Auditing patent portfolio for strategic exploitation:

A decision support framework for intellectual property managers

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INTRODUCTION

The quick transformations in the world economy have required firms to open to new ideas and acknowledge the importance of Intellectual Property (IP) to achieve a competitive advantage and profit from its commercial use (Hall & Ziedonis 2001; Gans & Stern, 2010). The acquisition of advantage from knowledge and its transformation into IP rights (Yoon et al. 2008) has resulted in several economic benefits for firms: getting a powerful market positioning, increasing their market, and conveying an image of high-level innovation. These targets cannot be pursued unless a strategic use of IP is adopted (Pitkethly 2007; Somaya 2012).

Patents, similarly to the other forms of IP, represent value assets and, as such, their proper strategic management can affect firm value creation (Klaila & Hall 2000; Teece, 2000). As is usual with all value assets, firms should understand the actual contribution of the patents to reach the objectives and, consequently, take on to manage patents in a strategic way by assessing their technological and monetary value (Jeong & Yoon 2015; Ponomarev et al. 2014). It is well known that highly technological firms, not only large ones, but also SMEs, benefit from patenting and own a multitude of patents in the result of the acceleration in the growth of their trend of patenting. This is because often firms' patenting answers the need for maintaining the strategic positioning in a given technology, or for expanding their activity in a different technological area from the core one, or for protecting or blocking their technological inventions

from other competitors. For these reasons, we can say that several factors lead firm managers to analyze the actual technology condition of patent portfolios. First of all, the frequently changeable technological context that requires a continual refresh of patent congruence with the firm goals. Second, the obsolescence, over time, of patents that end up to lose their core quality to the company for many of which it could be devised a better purpose. Third, firm budgetary adjustments that could inspire patent exploitation actions.

Consequently, it is necessary to help managers in exploiting their patent portfolio to extract value from it, by performing its accurate audit (Holgersson 2013). From the analysis of the literature about devices that IP managers utilize to audit patent features, we have ascertained the lack of a framework that can help scrutinize patents by applying appropriate indicators to select the most suitable patent exploitation strategy. More precisely, an approach should be devised that, by reducing the complexity of the analysis, usually carried out by the help of several indicators and complex variables (Reitzig 2004a), allows firms' managers to perform an evaluation process. The selection of patents can be therefore carried out for their characteristics of strategic relevance, technological and innovation advancement, and profitability (Ziegler et al. 2013). Thus, we have recognized the necessity of a framework able to audit patents by relating the decision process to strategy, business models, citations and technological features (Wirtz et al. 2016). The study poses two research questions: a) how to investigate a patent portfolio in order to draw out the more advantageous strategies of its exploitation; b) how to assist IP managers in selecting those patents which are worthy of exploitation.

In this paper, we address the problem of supporting managers of large high technology companies in their strategic decision-making process aimed to select out of a significant number of patents those suitable for strategic exploitation. Our main contribution is to advance an audit framework that, by making use of ad-hoc indicators, can sort patents by purpose, as well as merge complexity, applicability, and reiteration tasks. In particular, we propose a decision support framework that enables IP managers to inspect their portfolio of patented technologies along their decisional process and classify them into four groups: a) most valuable patent related to high growth business; b) patents that had no present or planned use but are

still of value to the firm; c) patents unlikely to be used; d) patents to be abandoned. The proposed framework allows IP managers to grasp whether patents are all aligned to the overall business model and to select the most appropriate exploitation strategy for each patent.

The remainder of the paper is structured as follows. Section 2 provides the theoretical background of our work and highlights the newness of our framework. In Section 3, we describe the framework, while, in Section 4, we illustrate practical applications carried out in three companies operating in the Aerospace and Defense sector. Finally, Section 5 discusses the implications of our work and concludes the paper.

LITERATURE BACKGROUND

The strategic management of the knowledge enclosed in IP is among the accomplishments necessary to preserve the competitive advantage of firms (Lang 2001; Pitkethly 2001). By focusing on IP firm resources, it was observed that IP intellectual assets share with all other resources the same characteristic: they have to be exploited to seek the best advantage in striving for the organization's goals using suitable methods. IP strategy and IP management slightly differ one from another: "the difference is between the general principles and aims that govern the course of action (strategy) and the actual implementation of those courses of action (management)" (Pitkethly 2007).

In the present work, we refer to internal and external strategic initiatives of exploitation of patents, taking for granted the existence of specific organization departments that handle patent management tasks from the point of view of the ordinary administration.

The strategies of patent exploitation: internal and external patent strategies

The primary concern of a patent strategy is its integration into the overall business model design and corporate strategy (Dolfsma 2011; Al-Aali & Teece 2013). Indeed, a patent strategy entails decisions about resources allocation and a consistent number of choices along the decision-making process of firms. Instead of considering patents as defensive tools to protect their IP, some firms started using patents as

business implements and leveraging them outside their own boundaries (Hanel 2006; Somaya 2012). Consequently, a market for IP developed, where innovators could sell their "products" just like any other asset (Rabino and Enayati, 1995; Arora & Gambardella 2010).

Strategic IP measures can be adopted both internally and externally to the firms. Internal IP strategy regards a range of internal issues related to the organization of resources within companies. To this end, it is necessary to evaluate the costs to obtain or preserve rights. In addition, diffusion and acquisition of patent and other IP information through publications and literature searches in order to better acquaint company decision-makers. Particular attention should be paid to the integration of people, skills, and qualifications required to the strategic management of IP. And to train all the individuals involved in managing IP to improve their awareness and to ensure the protection of the organization's IP interests (Gambardella 2013). However, above all, it is important to emphasize that senior managers are necessary to coordinate the overall strategic management of the organization's IP (Somaya 2012).

External IP strategy concerns questions related to IP exploitation, and patents can be considered as the most frequently "exploitable" IP elements. This process involves activities that look at patents as competitive weapons for profit and envisage the sharing of rights to benefit economically from the technology of patents. This is the result of the evolution of the knowledge economy, that from recognizing patents as legal issues have switched to take advantage of them in their quality of efficient means of firm strategy (Jolly 2012).

An external exploitation of patents must contemplate the analysis of patent portfolio technological features to increase firms' competitiveness while maximizing economic returns (Granstrand 2004). Some authors have reported that firms' value creation through patent portfolios depends on their strategic management modalities rather than on their numerical consistency (Grindley & Teece 1997; Davis 2004; Striukova 2007). Therefore, a patent strategic process is represented by the evaluation of patent portfolios, established by the degree of their alignment to the firm strategy (Phaal et al. 2004; Lee et al. 2007). A range of action items of a "strategy-centric" view focused on leveraging patents includes a patent evaluation process, that helps identify the technological advancement of patents. Also, it seems very

effective to understand the meaningful relationships of patents to the development of strategic objectives profit and competitive advantage. Indeed, patents are valuable assets for generating additional revenue. In this aspect, the strategic evaluation process of patent portfolios results in an efficient support to the specific requirement of managers' decision-making process to determine both patent valorisation and exploitation.

Exploitation of patents concerns a variety of patent utilizations. Through the direct commercialization (in-house exploitation) of the patented technology, economic returns are granted by the sales amount derived from the exclusive asset along with the possibility of fetching it at a high price in consequence of product differentiation (Hikkerova et al. 2014). This strategic choice depends on firm economic and productive resources, necessary to produce and distribute the patented technology profitably so as to reach a dominant position in that field, maintain the cost of the patent, and invest in R&D activities to strengthen the patented technology. Further examples of patent exploitation refers to all those actions that fall in the so-called "defensive" strategy activities that firms adopt to protect their business, some of them consisting of large volume portfolio patenting, patent blocking, preemption defensive thickets, validity challenges (Somaya 2012; Reitzig 2004b; Guellec & Van Pottelsberghe de la Potterie 2002).

From the point of view of a company which would profit from patents, Nermien Al-Ali (2003) and Hanel (2006) advanced that patents could be subdivided into three groups: those valuable and related to high growth business that must be left for business unit competitive purposes; those that have no present use but are still of value to others and can be offered for licensing; those that are unlikely to be used and must be donated or abandoned. Licensing, cross-licensing, patent pooling, and alliances are the most used settings that firms adopt, each of them offering a wide variety of clauses regarding the exclusivity and extent of the licensed rights (Grindley & Teece 1997; Hall & Ziedonis 2001; Arora & Ceccagnoli 2006; Kollmer & Dowling 2004).

Licensing represents a significant contractual tool to transfer technology (Motohashi, 2008). More in detail, licensing patents from a firm portfolio may be considered as a real strategic choice that, in addition to returns, can enhance technology, production, and image of firms (Kamiyama et al. 2006; Hsieh 2013).

Both small technology-based firms and large established companies consider licensing revenues as a portion of the overall return from their technological investments. Alternatively, cross-licensing enables two or more firms to make reciprocal (or cross) exploitation of their patents. Cross-licensing is commonly adopted when both actors want to take mutual advantage of their technological knowledge without making a capital expenditure or incurring litigations (Grindley & Teece 1997; Hall & Ziedonis 2001).

Selling is the patent external exploitation activity that is taken into consideration when firms have no more interest in the technology of one or more of their patents. Certainly, keep-or-sell decisions (very often tied to the technology life-cycle view) are strictly related to the patent strategic management process, that should encompass the coordination of internal and external patent exploitation and consider potential returns of patent technology as a whole (Ford & Ryan 1981; Lanjouw & Schankerman 2004a). The trading of the ownership of patents is often more advantageous than licensing, as firms can reinvest the financial value gained from sale and profit from the costs of renewal fees reduction. Furthermore, the financial value of patents is obtained by setting up a spin-off to which patents can be transferred for development or by forming a joint venture using patents as primary currency, instead of a liquid asset.

The patent strategic management process should also consider the decision of not paying patent renewal fees to interrupt the activity of operative patents before the natural end of their life-cycles. Usually, renewal decisions ground on economic criteria (Pakes 1986; Hikkerova et al. 2014). Renewal events along the patent life-cycle have been studied extensively and evidence has suggested that there is a relationship between the value of the patents and their renewal until the end of patent protection period Schankerman & Pakes 1986). Consequently, in some circumstances, firms can interrupt the life-cycle of patents voluntarily, as a consequence of fast technological changes, extensive modifications in production lines, and market transformations. Certainly, when technology and/or relative products of patents become obsolete and no returns can be derived neither from selling nor from licensing because there is a lack of possible buyers or licensees, patents must not be renewed (Reitzig et al. 2007).

In summing up, the existing strategic practices for exploiting patents are as follows: maintaining/direct commercialization; licensing/cross-licensing; selling; abandoning.

Tools proposed in literature for strategic patent exploitation

In the landscape of patent strategy literature, few works have proposed a tool that could support patent exploitation strategies of firms as highlighted by Granstrand (2004), Kamiyama et al. (2006) and Tseng et al. (2011). Schmoch (1995) has suggested a multi–dimensional scaling technique, which helps reduce complexity and bring out decisive features for the comparison and evaluation of technological strategies of firms. Pitkethly (2001) has identified seven important factors particularly relevant to licensing and cross-licensing decisions, which contemplate some aspects, such as technology, appropriability, commercialization, costs and revenues, and learning opportunities. Breitzman et al. (2002) have used patent analysis techniques to examine the market value and to evaluate the technological strength of M&A candidates. Ernst (2003) has worked out a conceptual framework for IP strategic planning purposes which proposes the application of patent information to core areas of technology management and makes use of indicators of patent strategies. The Danish Patent and Trademark Office has developed IPscore™ 2.0, a software tool which studies four patent profiles to help companies make better and wider use of their patent portfolio as part of their overall business strategy (Nielsen 2004). Petit et al. (2011) have presented an analysis for SMEs to audit, manage, and evaluate their patent portfolios to ascertain their levels of IP awareness, protection, management, and exploitation. Jolly (2012) has identified a limited set of criteria to measure "technological attractiveness" that is outside the control of the company, and "technological competitiveness" that is within the company's control. The criteria are measured through a useful set of questions at the operational level. Conley et al. (2013) have advanced a framework that helps assimilate IP management activities with the practices of marketing and strategy.

It is true that tools and frameworks have been advanced to perform the analysis of some key dimensions particularly relevant to support decisions on a single specific strategic choice at a time, such as licensing, or cross-licensing, or selling, or abandoning (Sherry & Teece 2004; Lemley & Shapiro 2007; Sohn et al. 2013; Santiago et al. 2015). But neither of the above-mentioned papers has suggested a strategic

procedure to be followed in the event that for each patent a decision had to be adopted for its strategic exploitation.

In conclusion, the so far advanced research about exploitation methodologies of patents presents some limitations. We can summarize them as follows: there is no framework, to the best of our knowledge, that helps managers 1) to understand whether patents are all aligned to the overall business model design and corporate strategy; 2) to select those which are not aligned, and 3) to evaluate the possibility of licensing, selling, or not renewing them. The existing tools carry out analyses on one single patent exploitation strategy, but they ignore the circumstance of making only one choice among the four possible strategies proposed for each patent.

In consideration of this evidence, our work aims to fill in this gap by proposing a framework intended for supporting decisions of managers on the strategic supervision of patent portfolios.

THE RESEARCH METHODOLOGY

This investigation takes the form of a qualitative case study for purposes of theory elaboration. Indeed, a qualitative case study method provides an exploratory and flexible approach to examine occurrences in condition of unstructured problems (Ghauri & Grønhaug, 2005). Case research is considered to be particularly suitable in management for exploring decision-making issues and behaviors of individuals within organizations (Barrat, Choi, & Li, 2011; Dubois & Gadde, 2002). This research methodology has been furthered to unfold the complexity of the problem in order to derive theoretical elements functional to the definition of a theoretical perspective, by means of an abductive approach (Dubois & Gadde, 2002) for elaborating, rather than testing or building, theory (Ketokivi & Choi, 2014). Therefore, our case study is characterized by open and explanatory considerations that drive our research questions.

After an accurate examination of the advantages and disadvantages of single versus multiple cases methods (Eisenhardt, 1989; Eisenhardt & Graebner, 2007; Siggelkow, 2007; Yin, 2003), a single case approach has been considered as the most adequate to investigate the context inside the Defense and

Security Electronic. More specifically, the authors have decided to adopt a research approach based on an embedded case study, preferred to a case study, for two reasons. First, the need of examining an environment where the boundaries between the phenomenon of interest and the context are not clearly evident. Secondly, the necessity of answering the research questions, which required the treatment and combination of a variety of information sources including documentation, interviews, and artefacts (Scholz and Tietje, 2002).

In this paper, we propose an audit framework that is designed to support the decision-making process of IP managers in patent portfolios strategic management. Data considered in this study are represented by the patents owned by a firm, on which a selection has to be performed to distinguish the exploitable from the not exploitable technology of patents.

The audit framework must be able to point out whether patents are aligned to the overall business strategy, to select those that are not aligned, and to identify the most appropriate exploitation strategy for each patent of the portfolio. The framework consists of two phases: ~~in~~ the first one, where patents are selected through the analysis of four dimensions that characterize the value of patents effectively; the second one that supports the strategic decision on patents, by means of a questionnaire distributed to IP managers.

The paper illustrates an embedded case study application of the audit framework. Selex ES represented the strategic consolidation of Leonardo's (ex-Finmeccanica) Defense and Security electronic business and originated from the merging of Selex Elsag, Selex Galileo, and Selex Sistemi Integrati. We have applied the audit framework to the patent portfolios of the above mentioned three companies. The choice of this field of application for the embedded case study has been caused by organizational and sectoral reasons, as explained in the following sections.

THE AUDIT FRAMEWORK

The two phases, which characterize our framework, are briefly outlined here below (Fig. 1):

1. In the first phase, externally exploitable patents are singled out of the entire patent portfolio. To select the externally exploitable patents, an analysis on the perceived value of each patent of the portfolio is conducted to evaluate whether they are essential/not essential to the firm.
2. In the second phase, further analysis, focused on the exploitable patents selected in the first phase, is carried out using a questionnaire to support the strategic decision. The questionnaire is distributed among IP managers to obtain from respondents a strategic decision on four possible alternatives of exploitation: maintaining, licensing, selling, abandoning.

Fig. 1 – The Audit Framework
around here

The first phase: selection of exploitable patents

Among the various qualification elements owned by patents, based on an analysis of literature, we assume that four dimensions characterize the relationship value/quality of patents efficiently and have a significant influence on the strategic decisions: Forward citation frequency (FCF), Technical Scope (TS), International scope (IS) and Strategic and Economic Relevance (SER).

Forward citation frequency

Forward citations refer to those citations a patent receives from other patents after it has been granted. The number of these citations represents one of the most important indicators of innovation and shows the quality of patents (Trajtenberg 1990), the measurement of their consolidated technological background (Jaffe & Trajtenberg 2002), and firms' strategic capability (Lanjouw & Schankerman 2004a). Several scholars agree on considering citations as fundamental proxies to not only value a patent and assess a patent portfolio but also to implement a strategic technology planning (van Zeebroeck 2011; Hikkerova et al. 2014).

Technical scope

The technical scope of a patent is defined by its claims. The list of claims of each patent specifies all the elements that the patentee "claims" as new and that characterize the patent. Many authors hold that the value of a patent or a patent portfolio can be leveraged by a large number of claims (OuYang & Weng 2011). Lanjouw and Schankerman (2004b) observe that claims reflect the technological importance of the innovation and that the number of claims shows that innovation has a wide potential of profitability embedded in it (Lagrost et al. 2010). A large number of claims of a patent indicates that the firm owner of that patent is intentioned to reduce the probability that inventors could patent inventions in the technologic subject matter area of their patent. However, the strength of this mechanism is weakened in case claims relate to several technological areas and firms cannot afford to track developments of their inventions in all the potential technological areas.

International scope

Companies or inventors, whose activity stands in relationship to international markets, need to protect their inventions by sole right in all those countries where they want to market their products (Ernst & Omland 2011). Even though highly expensive, a wider market coverage makes companies more competitive and allows them to obtain compelling advantages from stipulating license agreements or strategic alliances with other companies. Also, several types of research indicate that the value of patents is related to the number of countries in which those patents are filed (Lanjouw & Schankerman 2004a; Reitzig 2004a; Harhoff & Hoisl 2007).

Strategic and economic relevance

In addition to the variables mentioned above, traceable in the patent application, there are other important features, in patent life-cycle, which are strictly correlated with economic and strategic evaluations. As for the strategic side, companies often consider patents as strategic tools to pursue their objectives (Hsieh 2013). In this regard, Ernst (1998) showed how patent information can be used to monitor competitors, assess technology, and manage R&D portfolios. It is evident that these activities call the attention of managers and decision makers to establish a successful strategic technology planning. The economic

value of a patent is connected to technical, industrial, and commercial factors. Further, the technical - industrial value of the invention depends on its degree of technical originality and on the industrial and competitive advantages resulting from exploiting the invention (Hanel 2006).

For each of the four dimensions, we have identified a specific key indicator that can encompass crucial information to the acquisition of a deep knowledge of patent portfolios. The formulae employed to calculate the indicators of the dimensions are synthesized in Fig. 2. By an accurate analysis of literature, Grimaldi et al. (2015) proposed and described the following indicators in detail.

Fig. 2 - The formulae of the four indicators
around here

FCF indicates the average number of annual forward citations received by a patent, normalized for the maximum number of forward citations of the patents of the portfolio in the same IPC class and period. The value of FCF is comprised between 0 and 1.

TS expresses the value of the number of the claims, normalized for the maximum number of claims of a patent of the same company and the same IPC class and period. The value of TS is comprised between 0 and 1.

IS evaluates the market coverage using two addends. The former accounts for the number and type of the countries covered by the patent; while the latter accounts for the occurrence of the Patent Cooperation Treaty procedure or of the triadic share (the patent is granted at the patent offices of Europe, USA, and Japan). In virtue of the construction of the addends, the value of IS is comprised between 0 and 1.

SER is the mean value of Patenting Strategy and Economic Relevance of patents. Patenting strategy assesses the strategic positioning of a patent using four qualitative levels that were identified in the literature: competitive, business, defensive, and not essential. For each of these four levels, quantitative values - equally distributed along an interval comprised between 0 and 1 - are assigned (Table 1). Economic relevance assesses the economic importance of a patent using five qualitative levels, logically

linked to the economic relevance of a patent, such as core, high, medium, low and no relevance. For each of these five levels, quantitative values equally distributed along an interval comprised between 0 and 1 are assigned (Table 1). The value of SER is comprised between 0 and 1.

Since the main purpose of this phase is to identify those patents that are considered as exploitable externally, we decided to put into evidence the role of the FCF and SER dimensions, which are the two most critical dimensions that cover the technological and strategic aspects of patents. FCF is the dimension that accounts for the patent innovativeness, while SER is the dimension that accounts for its economic-strategic feature. This last is essential to evaluate the quality of a patent family regarding strategic, economic, and financial potential. To this end, we plotted information acquired about these innovative and economic-strategic characteristics into a Cartesian coordinate system, where FCF and SER represent the abscissa and the ordinate axes respectively (Fig. 3). In this way, the patents of a company are positioned in the system based on their values of FCF and SER. Moreover, to evaluate the external exploitation of the patents their TS and IS values are analyzed.

Figure 3: The four quadrants of the strategic-economic and innovative analysis (first phase) around here

The possible combinations of low and high values of FCF and SER can be visualized in the four quadrants of the Cartesian coordinate system, where the positioning of FCF and SER values is intended to be of help in showing information about the patent values. We decided to adopt the arithmetic mean of the maximum and minimum values (mid-range) to make it possible to represent values between low and high values of FCF and SER.

The four possible combinations of the dimensions are explained as follows:

- **Low level of FCF and low level of SER (NOT RENEWING OR NOT EXPLOITABLE)**

  Patents located in this area are characterized by few citations, showing poor technological esteem about future development and inadequate economic-strategic performance. Despite their

unforeseen occurrences of exploitability, it is presumable that an initial incorrect evaluation of their technological invention leads these patents to be not aligned to the firm technological background. These patents are bound to be not renewed and do not undergo any further analysis since it is hard to hypothesize that other companies could be interested in their exploitation.

- **Low level of FCF and high level of SER (MAINTAINING OR NOT EXPLOITABLE)**

  Even though economically and strategically significant, patents falling in this area have received few citations. However, they are considered as "core" by the firm, which has decided to maintain and protect them. Some hypotheses can be advanced about these patents: they represent radical innovations, not yet extensively cited because of its complexity; they are intrinsically tied to a recent technological leadership that must be preserved; they could be added in the past as incremental additions of an obsolete technology, still considered as "cash cow" and not saleable. In conclusion, even if there could be the possibility that these patents could provide financially and strategically interesting licensing opportunities (e.g. for licensees in foreign markets or different sectors), they do not undergo any further analysis as, despite the small number of citations, they still have a strategic potential, which is relevant to the company.

- **High level of FCF and low level of SER (FURTHER ANALYSIS)**

  The high value of FCF shows that patents falling in this area are characterized by a highly appreciated technology, both developed by the firm and/or developed by other inventors. However, their economic and strategic relevance appears as unsatisfactory. Some suggestions can be set forth: they are patents used as imitation barriers or to prevent competitors from patenting related inventions (blocking, fences, and thickets) and there is the risk that they could be incrementally ameliorated and successively exploited or infringed. Therefore, it is necessary for them to pass through a further analysis (second phase).

- **High level of FCF and high level of SER (MAINTAINING OR FURTHER ANALYSIS)**

  These patents are valuable for both their internal economic-strategic role and their external acknowledgement. They seem to have a core value to the company, which would not exploit

them externally. However, to evaluate a trustworthy external exploitation, it is necessary to analyze their TS and IS values. As a broad range of potential applications correspond to high values of TS, and a considerable extent of market coverage corresponds to high values of IS, a further analysis of these patents is advisable to evaluate their most profitable exploitation. Therefore, it is necessary that patents, showing at least one value between TS and IS higher than the median value, pass through a further analysis (second phase).

In conclusion, patents positioned in the lower right-hand quadrant of the Cartesian coordinate system and those placed in the upper right-hand quadrant of the Cartesian coordinate system, showing at least one value between TS e IS higher than the median value, have the possibility to be externally exploited and, therefore, are analyzed furtherly in the second phase.

The second phase: the further analysis

Only the patents selected in the previous phase and considered as externally exploitable undergo this phase. The phase consists in interviewing firm management about patent exploitation possibilities. A questionnaire is distributed to the IP managers. For each patent, respondents are asked to evaluate four specific properties: market potential; competition level in the market; technical potential; development level of the patented technology. We have derived the first three properties from literature studies on strategic evaluation of technologies regarding attractiveness and competitiveness (Lagrost et al. 2010; Tseng et al. 2011; Jolly 2012). The fourth property, the Technology Readiness Level (TRL), was suggested to us by a method developed by NASA in the 1980s to assess technology maturity at a given point in time (Mankins, 1995).

As for patent market potential, respondents are asked to evaluate the following features: market sensitivity to its technological factors; entry barriers and fixed costs of implementing its technology; availability of other similar patents in the portfolio; demand for the patented product. For each patent

respondents are required to choose one of the proposed five following alternatives, each of them corresponding to an evaluation numbered in ascending order from 1 to 5:

1. The absence of demand, strong barriers to entry, and high development costs. No complementary patents;
2. Low demand, strong entry barriers, few complementary patents (not standing alone patent);
3. Stable demand, strong entry barriers, and market sensitivity to technological factors;
4. Growing demand, low entry costs, market sensitivity to technological factors;
5. Emerging market and high market sensitivity to technological factors, low entry costs, and low development costs.

As for the competitive market situation, respondents are asked to evaluate the presence and the strength of competitors in that technology, considering some aspects, such as competitors' number and strength (regarding the market share and the number of patents granted in that technology); the substitutability of competitive products. For each patent, respondents are required to choose one of the proposed five following alternatives, each of them corresponding to an evaluation, numbered in ascending order from 1 to 5:

1. The market is dominated by competitors totally;
2. Strong market competition, but there is the possibility to enhance market shares;
3. Competitors leave market niches free to gain market share;
4. Market competition is on equal terms and there is the possibility to entry the market with firm's technology;
5. The market is free from relevant competitors and the patent can open a new market.

As for the technical potential of each patent, questionnaire respondents are asked to evaluate its technological impact, considering the following aspects: useful advance over prior art, the existence of substitute technology, positioning on technology life-cycle. Each respondent is required to choose one of

the proposed five following alternatives, each of them corresponding to an evaluation, numbered in ascending order from 1 to 5:

1. The patent technology is rather outdated and not used anymore as other more performant technological alternatives exist;
2. The patent cannot improve the existent technology and shows its technology obsolescence that can be substituted easily;
3. The patent is still innovative, its technology is attractive but replaceable;
4. The patent shows relevant innovations compared to prior art, its technology is not replaceable, and is advancing towards industrial maturity;
5. The patent is very innovative, its technology is under development and not replaceable.

As for the TRL, respondents are asked to evaluate the degree of development of the patented technology by choosing one of the proposed following, alternatives, each of them corresponding to an evaluation, numbered in ascending order from 1 to 9:

1. Basic principles observed and reported;
2. Technology concept and/or application formulated;
3. Analytical and experimental critical function and/or characteristic proof of concept;
4. Component validation in laboratory environment;
5. Component validation in relevant environment;
6. System/subsystem model or prototype demonstration in a relevant environment;
7. System prototype demonstration in an operational environment;
8. Actual system completed and qualified through test and demonstration;
9. Actual system proved through successful mission operations.

During formal workshops, IP managers have to agree on which evaluation number, related to each of the four properties, has to be assigned each patent.

To transform the evaluation numbers of the four properties into an exploitation strategic decision, we have matched them to the four strategic decisions (maintaining, licensing, selling and abandoning) following the suggestions from the IP managers of the companies where the framework has been implemented (Table 1).

It must be noted that evaluations of the "market potential" allow discriminating between the internal (maintaining) and external (licensing, selling, and abandoning) exploitation strategies, while the evaluations relative to the "market competitive situation" allow to distinguish between exploitation strategies, where the property of the patent is maintained (maintaining and licensing), and those where the property is disposed of (selling and abandoning). As for the evaluations of the "technical potential" and "TRL", the matching has been performed by taking into account the combinations of the exploitation strategies, with technologic-innovative aspects, and development degree, respectively. It must also be underlined that some combinations of the various evaluations are missing in consequence of the fact that IP managers considered them as not meaningful, that is, those combinations showed contradictory evaluations of the different properties. Finally, it might happen that the matching of a combination of the four properties does not correspond to any strategy: in this case, it is necessary to select the strategic choice that approximates the closer one, that is, the matching would result from 3 evaluations instead of 4. For example, to a patent that receives the evaluation numbers of 1, 1, 1, 1, the framework would best fit the strategic decision of "abandoning" it.

Tab. 1: The matching between the values of the four properties and the exploitation strategies

around here

The evaluation numbers can also be plotted along the spokes of a radar chart. Polygons can be derived from connecting numerical evaluations for each spoke by a line. The wider the polygon size, the higher the possibilities of maintaining the patents; the narrower the polygon size, the higher the opportunities for

the patent to be abandoned. For example, to a patent that receives the evaluation numbers of 3, 4, 3, 5, as illustrated in Fig. 4, the framework would match the strategic decision of "licensing" it.

Fig. 4: The radar chart of the numerical evaluations of the four properties (second phase) around here

THE APPLICATION OF THE AUDIT FRAMEWORK

We implemented the audit framework, proposed in the previous section, into Selex ES, one of the companies of Leonardo (ex-Finmeccanica). Leonardo is the third ranked world industrial group by its investments in R&D of Aerospace and Defense Sector. Despite what happens in very innovative technological areas, congested by a robust and fast growth of patent number, this sector benefits from a steady development of the market, not influenced by time. After a fundamental recent rearrangement process carried out by Finmeccanica in 2013, Selex ES represented the strategic consolidation of Finmeccanica's Defense and Security electronic business and originated from the merging of Selex Elsag, Selex Galileo, and Selex Sistemi Integrati. We applied the framework to the patent portfolios of the above mentioned three companies, by means of an embedded case study approach.

All the patents of Selex Elsag, Selex Galileo, and Selex Sistemi Integrati, published from 1995 to 2014, and still active in December 2014, have been identified. We decided to survey a period of 20 years because, in the sector of Aerospace and Defense & Securities Electronics technologies, patents have long life cycles or are kept alive for a prolonged time. We have retrieved all the patent information related to the patent documents out of the Thomson Innovation database. For the three companies, 273 patent documents have been examined.

In the application of the first phase of the framework, the indicators of the four dimensions have been calculated for each patent family. Data regarding FCF, TS and IS have been computed using the

information derived from the Thomson Innovation Database. We determined SER from the information acquired through the interviewing process carried out with the members of the IP Governance Board of Leonardo and Selex ES.

In the period from June to October 2015, to apply the second phase of the framework, that is the evaluation of the four properties, we conducted four workshop sessions with the IP managers both of Leonardo and of the three Selex companies. In particular, the first three sessions were performed with each of the three companies, while the fourth session was dedicated to the analysis and discussion of the obtained results.

The application in Selex Elsag

We applied the framework to Selex Elsag. The results of the implementation of the first phase of the framework (patent selection) provided the values of FCF and SER and these were plotted on the Cartesian system as shown in Fig. 5a. From the data in Fig. 5a, it is apparent that most patents lie in both upper and lower left-hand quadrants; these patents are therefore considered respectively as to be maintained/not exploitable (upper left) and not renewable/not exploitable (lower left). All these patents do not undergo a further analysis (second phase). Moreover, two patents lie in the lower right-hand quadrant. As planned in the framework, they pass to the second phase and have to undertake the evaluation fulfilled by the questionnaire. Finally, three patents lie in the upper right-hand quadrant. As suggested by the framework, the values of TS and IS of these three patents have been calculated. Of these three patents, all of them are considered as potentially exploitable since their TS and IS values are suitable to pass to the second phase: a patent has both TS and IS values higher than midrange values, another patent has the TS value higher than the midrange value and, finally, a patent has the IS value higher than the midrange value of the portfolio.

Fig. 5: The first phase of the framework in Selex Elsag, Selex Galileo and Selex Sistemi Integrati around here

In summing up, five patents circled in Fig. 5a have passed to the second phase, where their four properties have been evaluated about external exploitability. In Fig. 6a, the results of the questionnaire are synthesized.

Fig. 6: The second phase of the framework in Selex Elsag, Selex Galileo and Selex Sistemi Integrati around here

From the analysis of the evaluations gathered in the second phase of the framework, it has emerged that as for patents 1 and 3 the strategic decision is "maintaining". Indeed, the patent 1 is a proven and very innovative system, and Selex Elsag managers have confirmed that it can be implemented internally to the other companies of Leonardo group or exploited externally. Patent 3, instead, is currently in use and, for this reason, it is preferable to focus on internal exploitation than on licensing strategies, despite the high potential interest of the external market. A different approach has to be arranged for patents 2 and 4, for which the framework suggests a strategic decision of "selling". The patent 2 is completely out of the business line of the group. Selex Elsag managers charged a broker with selecting a buyer, other than a competitor of the companies of the group. The position of patent 4 is doubtful: even though it is still technologically conducive, as suggested by the latest citations from Siemens Germany and inventors, specialized in the field of the patent (such as Robert Louis Stone), Selex Elsag and Leonardo customers do not show interest in it. Similarly to patent 2, also for patent 4, it has been entrusted a broker with selling it; however, as it seems difficult to discard it, it is supposed to be abandoned. Finally, the strategy suggested by the framework for the patent 5 is "abandoning". Indeed, the patent was registered 13 years ago and was maintained because of its positive impact on the brand image of company's technologic capability within the sector.

The application in Selex Galileo

In line with what accomplished for Selex Elsag, we applied the framework to Selex Galileo. FCF and SER values of patents have been plotted on the Cartesian plane. As shown in Fig. 5b, most of patents lie in the upper and lower left-hand quadrant; this means that these patents are supposed to be kept (not exploitable). Three patents lie in the upper right-hand quadrant. As suggested in the framework, TS and IS values of these three patents have been calculated. For two of them, these values resulted in being around the mid-range value of the portfolio, while the third patent showed a very high TS value and an IS average value. Therefore, all the three patents circled in Fig. 5b have passed to the second phase.

In the second phase of the framework, the four properties of these three patents have been evaluated about their external exploitability. In Fig. 6b, the results of the questionnaire are synthesized.

From the chart (Fig. 6b), it can be seen that the exploitation strategy for the patent 1 is “licensing”. Nevertheless, managers from Selex Galileo have thought that this patent would face poor market opportunities as it is bordering on the maturity of its technology. Also, the strategy for the patent 2 is “maintaining”, as this patent shows a technological solution still in use on the product, along with a full technological maturity, and a worldwide coverage and protection. Finally, the strategy for patent 3 is “abandoning”. Indeed, this patent is technologically obsolete and it is going to expire within 2016.

The application in Selex Sistemi Integrati

In the same way, as for the previous companies, the framework has been applied to Selex Sistemi Integrati. FCF and SER values of patents have been plotted on the Cartesian plane. As shown in Fig. 6c, most of patents lie in the upper left-hand quadrant; this means that these patents are supposed to be kept (not exploitable). Only one patent lies in the lower left-hand quadrant, and this is considered as not

exploitable. In the upper right-hand quadrant, six patents are distributed. As suggested in the framework, TS and IS values of the six patents lying in the upper right-hand quadrant have been calculated. For three of these patent, the values of TS and IS result to be very low, that is lower than the mid-range value of the portfolio. For the other three patents, the values of IS resulted higher than the mid-range value. Therefore, three of the selected six patents circled in Fig. 3c have passed to the second phase.

In the second phase of the framework, the four properties of these three patents have been evaluated about its external exploitability. The obtained results are synthesized in Fig. 6c.

Data from the radar chart (Fig. 6c) have made clear that for patent 1 the exploitation strategy is "licensing". Effectively, this patent refers to a very innovative application that, however, is not core to the company as in Leonardo there are other alternatives and substitutable technologies. Managers from Selex Sistemi Integrati have agreed on the fact that patent 1 constitutes the typical example of an invention that is not bound for becoming an innovation and that too much investment is needed for it to develop a technology in use. Strategy for patents 2 and 3 is "maintaining", as patent 2 refers to an industrialization prototype, while patent 3 is waiting for an opportunity that could strengthen its development. Managers from Selex Sistemi Integrati have affirmed that it should be advantageous to go on investing in both specific technologies.

DISCUSSION

The more relevant considerations on the results analyzed above concern the functional efficiency of the audit framework. Firstly, it has succeeded in reducing the complexity of patent management problem, then, more specifically, it has accomplished the task of pointing out information derived from the analysis of the application of the framework to the case study of the three Selex ES companies.

The first of the two phases of the framework described above is based on an automated computing approach and makes use of bibliometric objective data. It thus allows for the reduction of the complexity

of a multidimensional problem by turning it into an objective decisional problem, based on subjective evaluations and perceptions obtained through questionnaires and managers' review workshops. The reduction of the complexity allows for the full involvement of the high-profile company management in a more detailed problem, concerning a strategic-competitive analysis of a limited number of items. This observation is confirmed by the fact that, by applying the framework to the study case, after the first phase, the number of patents under investigation has been reduced to 11 from the initial 273.

Moreover, it is necessary to put into evidence that the project modalities of the second phase of the framework have facilitated the direct involvement of managers in the decisional process, making use of their essential evaluations for a strategic management of the intellectual property.

A further advantage gained from the application of the second phase of the framework has consisted in the involvement of a high number of organizational functions of the company. This has allowed for a decision obtained through a company strategic insight, in full compliance with the company value proposition, rather than an outcome from few functional areas. Indeed, the decision of having structured the second phase in four macro-areas (Market Potential, Market Situation, Technological Potential, Technology Readiness Level) has derived from the need of taking into consideration the different opinions and perceptions of heterogeneous expertise, each having divergent company business interests. In practice, by applying the second phase of the framework in Selex-ES, it has been possible to take into account different opinions of managers such as chief technical officers, heads of engineering department, business developers, commercial agents, persons in charge of manufacturing processes, legal and paralegal counsels, heads of strategy, M&A supervisors.

Furthermore, the framework achieves the not negligible job of making managers converge on a complex and multidimensional decision. An industrial, as well as a technologic and commercial point of view, must be kept into consideration at the same time in order to decide on the strategic decisions of maintaining, licensing, selling, or abandoning specific patents. To obtain productive results and highlight business opportunities, it is necessary that a managerial discussion be enabled. Also, it is fundamental that the past, present and future investments made on each specific technology be taken into account, as well

as the real possible consequences of the strategic decision, the crucial threats, and the opportunities of the competitive context.

The above-mentioned considerations have been implemented for the patent strategic exploitation of the three companies Selex Elsag, Selex Galileo, and Selex Sistemi Integrati, each of them depending on different evaluations. Patents worthy to be admitted to the four strategic options have been the following: five in "maintaining"; two in "licensing"; two in "selling", and two in "abandoning". However, the analysis of the results has showed that supplementary consideration has guided the final destination of each of these patents:

- Among the "maintaining" ones: the technology of two of them has been considered immature; other two patents are still in use as products "off the shelf" and then have to be maintained as defensive patents; finally, another patent concerns a highly innovative technology and has to be protected and monitored carefully by the company.
- Among the "selling" ones, it has been decided to give the first patent an external broker for its commercialization and to abandon the latter in consequence of the difficulties of transforming its know-how into a realization.
- Among the "licensing ones", it has been resolved to give the first patent an external broker for its promotion to third parties; as for the latter patent – supposedly exploitable externally – it turned out to have a too small potential market, almost a niche, uneasily accessible by third parties such as SMEs, unable to valorize it by their investments.
- Among the "abandoned", the technology of the first patent has been considered obsolete, while the latter, even though not industrially relevant anymore, has been maintained in the portfolio because of its return in terms of image.

In summing up, the proposed framework illustrates a methodology that can be standardized and reproducible in industrial contexts. In addition, the framework is able to meet management requirements

of managing patent portfolios by means of structured procedures, which are usually adopted for strategic managerial initiatives, different from those concerning Intellectual Property.

CONCLUSIONS

It is acknowledged that, since large companies hold relevant resources, they are facilitated in putting into effect an IP strategy and handle IP issues promptly. However, large corporations have to cope with several IP strategy problems, such as the need for a continued investment to support their technological and innovation strength and for an appropriate strategic management of patents. In this view, the aim of this paper was to shape a framework that could support the decision of IP managers on the strategic supervision of patent portfolios.

The framework has been built to provide a suitable decision support tool that was in-line with the expectations by the IP managers of the involved companies. The developed framework has proved to be particularly able to understand whether patents are aligned to the overall business strategy, to select those that are not aligned and to identify the most appropriate exploitation strategy for each patent of the portfolio. Moreover, the empirical findings of the application of our framework have substantiated the possibility for the managers of a large company to be effectively supported in quickly assessing technologies of their voluminous patent portfolios when tackling their decision process on the exploitation of each patent. This has been confirmed by the fact that the companies, once approved of the suggestions provided by the framework, implemented them promptly. Moreover, the usefulness and practicability of the framework have been validated by questioning the involved managers that acknowledge that they derived faster decisions when using the framework.

The findings of this study suggest that the framework, by reason of its rapid and efficient performance, can be employed periodically in order to check for patents' healthy life cycle development, with a particular attention to those patents that linger on without a satisfying strategic-economic relevance for a "long" time lapse and are bound to be abandoned. A secondary, but positive result of the application of

our framework to a large company has been that, by virtue of its questionnaire-structured interviews, it has helped a more purpose-effective internal communication among the different levels of supervisors and employees on patent management action items, in order that an exploitability policy could derive from collective decisions.

Despite the fact that the three applications of the framework referred to a specific sector of industrial activity, it is possible to generalize its use, by framing its structure in dependence of its implementation into different industries. However, approaches of this kind carry with them some shortcomings related to the choice of the numerical values inherent to the intervals of the quadrants, in the first phase, and to the numerical combinations between the properties and the exploitation strategies, in the second phase. However, even if these aspects can represent a limitation of the framework, both the selections mentioned above can be varied in dependence of the peculiarities of the patent portfolio, such as its internal homogeneous or not homogeneous structure.

An important limitation of the present study lies in the fact that the collected data refer to three organizations of the same company, placed in the same national geographic location. More research is therefore needed to derive data from firms and industrial settings at different locations. By starting from the findings presented in this work and looking to directions for future research, further work could address: a) the analysis of other business sectors; b) the benchmarking of larger study applications; c) the development of a multiple case study relative to different industries.

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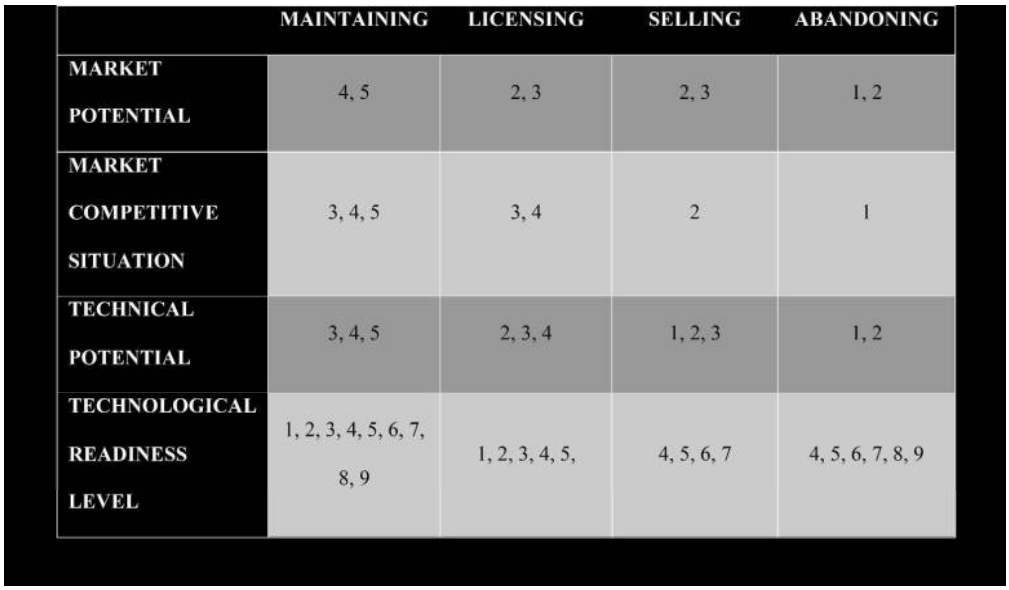

	MAINTAINING	LICENSING	SELLING	ABANDONING
MARKET POTENTIAL	4, 5	2, 3	2, 3	1, 2
MARKET COMPETITIVE SITUATION	3, 4, 5	3, 4	2	1
TECHNICAL POTENTIAL	3, 4, 5	2, 3, 4	1, 2, 3	1, 2
TECHNOLOGICAL READINESS LEVEL	1, 2, 3, 4, 5, 6, 7, 8, 9	1, 2, 3, 4, 5,	4, 5, 6, 7	4, 5, 6, 7, 8, 9

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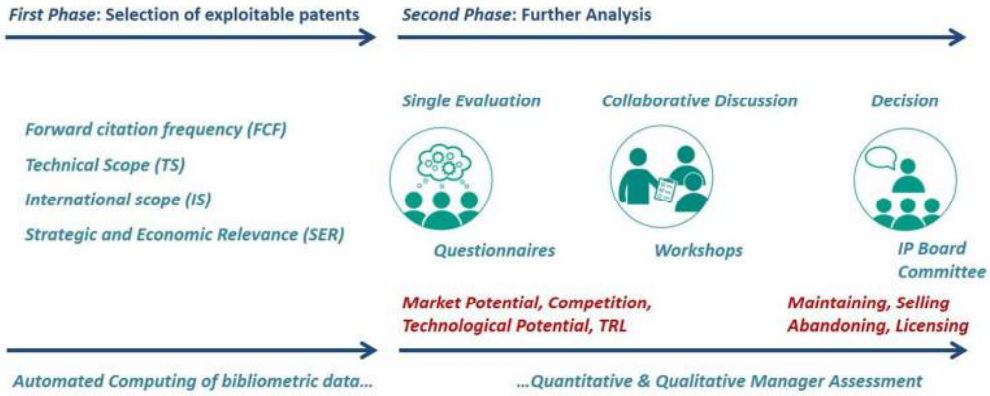
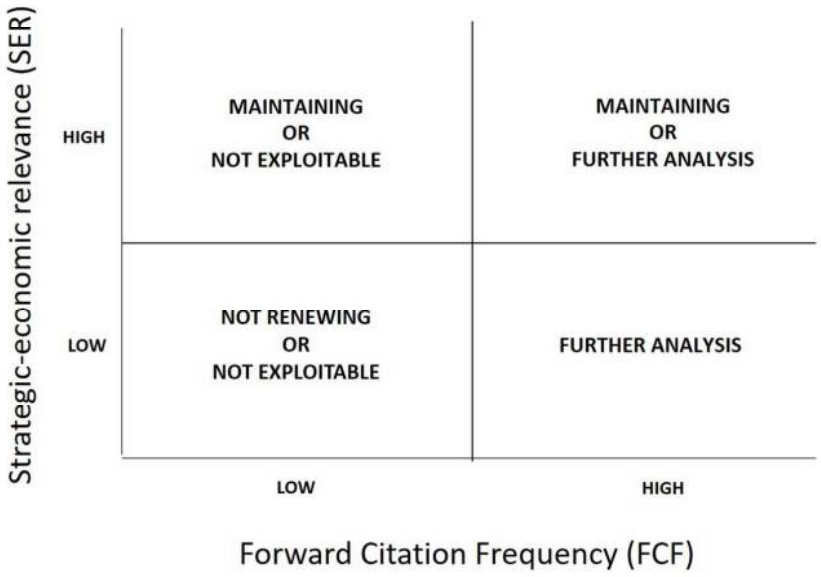


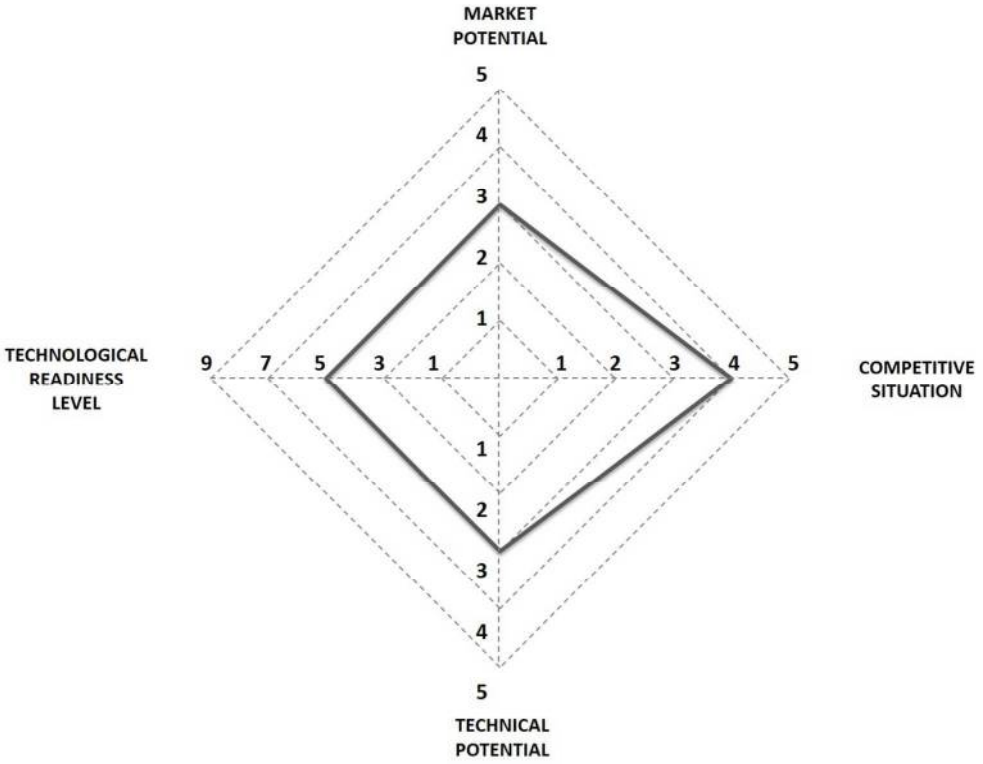
254x104mm (150 x 150 DPI)

Dimension	Indicator	Formula
Forward citation frequency	**FCF**	$FCF = \frac{\text{Number of forward citations/Age of the patent}}{\text{Maximum number of forward citations of the patents of the portfolio in the same IPC class and period}}$
Technical scope	**TS**	$TS = \frac{\text{Number of claims of the patent}}{\text{Maximum number of claims of the patents of the portfolio within the same IPC class}}$
International scope	**IS**	$IS = IS_a + IS_b$ where: IS_a depends on number and typology of countries and assumes a value comprised between 0 and 0.7 in dependence of the number of those countries where the patent has been granted. IS_a is the result of three contributions: a value of 0.1 if the patent is granted in U.S.A.; a value up to 0.2 if the patent is granted in more than 2 European countries; a value up to 0.4 if the patent is granted in more than 6 extra-European countries. IS_b is a dummy variable that takes null value or 0.3 value in dependence of two different situations of patent granting: the Patent Cooperation Treaty (PCT) procedure and the triadic share.
Strategic and economic relevance	**SER**	Mean value of Patenting Strategy and Economic Relevance, where: Patenting Strategy: Scale of patent qualitative judgments of managers turned into quantitative data (competitive = 1, business = 0.66, defensive = 0.33, not essential = 0). Economic Relevance: Scale of patent qualitative judgments of managers turned into quantitative data (Core=1; High=0.75; Medium=0.50; Low=0.25; No relevance = 0).

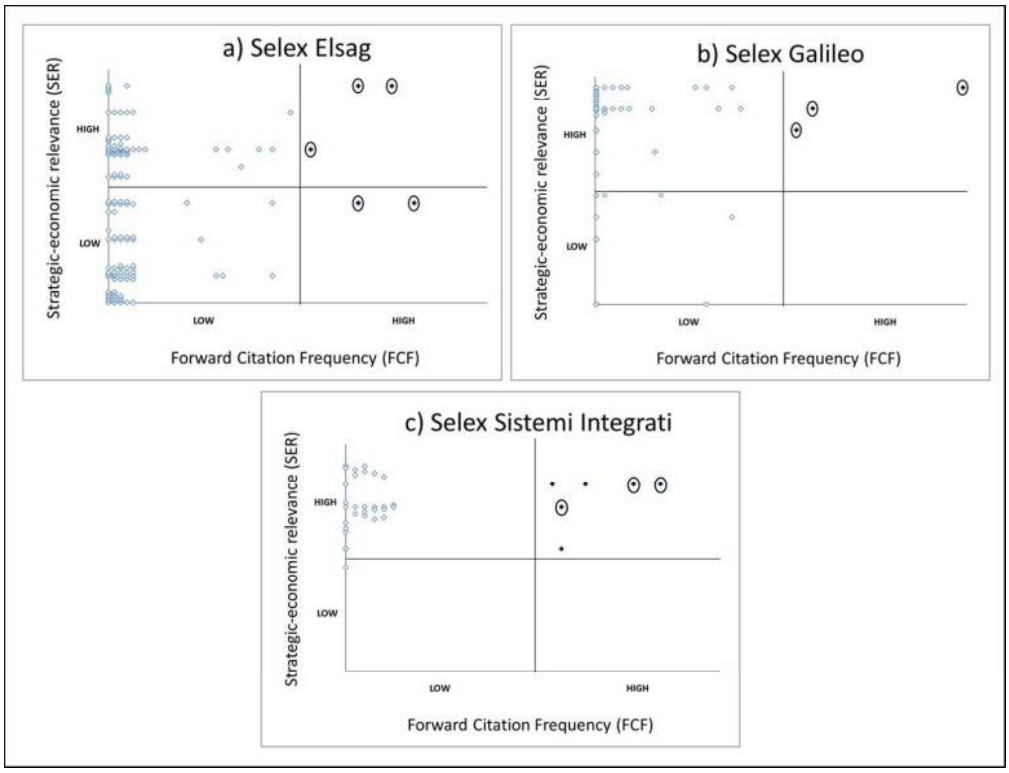
183x145mm (150 x 150 DPI)



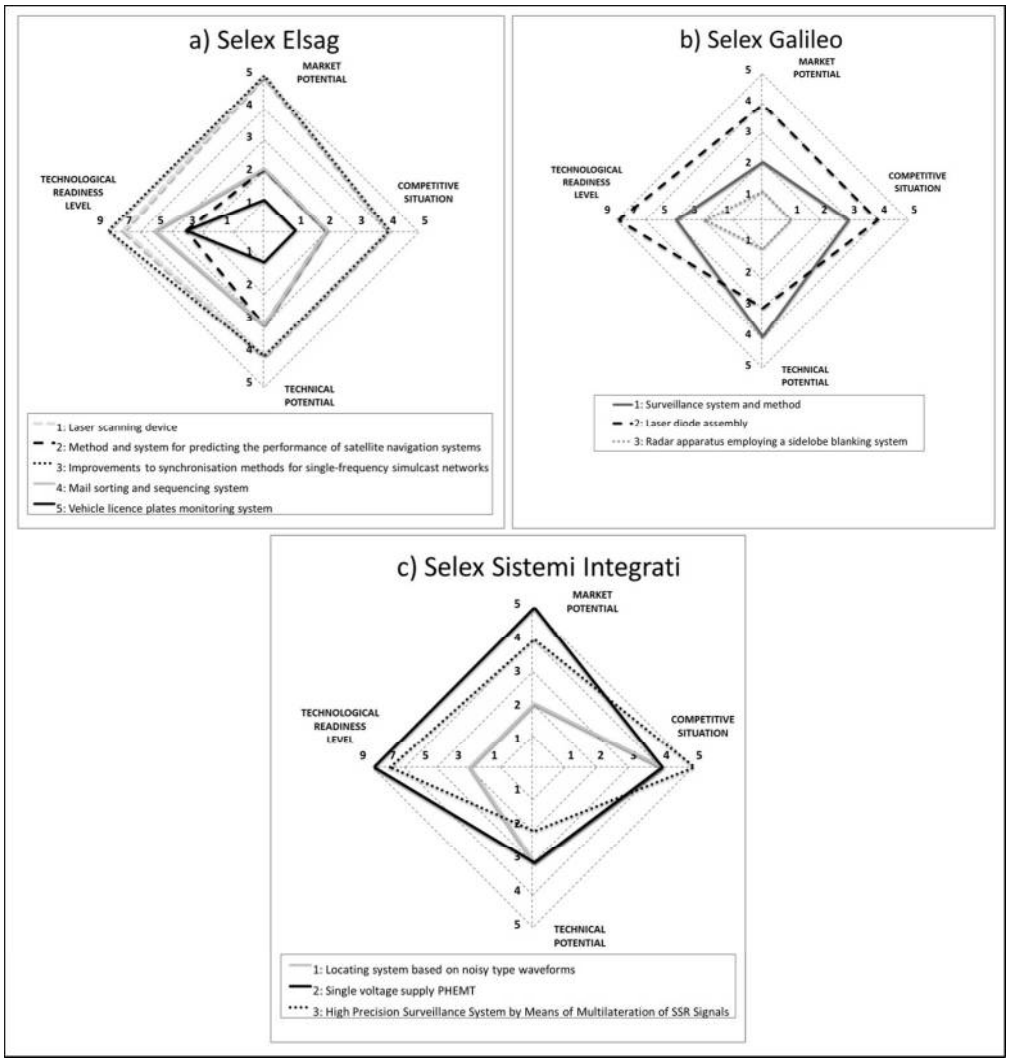
251x166mm (150 x 150 DPI)



242x189mm (150 x 150 DPI)



246x187mm (150 x 150 DPI)



249x262mm (150 x 150 DPI)