition	
A3-Knowledge Multiplication Capability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A5-Knowledge Exchange	
A3-Knowledge Multiplication Capability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A6-Knowledge Sharing	
A4-Knowledge Acquisition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A5-Knowledge Exchange	
A4-Knowledge Acquisition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A6-Knowledge Sharing	
A5-Knowledge Exchange	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A6-Knowledge Sharing	

2. Compare the importance of the two criteria in each line with respect to the reference criterion (A₂-Access to Scientific Knowledge).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more

Criterion 1																			Criterion 2
A1-Absorptive Capacity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A3-Knowledge Multiplication Capability	
A1-Absorptive Capacity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A4-Knowledge Acquisition	
A1-Absorptive Capacity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A5-Knowledge Exchange	
A1-Absorptive Capacity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A6-Knowledge Sharing	
A3-Knowledge Multiplication Capability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A4-Knowledge Acquisition	
A3-Knowledge Multiplication Capability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A5-Knowledge Exchange	
A3-Knowledge Multiplication Capability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A6-Knowledge Sharing	
A4-Knowledge Acquisition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A5-Knowledge Exchange	
A4-Knowledge Acquisition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A6-Knowledge Sharing	
A5-Knowledge Exchange	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A6-Knowledge Sharing	

Data Form – II: Rating With Respect to the Alternatives

3. Compare the importance of the two open innovation types (alternatives) in each line with respect to the reference criterion (A₁-Absorptive Capacity)

		1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more																	
Coupled		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inbound
Coupled		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Outbound
Inbound		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Outbound

4. Compare the importance of the two open innovation types (alternatives) in each line with respect to the reference criterion (A₂-Access to Scientific Knowledge).

		1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more																	
Coupled		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inbound
Coupled		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Outbound
Inbound		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Outbound

5. Compare the importance of the two open innovation types (alternatives) in each line with respect to the reference criterion (A₃-Knowledge Multiplication Capability).

		1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more																	
Coupled		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inbound
Coupled		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Outbound
Inbound		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Outbound

6. Compare the importance of the two open innovation types (alternatives) in each line with respect to the reference criterion (A₄-Knowledge Acquisition).

		1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more																	
Coupled		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inbound
Coupled		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Outbound
Inbound		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Outbound

Data Form – III: Rating With Respect to the Criteria Dimensions

7. Compare the importance of the two dimensions in each line with respect to the reference dimension (A-KM)

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Exteremely more																		
Dimension 1																		Dimension 2
B- Organizational Culture	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C- Project Characteristics

8. Compare the importance of the two dimensions in each line with respect to the reference dimension (B-Organizational Culture).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more																			
Dimesion 1																		Dimension 2	
A-Knowledge Management		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C- Project Characteristics

9. Compare the importance of the two dimensions in each line with respect to the reference dimension Alternatives (Inbound, Outbound or Coupled open innovation types).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Exteremely more																			
Dimension 1																		Dimension 2	
A- Knowledge Management		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	B- Organizational Culture
A- Knowledge Management		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C- Project Characteristics
B- Organizational Culture		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C- Project Characteristics

Sample Questions for Stage III

Data Form – I: Rating With Respect to the Criteria

1. Compare the importance of the two criteria in each line with respect to the reference criterion (A₁-Commercialization Capabilities and Success).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more

Criterion 1																			Criterion 2
D3-Firm's Knowledge Base Capital and Type	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D5-Knowledge Co-Creation Capability	
A2-Development and Commercialization of Radically New Product	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A3-Reduced Development and Time to Market	

2. Compare the importance of the two criteria in each line with respect to the reference criterion (A₂-Development and Commercialization of Radically New Product).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Extremely more

Criterion 1																			Criterion 2
A1-Commercialization Capabilities and Success	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A3-Reduced Development and Time to Market	
D1-Absorbtive Capacity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D2-Access to Scientific Knowledge	
D1-Absorbtive Capacity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D3-Firm's Knowledge Base Capital and Type	
D1-Absorbtive Capacity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D4-High Innovation Complexity (Multidisciplinary Requirement)	
D2-Access to Scientific Knowledge	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D3-Firm's Knowledge Base Capital and Type	
D2-Access to Scientific Knowledge	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D4-High Innovation Complexity (Multidisciplinary Requirement)	
D3-Firm's Knowledge Base Capital and Type	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D4-High Innovation Complexity (Multidisciplinary Requirement)	
E1-Horizontal and Vertical Network Relationships	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E3-Partner's Information	

Data Form – II: Rating With Respect to the Alternatives

3. Compare the importance of the two collaboration types (alternatives) in each line with respect to the reference criterion (A₁-Commercialization Capabilities and Success).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Exteremely more

Market-Based	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Science-Based
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4. Compare the importance of the two collaboration types (alternatives) in each line with respect to the reference criterion (A₂-Development and Commercialization of Radically New Product).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Exteremely more

Market-Based	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Science-Based
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5. Compare the importance of the two collaboration types (alternatives) in each line with respect to the reference criterion (A₃-Reduced Development and Time to Market).

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Exteremely more

Market-Based	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Science-Based
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Data Form – III: Rating With Respect to the Criteria Dimensions

6. Compare the importance of the two dimensions in each line with respect to the reference dimension **(A- Commercialization)**.

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Exteremely more

Dimension 1																			Dimension 2
B- Innovation Approach	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C- IP Rights Management	
B- Innovation Approach	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D- Knowledge Management	
B- Innovation Approach	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E- Network Management	
C- IP Rights Management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D- Knowledge Management	
C- IP Rights Management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E- Network Management	
D- Knowledge Management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E- Network Management	

7. Compare the importance of the two dimensions in each line with respect to the reference dimension **Alternatives (Science-Based or Market-Based collaboration type) açısından karşılaştırınız**

1=Equal 3=Moderately more 5= Strongly more 7=Very strong more 9= Exteremely more

Dimesion 1																			Dimension 2
A- Commercialization	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	B- Innovation Approach	
A- Commercialization	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C- IP Rights Management	
A- Commercialization	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D- Knowledge Management	
A- Commercialization	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E- Network Management	
B- Innovation Approach	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C- IP Rights Management	
B- Innovation Approach	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D- Knowledge Management	
B- Innovation Approach	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E- Network Management	
C- IP Rights Management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D- Knowledge Management	
C- IP Rights Management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E- Network Management	
D- Knowledge Management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E- Network Management	

APPENDIX 6. FANP Results

Table 7.7. Weighted supermatrix for *Stage I*

	A ₁	A ₂	A ₃	A ₄	A ₅	B ₁	B ₂	B ₃	C ₁	C ₂	C ₃	D ₁	D ₂	C	O
A ₁		0.04	0.06	0.04	0.04	0.03	0.09		0.04			0.05		0.20	0.80
A ₂	0.05		0.04	0.04	0.05	0.03	0.03		0.07		0.04		0.06	0.17	0.83
A ₃	0.04	0.02		0.02	0.02		0.03						0.09	0.21	0.79
A ₄	0.03	0.03	0.04		0.04	0.03								0.16	0.84
A ₅	0.04	0.07	0.02	0.32		0.07			0.05		0.11	0.1		0.14	0.86
B ₁	0.03	0.06					0.04	0.05	0.04		0.07		0.05	0.14	0.86
B ₂	0.07	0.04				0.06		0.06	0.02					0.18	0.82
B ₃						0.05	0.06		0.04		0.03		0.05	0.13	0.87
C ₁	0.17	0.26			0.15	0.14		0.2		0.25	0.34	0.13		0.28	0.72
C ₂	0.31					0.08			0.23		0.14			0.46	0.54
C ₃		0.22			0.33	0.25		0.28	0.25	0.22		0.35		0.15	0.85
D ₁						0.17					0.19			0.13	0.87
D ₂						0.1					0.08			0.17	0.83
C	0.20	0.17	0.21	0.16	0.14	0.14	0.18	0.13	0.28	0.46	0.15	0.13	0.17		
O	0.80	0.83	0.79	0.84	0.86	0.86	0.82	0.87	0.72	0.54	0.85	0.87	0.83		

C: Closed Innovation O: Open Innovation

Table 7.8. Weighted supermatrix for *Stage II*

	A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	B ₁	B ₂	C ₁	C ₂	C ₃	C	I	O
A ₁		0.11	0.19	0.22	0.12	0.1						0.51	0.34	0.15
A ₂	0.06		0.06	0.09	0.11	0.04					0.11	0.60	0.28	0.11
A ₃	0.08	0.08		0.08	0.11	0.08						0.54	0.33	0.13
A ₄	0.16	0.15	0.1		0.08	0.06			0.29		0.17	0.61	0.27	0.12
A ₅	0.08	0.07	0.06	0.05		0.19			0.09		0.1	0.70	0.13	0.17
A ₆	0.1	0.07	0.06	0.04	0.07				0.09		0.09	0.60	0.16	0.25
B ₁												0.60	0.19	0.21
B ₂												0.40	0.39	0.21
C ₁				0.17	0.23	0.2				0.23	0.15	0.39	0.20	0.41
C ₂									0.26		0.19	0.50	0.28	0.22
C ₃				0.17	0.1	0.13			0.07	0.1		0.49	0.28	0.23
C	0.51	0.60	0.54	0.61	0.70	0.60	0.60	0.40	0.39	0.50	0.49			
I	0.34	0.28	0.33	0.27	0.13	0.16	0.19	0.39	0.20	0.28	0.28			
O	0.15	0.11	0.13	0.12	0.17	0.25	0.21	0.21	0.41	0.22	0.23			

C: Coupled Open Innovation I: Inbound Open Innovation O: Outbound Open Innovation

Table 7.9. Weighted supermatrix for *Stage III*

	A ₁	A ₂	A ₃	B ₁	B ₂	B ₃	C ₁	C ₂	C ₃	C ₄	C ₅	D ₁	D ₂	D ₃	D ₄	D ₅	E ₁	E ₂	E ₃	E ₄	MB	SB	
A ₁		0.2	0.17											0.14								0.65	0.35
A ₂	0.13		0.1											0.13			0.11		0.12			0.54	0.46
A ₃	0.13	0.06															0.16		0.15			0.73	0.27
B ₁					0.07	0.08								0.11								0.64	0.36
B ₂				0.11		0.12								0.09		0.09						0.29	0.71
B ₃				0.09	0.13											0.11						0.55	0.45
C ₁								0.05	0.05	0.04	0.04	0.11								0.11		0.28	0.72
C ₂							0.04		0.03	0.02	0.03											0.71	0.29
C ₃							0.07	0.05		0.1	0.06											0.29	0.71
C ₄							0.07	0.08	0.1		0.07	0.09								0.1		0.36	0.64
C ₅							0.03	0.03	0.03	0.05												0.56	0.44
D ₁		0.03			0.04								0.04	0.03	0.04	0.03				0.04		0.38	0.62
D ₂		0.02										0.03		0.04	0.03	0.02						0.14	0.86
D ₃	0.06	0.02			0.04				0.08			0.03	0.03		0.03	0.04		0.03	0.06			0.31	0.69
D ₄		0.05										0.04	0.02	0.03		0.03		0.05	0.07	0.04		0.40	0.60
D ₅	0.07				0.05				0.05			0.03	0.03	0.03	0.04			0.06		0.05		0.35	0.65
E ₁		0.13	0.11			0.05												0.1	0.06	0.07		0.47	0.53
E ₂						0.07				0.1				0.12	0.07	0.07	0.1		0.07	0.09		0.66	0.34
E ₃		0.06	0.08			0.06								0.07	0.04		0.02	0.02		0.03		0.64	0.36
E ₄										0.1					0.08	0.13	0.07	0.07	0.07			0.63	0.37
MB	0.65	0.54	0.73	0.64	0.29	0.55	0.28	0.71	0.29	0.36	0.56	0.38	0.14	0.31	0.40	0.35	0.47	0.66	0.64	0.63			
SB	0.35	0.46	0.27	0.36	0.71	0.45	0.72	0.29	0.71	0.64	0.44	0.62	0.86	0.69	0.60	0.65	0.53	0.34	0.36	0.37			

MB: Market-Based Collaboration **SB:** Science-Based Collaboration

Table 7.10. Limit supermatrix for *Stage I*

	A₁	A₂	A₃	A₄	A₅	B₁	B₂	B₃	C₁	C₂	C₃	D₁	D₂	C	O
A₁	0.0406	0.0406	0.0406	0.0406	0.0406	0.0406	0.0406	0.0406	0.0406	0.0406	0.0406	0.0406	0.0406	0.0406	0.0406
A₂	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427
A₃	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355
A₄	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339
A₅	0.0517	0.0517	0.0517	0.0517	0.0517	0.0517	0.0517	0.0517	0.0517	0.0517	0.0517	0.0517	0.0517	0.0517	0.0517
B₁	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404
B₂	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358
B₃	0.0367	0.0367	0.0367	0.0367	0.0367	0.0367	0.0367	0.0367	0.0367	0.0367	0.0367	0.0367	0.0367	0.0367	0.0367
C₁	0.0796	0.0796	0.0796	0.0796	0.0796	0.0796	0.0796	0.0796	0.0796	0.0796	0.0796	0.0796	0.0796	0.0796	0.0796
C₂	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556
C₃	0.0854	0.0854	0.0854	0.0854	0.0854	0.0854	0.0854	0.0854	0.0854	0.0854	0.0854	0.0854	0.0854	0.0854	0.0854
D₁	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411
D₂	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
C	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079
O	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.30695	0.30695	0.3069

C: Closed Innovation O: Open Innovation

Table 7.11. Limit supermatrix for *Stage II*

	A₁	A₂	A₃	A₄	A₅	A₆	B₁	B₂	C₁	C₂	C₃	C	I	O
A₁	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
A₂	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053
A₃	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
A₄	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073
A₅	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
A₆	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
B₁	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
B₂	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
C₁	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
C₂	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
C₃	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
C	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213
I	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104
O	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080

C: Coupled Open Innovation **I:** Inbound Open Innovation **O:** Outbound Open Innovation

Table 7.12. Limit supermatrix for *Stage III*

	A₁	A₂	A₃	B₁	B₂	B₃	C₁	C₂	C₃	C₄	C₅	D₁	D₂	D₃	D₄	D₅	E₁	E₂	E₃	E₄	MB	SB
A₁	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031
A₂	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
A₃	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
B₁	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026
B₂	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
B₃	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
C₁	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
C₂	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
C₃	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027
C₄	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
C₅	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
D₁	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026
D₂	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
D₃	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
D₄	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
D₅	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
E₁	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
E₂	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
E₃	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
E₄	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
MB	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202
SB	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218

MB: Market-Based Collaboration **SB:** Science-Based Collaboration

