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MANAGING R&D AND INNOVATION PROJECTS: AN INTEGRATED CONCEPTUAL MODEL FOR TECHNOLOGY TRANSFER

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Abstract

Projects start with an idea, which is deployed into a set of actions to deliver expected or foreseen outcomes, and they should be carried out in a cohesive and unified context. In this article contributions are devised to integrate project management and technology transfer practices to drive the transformation of knowledge into innovation within the scope of research and development projects at universities and research laboratories or centers. These contributions are presented in the form of a conceptual model that includes three interrelated groups. The first group is focused on project ideas definition and selection, the second group on project management, and the third group on knowledge and technology transfer, these groups are supported by improvement, innovation and project management guidelines and standards. To obtain insights to define the model, quantitative and qualitative methods have been used and the data was processed using content analysis and descriptive and inferential techniques meant to ensure the complementarity of the data to obtain a holistic understanding of the practices under analysis. The approach was exploratory and descriptive, but also analytical in the sense that it states the issues at stake to support project management and technology transfer.

Keywords
Research and development; Project management; Technology evaluation and licensing; Technology transfer; Innovation.

1. Introduction

In this article, a conceptual model is proposed anchoring project ideation, project management and technology transfer, to drive the transformation of knowledge into innovative, competitive products and services that are critical for competitiveness, long-term sustainability and growth. The model, primarily targets research and development projects in the context of universities or research labs or centers, some of its concepts, such as the cooperation between technology transfer offices, or the cooperation between R&D teams with similar and/or convergent purposes are mainly applicable among universities.

The model includes three interrelated groups: (1) surveillance, ideation and selection, (2) project management and (3) knowledge and technology transfer. The goal is to set the stage to take the lead of innovation by strategically driving R&D projects thinking on benefits, market needs, and project outcomes that are both efficient and of the highest quality since the project inception till the disclosure of the project deliverables to the university technology transfer office to generate wealth through knowledge and technology transfer.

The conceptual model shall not be understood as prescriptive or linear, it shall be understood as a reference for R&D and innovation projects targeting knowledge and technology outcomes and its market release, being up to each organization to determine which concepts and practices should be used.

2. Data and methods

To support the design of the conceptual model two objectives have been defined upfront:

1st objective: to gain knowledge about R&D and Innovation project management practices adopted by companies. The scope of the study addressed the practices of companies certified under the Portuguese standard NP4457 that defines the requirements of an R&D and Innovation system, as well as, non-certified companies holding R&D units, according to the Portuguese scientific and technological potential survey (IPCTN, 2017[1])

2nd objective: to gain understanding about knowledge and technology transfer practices employed by Technology Transfer Offices (TTOs) to value project outcomes.

To address the first objective, an on-line semi-structured survey has been created to support data collection. The survey included 107 questions referring to project management practices, namely, 13 questions referring to the project initialization process, 48 to the planning process, 10 to the execution process, 29 to the monitoring and controlling process and 7 to the closing process. The questions aimed to characterize the frequency of use of each practice. Respondents based their answers on a scale from 0 to 5, where 0 corresponded to "was never used" and 5 to "always used". The survey has been answered by 15 out of 164 certified companies under the standard NP4457 (IPAC, 2017[2]), and 34 out of 1511 companies with R&D units not certified under the standard NP4457 (IPCTN, 2017).

Companies certified under the standard NP4457 "Certification of research, development and innovation management systems", have been the target of the survey, because this standard defines the requirements of a research, development and innovation system (R&D+I) and is supported by the standard NP 4458 that defines the requirements of an R&D+I project. NP 4458 is meant to facilitate the systematization of R&D+I projects and improve its management. This standard is used as a reference to identify the project characteristics and ensure its planning, documentation, realization and evaluation, and certified companies under NP 4457, are expected to have more mature and defined project management practices, when compared to non-certified companies.

The survey was also answered by 36 project management students from the Alumni Association of the University of Minho (AAEUM) to get to know their expectation of applying the practices under analysis. Data analysis involved descriptive and inferential statistics, following standard procedures, and using the ANOVA one-way, the Levene test to assess the variables homogeneity and the Scheffe test to assess if there were significant differences between groups in the sample. For the analysis, a confidence interval of 95% has been used. Data analysis was supported with the software IBM SPSS Statistics.

[1] IPCTN - Portuguese scientific and technological potential survey. DGEEC – General direction of statistics in education and science. http://www.dgeec.mec.pt/np4/44/?page=0, July, 2021.

[2] IPAC - Portuguese institute of accreditation. http://www.ipac.pt/, July, 2021.

To address the second research objective, a semi-structured survey has been used to collect information among eight TTOs of Portuguese Universities, namely:

1. University of Minho: TecMinho
2. University of Porto: UPIN
3. University of Aveiro: UATEC
4. University of Coimbra: DITS
5. University of Beira Interior: Innovation and development office
6. University Nova of Lisboa: RIA – Research and Innovation Accelerator
7. University of Évora: Technology transfer office
8. University of Algarve: CRIA

Five out of the eight universities appear regularly in world rankings of the top 1000 universities (CWUR, 2019). The semi-structured survey was divided in two parts, one focused on the frequency of use of technology evaluation practices, and the other one on the frequency of use of evaluation methods and instruments. A rating scale, ranging from 1 to 5 has been used, where 1 corresponded to “was never used” and 5 “very frequently used”. The survey also included open-questions to get to know initiatives developed by TTOs to pull investment and push R&D and technology towards industry. The approach was exploratory and descriptive, but also analytical in the sense that it states the issues at stake in the process of technology evaluation and licensing.

3. Project ideation, management and deliverables valorization

3.1. Project ideation

To gain knowledge and competitive advantage many organizations are investing substantial resources in research and development (Jeng & Huang, 2014). However, R&D investment decisions are usually taken based on information which many times is highly uncertain, inaccurate, unclear regarding technical applications, products and market outcomes (Eldermann, 2012). Selecting which R&D projects to undertake is crucial not only to move forward the state of the art but also to ensure technology transfer of project outcomes. Selecting valuable R&D projects that satisfy market demands, technological trends and future industrial developments is a challenge for organizations and specially for those organizations working on applied research and technology developments, like many University associated laboratories or research centers. R&D selection involves major considerations, such as, the association of the project with the organization strategies, assessment of qualitative and quantitative benefits and risks of undertaking the project, and integration of the stakeholders needs and desires through product, service or technological improvement or differentiation (Jeng & Huang, 2014).

The decisions as to which project ideas should be developed into preliminary concepts and then into project proposals and afterwards which of these proposals should become projects implies an efficient screening process to better fund valuable project proposals (Cooper, 2008 and Heising, 2012).

In addition, an efficient screening process will benefit from a previous focused ideation process, that is aligned with the organizational vision and strategic goals (Boeddrich, 2004 and EFQM, 2020), therefore, a focused ideation strategy will canalize creativity, which might lead to figuring out valuable ideas that fit the scope and boundaries of the organization (Salomo et al., 2008 and Kock, Heising and Gemunden, 2014), rationalizing the scouting, scanning and screening process of project selection.

Scouting, Scanning and Screening are concepts typically used in scrutiny, diagnosis, retention, evaluation and selection actions e.g. Technology scouting and scouting networks (Rohrbeck, 2010); Knowledge-scanning innovation methods (Arundel & Casali, 2015); Screening for prospective innovations that provide focus, action-oriented, and comparable reflections of future developments. (Könnölä & Salo, 2007).

To obtain a well-balanced portfolio of promising ideas, concepts and project proposals, organizations must (1) establish organizational conditions to generate a sufficient number and variety of high-quality ideas aligned with its vision and goals, (2) it must implement processes and routines to search, retain, evaluate, select and further elaborate the most promising ideas and concepts and (3) it must ensure that those promising and high-quality opportunities relevant to the organization future business are pursued (Ernst & Kohn, 2007, Koen *et al*., 2001 and Kester, *et al*., 2011).

Encouragement of new idea generation and expression is an organizational condition that facilitates creativity (Mainemelis, 2010) and a systematic assessment of search criteria and search fields with clearly defined goals for ideation provides focus and allows organizations to concentrate their resources on further elaborating those ideas that are consistent with specific market and costumer needs or that are deemed to be relevant for the organization future and core competencies (Solomo et al, 2008 & Kock, Heising and Gemunden, 2014).

According to the Portuguese standard NP4457 "Certification of research, development and innovation management systems" the organization must establish procedures for the capture, analysis, evaluation and pre-selection of ideas in order to assess which ones can constitute opportunities for innovation (article 4.3.2, p.10, NP4457). In this context, the organization must:

1. Ensure the circulation and transfer of knowledge through the analysis of its internal and external environment, identifying elements within the organization that ensure the flow of communication and exchange of information (refer to points a., b. and c. of article 4.3.1, p.9, NP4457);
2. Identify and plan surveillance, cooperation and technological forecasting activities, necessary for the transfer of knowledge, continuous improvement and disruptive innovation and the valorization and exploitation of technology and intellectual property rights (refer to points d. and e. of article 4.3 .1, p.10, NP4457);
3. Identify, provide and organize internal creativity activities (which include problem solving and opportunity identification and analysis activities) and knowledge management tools that drive learning, change, discovery and application of new solutions, ensuring that they are planned, implemented, maintained and updated (refer to point f. of article 4.3.1, p.10, NP4457);
4. Define criteria for the evaluation and selection of ideas that must be consistent with the mission and strategic orientation of the research, development and innovation policy (refer to article 4.3.2, p.10, NP4457);

5. As far as relevant, proceed with the assessment of the potential market considering risk factors, technical and economic feasibility criteria, and legal, social, technological and financial requirements (refer to article 4.3.2, p.10, NP4457);
6. Determine and ensure the necessary resources for RDI (Research, development and innovation) activities and for the enhancement of the portfolio of knowledge, technology and intellectual property rights (refer to point g. of article 4.3.2, p.10, NP4457);
7. Establish procedures for the collection, documentation, analysis and processing, dissemination and valorization of knowledge (refer to point h. and j. of article 4.3.1, p.10, NP4457).

A strategic innovation orientation, as set by NP 4457, signals the importance of idea generation, knowledge integration, evaluation, prioritization and selection to effectively and efficiently further develop promising ideas and concepts into projects that blend R&D, project management and innovation to successfully value knowledge and technology outcomes.

3.2. Models supporting project management

To drive knowledge advancement, innovation and organizational excellence several models have been developed. One of those models is the Project Excellence Baseline, by the International Project Management Association (IPMA) to assess and reward projects and programs. The model is derived from Total Quality Management (TQM) and models such as EFQM model from the European Foundation for Quality Management (IPMA/PEB, 2016).

The three key areas of the IPMA model are: people and purpose, processes and resources and project results. These areas are closely related to the EFQM criteria often used for the assessment of organizational performance (IPMA/PEB, 2016).

The IPMA Project Excellence Model is used as an assessment tool for projects that apply for the IPMA International Project Excellence Award (IPMA/PEB, 2016), but the model is suitable to assess projects outside of the award process and if correctly used can help with continuous improvement and help organizations to achieve their project goals (Kristinsdóttir & Jónsdóttir, 2017).

Project success can be achieved by applying and accommodating management principles and knowledge from various project methodologies, the PMI Pulse of Profession 2019 report, highlights that increasingly project management professionals enrolled in innovation processes are implementing hybrid project management practices. Hybrid project management approaches use a combination of traditional and agile methodologies accepting the fluidity of projects and allowing for a more nimble and nuanced approach, the project methodologies can be applied completely or partially increasing its flexibility and building unique strengths (Papadakis & Tsironis, 2018 and Jovanović & Berić, 2018).

Project management methodologies must also be tailored to the organization context, needs and to the specific requirements of the project (Avery, 2015).

Using tailored and standardized practices and procedures allows project managers to implement an appropriate management plan (PMI Pulse of the Profession, 2015).

Organizations should be able to use a number of available project management methodologies and to observe a principle of amendment or remake and adjustment of them to a certain type of project (Chin & Spowage, 2010). Shenhar & Dvir, 2007, in the book "Reinventing project management: the diamond approach to successful growth and innovation" present the "Diamond framework" an adaptative model for planning and managing projects that includes four dimensions (1) novelty, (2) technology, (3) complexity and (4) pace, and each dimension can be seen as a base that represents three or four possible project types:

1. Novelty includes three types: derivative, platform, and breakthrough;
2. Technology includes four types: low-tech, medium-tech, high-tech, and super-high-tech;
3. Complexity of the product, the task, and the project organization includes three types: assembly, system, and array (or system of systems);
4. Pace, how much time do we have to complete the work, it includes four types: regular, fast/competitive, time-critical, and blitz.

The diamond framework was designed to figure out the uniqueness of the project in the proposed four dimensions to understand the project, and to diagnose gaps between our capabilities and what is needed to make the project a success.

Further developments have been done taking per reference the diamond framework, such as, the "Strategic Project Leadership (SPL)" approach by Shenhar (Shenhar, 2004 and Shenhar 2015), that aims to inspire project managers to be leaders, inspiring and motivating the team, and connecting the project to business results. To this end seven principles have been proposed (Shenhar, 2004 and Shenhar, 2015):

1. Leadership: Project managers must be leaders responsible for business results.
2. Strategic project portfolio management: projects should be grouped and selected based on their strategic impact and different types of business objectives.
3. Project strategy: The competitive advantage of project outcomes must be defined to win in the marketplace.
4. Project spirit: Define a project vision and a compelling project spirit that will support the strategy and create energy, motivation, and commitment among team members.
5. Adaptation: Assess the project and tasks context and environment to classify the project using the diamond framework to select an adequate project management approach.
6. Integration: Create an integrated project plan considering the strategy, the spirit, the organization, the processes, and project tools (Shenhar, 2004).
7. Learning: Create a project learning organization that captures lessons from its deployment and monitoring and controlling tasks.

"Strategic Project Leadership (SPL)" is an integrated approach to inspire project managers to be business leaders of their projects addressing the projects uncertainty in a dynamic and flexible way engaging and empowering people and teams to instill energy, gain commitment and to influence innovative and successful project outcomes (Shenhar, 2015).

Project management references such as PMBOK (PMI, 2017), Prince 2 (OGC, 2009), SCRUM (Schwaber & Sutherland, 2013), Kanban (Alcarria, *et al.*, 2019), RUP - Rational Unified Process

(RUP, 1998), eXtreme Programming – XP (Beck & Andres, 2004), Dynamic systems development method – DSDM (Voigt, 2004), Feature Driven Development – FDD (Fridaus, 2014), Crystal clear, Crystal orange, and Crystal orange web methodologies, which rely on incremental development cycles, wide communication flow, and good collaboration (Cockburn, 2002), the project management diamond approach to successful growth and innovation (Shenhar & Dvir, 2007) and Strategic project leadership approach (Shenhar, 2004 and Shenhar 2015), among other project management references, can be used to guide project deployment.

Guiding or requirement standards can also be used, such as the ISO 21500, which provides guidance on the application of concepts and processes of project management with the goal of improving project management performance, and the Portuguese standards NP 4458, which establishes the requirements to manage R&D and Innovation projects, and NP 4457, which defines the requirements of an R&D and Innovation system.

Notwithstanding, supporting models aiming not only at project success, but also and for most, on achieving operational excellence and how it can be sustained, can be considered.

One of the most notorious work and model has been developed by Shigeo Shingo according to the Shingo Institute, the Shingo Prize is the world's highest standard for organizational excellence. (Shingo Institute, 2020).

The Shingo model is oriented by a baseline of principles to establish a culture of continuous improvement and sustainable success including the alignment of management systems and the wise application of improvement techniques across the entire organizational enterprise. These guiding principles are divided into four dimensions: results, enterprise alignment, continuous improvement, and cultural enablers (Kelly & Hines, 2019).

The Baldrige excellence framework is another reference that can be considered when aiming at sustainable success and organizational success, this reference provides leadership and management practices for organizations to achieve high performance (Baldrige Foundation, 2019).

According to PMI (Project Management Institute), over 80 per cent of high-performing organizations report that the most important skill to successfully manage complex projects are leadership skills "to deal with ambiguity, take ownership of the vision, foster collaboration, gain buy-in and motivate the team to achieve the expected outcomes" (Madsen, 2015).

Project management models and methodologies support project managers and teams to bridge the conversion of a project idea into a project deployment, transforming knowledge and resources into project outcomes, that must be transferred to those organizations and people that can translate deliverables into technical and service innovations or knowledge for the advancement of science and future discoveries.

3.3. Project deliverables valorization

Technology transfer "refers to the process of conveying results stemming from scientific and technological research to the marketplace and to wider society, along with associated skills and procedures, and is as such an intrinsic part of the technological innovation process" (CCTT, 2021).

The technology innovation process links research and project deployment to its application or use creating utility for the ones who benefit from the project outcomes. Utility is expressed as benefits that go beyond the opportunity of making money, and it usually involves performing a technical and market assessment, protecting intellectual property rights, promoting, negotiating, and reaching a commercial deal for a technical solution that is novel, has industrial applicability and involving an inventive step that moves knowledge and technology forward (Hockaday, 2020).

To disseminate and effectively exploit the project results in view of reaching the market, within universities, the project results must be disclosed to the Technology Transfer Office (TTO). The main goal of University technology transfer offices is to assess, protect and support researchers in their efforts to value knowledge and to promote and commercialize technology (Young, 2007 and Fitzgerald & Cunmingham, 2016).

TTOs when aiming to understand the technology and its market potential, conduct patent searches and market assessment evaluations to figure out the invention novelty, inventive activity and industrial applicability, and also to identify competing technologies targeting the same or similar issues to determine market potential and utility (Speser, 2006). Additionally, technology transfer professionals want to identify the strongest links between the technology, its applications and its market. The TEC algorithm (Technology, Entrepreneurship, and Commercialization Algorithm) can be used to analyze the technology alternative applications to determine which have a stronger link between Technology, Product and Market (T-P-M) to relate the technology capabilities to product ideas and to the customers real needs to figure out what constructs are most valuable for market niches (Schiltz, 2019).

An effective intellectual property management is essential to protect future investments, to support business strategies and gain competitive advantages, and also to unlock the potential of science and technology to continue to built-in and spin-out valuable outcomes from R&D projects. To value those outcomes there are essentially three options, we can either keep the technical solutions as a secret, we can publish the results or we can apply for a patent (Hockaday, 2020). Within the academic realm keeping a technical solution a secret is not usually an option unless the research team is considering the creation of a university spin-off company. Publishing is the straightest route, but in Europe publishing before applying for a patent means that the invention will belong to the public domain (EPO, 2021), while in the US inventors have a grace period of one year for filing a patent after public disclosure (USPTO, 2021).

The way to grant profit from inventive results is to file for a patent and to pursue technology transfer by making it visible and accessible, either in technology transfer websites and databases, such as the Enterprise Europe Network[3] or by attending industry exhibitions and technology transfer events, but most of all, by contacting potential licensors and collaboration partners and investment parties, such as business angels or venture capitalist in case the research team has decided to create a spin-off company.

Upon receiving a manifestation of interest negotiation begins to get a balanced win-win agreement, this agreement can be reached either through selling, licensing or through a spin-out

[3] Enterprise Europe Network: https://een.ec.europa.eu/, July, 2021.

company creation (WIPO, 2005). In case of selling the new owner will have all the rights over the intellectual property assets, in the case of licensing multiple considerations must be negotiated, including level of exclusivity and rights over further developments, in the case of a spin-out the technology will be licensed to the newly created company (EU-2008/416/EC). Other types of agreements are possible, such as collaboration and consortium agreements but they are first-of-all meant to further advance knowledge and technology and not as much to gain profit outcomes. Collaboration agreements concern the development of projects and tasks of common interest where parties provide access to knowledge, skills and intellectual property rights to one another usually under non-disclosure agreements and intellectual property rights provisions regarding co-ownership of research results. Consortium agreements can bring together many parties: such as, companies, research labs of the same or different research fields, and universities, adding complexity to the intellectual property rights management, but they also provide a ground for a more successful technology transfer due to the involvement of industrial companies and partners (Hsu, Shen, Yuan & Chou, 2015).

Knowledge and technology transfer shall be the ultimate goal of R&D projects, the challenge must start from early R&D to strategically think ahead and make decisions that ensure projects are of highest technical quality addressing market and society needs to create sustainable competitive advantages that can bring gains to companies and other stakeholders willing to license, invest or get hands-on project outcomes (Yunhe, 2010).

3.4. Motivation to propose an integrated model for technology transfer

There are several models and frameworks that can be considered to support project managers and organizations to achieve sustainable performance and results, however, a conceptual model anchoring project management principles and culture to surveillance, ideation, selection and technology transfer, is seldom clearly presented in the reviewed models and frameworks. To address this interconnection, a conceptual model for technology transfer is proposed, anchoring market surveillance endeavors, project management processes and technology transfer practices. The model, presented in this article, primarily targets the integration of research and development projects in the context of universities or research labs or centers, but it is not exclusive and can be applied by organizations engaged in research and technology development aiming to successfully transfer project outcomes to organizations and people that can benefit from technical and service innovations or from knowledge that can advance science, people skills and future discoveries.

4. A Conceptual Model for technology transfer

4.1. 1st group: Surveillance, ideation and selection

The first group of the conceptual model, presented in subsection 4.4., refers to technology and market surveillance, ideation and project ideas analysis and selection, and includes scouting, scanning and screening actions, and supporting activities.

Scouting, Scanning and Screening, these three concepts are typically used in scrutiny, diagnosis, retention, evaluation and selection actions e.g. Technology scouting and scouting networks (Rohrbeck, 2010); Knowledge-scanning innovation methods (Arundel & Casali, 2015); Screening for prospective innovations may provide more focused, action-oriented, and comparable reflections of future developments. (Könnölä & Salo, 2007).

Among the supporting activities to be fostered are:

a. Cooperation between R&D teams with similar and/or convergent purposes to enhance knowledge and resources, coming either from the same or different research fields, in which cooperation is perceived as advantageous to reach project outcomes.
b. The establishment of industrial and strategic partnerships to leverage resources and seek technology adoption, and also to develop tailor-made projects, projects to create a new product or a new integration of a product into a system, or to update, replace or diversify a product or product range and specifications, or to solve a particular problem or to pursue a desired knowledge or technological advancement.
c. TTOs (Technology Transfer Offices) identification of R&D investment programs, to pull investment and push R&D and technology towards industry, and also to promote an intellectual property and entrepreneurial culture among researchers.

Scouting includes knowledge acquisition activities, including internal and external environment analysis (what we have, what we want and idealize), the analysis and description of the technical and scientific state of the art (including literature and patents review – "patents review reduce R&D costs and time" (Smith, 2005)), considering industrial surveillance practices, technological forecast, market demand and trends analysis, and ideation and creativity actions. The concepts, opportunities and knowledge gained through scouting activities should be reviewed to identify the most relevant inventive concepts and insights which should be systematized and selected to become part of the portfolio of ideas susceptible of being developed[4] – the establishment of a portfolio of ideas susceptible of being developed is the purpose of the «scanning» actions.

Scanning implies the analysis of the collected information, knowledge and insights raised during the scouting actions, compiling and organizing it, considering its impact and alignment with research lines and business context and scope, striving to figure out emergent trends and valuable deliverables. From this organization and systematization work, the most promising concepts with foreseen market and scientific potential must be retained as a baseline for developing specific projects. The ultimate aim of the scanning process is to create a portfolio of project ideas that might be developed in the short, medium or long term, according to a given context and available resources, which may deem them doable and viable – this focused, action-oriented and comparable assessment of project ideas must be done during the «screening» process (Könnölä & Salo, 2007).

[4] The «backlog» concept of the SCRUM methodology (Schwaber & Sutherland, 2013) can be applicable to this stage of the conceptual model, in the sense that we want to obtain a list of items, ideas, requirements, stories, specifications, characteristics, etc., which may be carried out to obtain portions of project work. The model also mentions the concept of «sprint» which refers to work packages to be carried throughout the project.

Screening refers to the selection of a project idea and related concepts and information to deliver defined outcomes. In the scope of the screening stage, are comparable assessments of project ideas, to determine the most feasible, desirable and valuable ones attending to specific goals and constraints. In this assessment process multiple evaluation methods can be used, among which, are multicriteria decision-making methods that allow us to consider tangible and intangible assessment criteria, such as:

a. AHP – Analytic Hierarchy Process (Saaty, 2005), which uses a preference scale to rank the options and their criteria through paired-wise comparisons;
b. ELECTRE – Élimination et Choice Traduisant la Réalité (Figueira and Roy, 2005), is an outranking method, which uses reference threshold as acceptable limits for tradeoffs;
c. PROMETHEE – Preference ranking organization method for enrichment evaluations (Brans and Marschal, 2005), is also an outranking method, which uses reference thresholds to rank the options under assessment;
d. PROV exponential decision method – Preferences Ranking and Options Value using linear and exponential normalization (Rocha, *et al*., 2012 and 2013), is a method developed to express the stakeholders knowledge, objectives and preferences using linear and exponential methods to identify the most promising options.

The scouting, scanning and screening processes, are recursive and interactive processes meant to gather knowledge and information to base and enforce the project idea(s) to be developed, and at this first stage of the model, it is essential to determine, which parts can provide the required material and financial resources and also, which connections and people can support us transforming the project idea into valuable deliverables that will be licensed or sold. In this respect, the establishment of industrial and strategic RTD (Research and Technology Development) partnerships must be considered to leverage resources and seek technology adoption, as well as the cooperation between R&D teams with similar and/or convergent purposes to enhance knowledge and resources, being the support of technology transfer offices, technology clusters or similar organizations useful in the identification of R&D investment programs, to pull investment and push R&D and technology towards industry, and also to promote an intellectual property and entrepreneurial culture among researchers.

4.2. 2nd group: Project management

Projects start with an idea, which is deployed into a set of actions to deliver expected or foreseen outcomes, and a conceptual model reinforcing project management processes may give us a more coherent and integrated understanding of the work to be done, as represented in the model presented in subsection 4.4.. Typically projects are demanding, dynamic and non-repetitive (PMI, 2013) and a single project management methodology is not expected to serve all projects, it may well be advantageous to combine different project management approaches, both, formal and agile (Spundak, 2014). Formal, to have a macro-perspective of the project and a basis to monitor the work planned and deliverables. Agile, to guide short term activities and deliverables, which can be planned as «sprints» to be done and reviewed to plan further «sprints» i.e. chunks of work to be accomplished in the short term as described in the SCRUM methodology (Schwaber & Sutherland, 2013).

A project management methodology with sufficient margin to incorporate agile practices may help us to cope with the unpredictability and uncertainty of project events, occurrences, stages and outcomes while keeping track of business trends and product and market dynamics. In this context it is useful to have an integrated vision of the systems to be deployed, which may require several stages of development, including basic, applied and experimental research (Faulconbridge & Ryan, 2015). In compliance with the identified project development stages the project must be planned and executed. To guide an R&D and innovation project, international standards can be used, e.g. ISO 21500 establishes the guidelines for project management, NP 4458 establishes the requirements to manage R&D and Innovation projects, and NP 4457 defines the requirements of an R&D and Innovation system. These standards serve as an underline framework for the proposed integration model supporting project processes i.e. initiation, planning, implementation, control and closure (PMI, 2013), which include the project scope, time, resources, costs, quality and risk management, communication, acquisition and the project work and deliverables alignment with its context and stakeholders, to move the project results towards its application and valorization in compliance with the purpose of the 3rd group of the conceptual model.

To this end, project managers are required to have a systems approach and a much greater level of understanding of non-technical issues surrounding technological invention and innovation (Grasso & Burkins, 2010). Projects when linked to the organization strategy act as engines of innovation, and managing technology, people and project specificities have to be considered holistically (Apenko, 2017), with context taking perspective, setting the stage for, and playing a prominent role in the collaborative development of solutions (Guthrie, 2010).

Therefore, organizations should focus on fundamental aspects of culture, talent and processes that support excellence in project, program and portfolio management to meet their goals (PMI Pulse of the Profession, 2015). Principles of excellence and culture as stated in the EFQM model (EFQM, 2019), Shingo model (Shingo Institute, 2020), Baldrige excellence framework (Baldrige Foundation, 2019) and in the IPMA Individual Competence Baseline (IPMA/ICB, 2015), can be useful to nurture a culture of sustainable success within the organization, its people and projects. High performance R&D and innovation organizations report that leadership skills are at the core of complex projects success, project leaders must handle ambiguity, take ownership of project vision, foster collaboration and gain buy-in and motivate the team to achieve the expected deliverables (Madsen, 2015). Concurrently, to take lead in innovation activity that creates the highest quality and most efficient and effective outcomes, project managers, must think strategically the overall development process from early R&D to commercialization considering cost expenses and savings, benefits, and market potential throughout a project, or multiple projects, before making final decisions (Yunhe, 2010).

Engineering and leadership involve imagination, experimentation and iterative improvement seeing opportunities rather than problems, taking initiative and risk, and through sustained effort making a positive difference in a process involving the intersection of feasibility, viability and desirability (Grasso & Burkins, 2010), to ensure projects are of highest technical quality, but that outcomes are also in harmony with the community needs and vision (Yunhe, 2010).

This tinkering and creativity is the inner driving force that pushes individuals into trying new ideas, and project team members who understand technical engineering as well as economics, environmental science, and business methods (Yunhe, 2010) are much likelier to bridge scientific discovery and practical application (Duderstadt, 2010).

Communication, knowledge sharing and a collaborative culture among the project team members (Kucharska, & Kowalczyk, 2016), as well as, people management practices are influential in driving projects success (Popaitoon, & Siengthai, 2014), moreover, skilled, focused, multidisciplinary teams, aware of project internal and external perspectives and counting with the support from senior management and the active involvement of the client or project sponsor might increase the chance of successful outcomes (Molaei, Bosch-Rekveldt & Bakker, 2019).

With agile or hybrid project management approaches, self-organizing and autonomous teams are common, those teams share the project management practices such as estimation, planning, and requirement analysis with managers and customers, therefore, project management require a much greater level of people centered skills (Dwivedula, 2019). Traditionally, to asses project success it is used the iron triangle criteria, which assesses the project in terms of meeting time, budget, and quality constraints, however, this approach might be too simplistic (Atkinson, 1999. Turner & Zolin, 2012), and we should look for a more holistic and systemic approach, considering technical, contextual and human factors, as well as, the diffusion of knowledge and technology in terms of benefits created and profitability.

To get to know if there were significant differences among project management practices of R&D and innovation certified and non-certified companies under the Portuguese standard NP4457, and also between these companies and the expectation of implementing project management practices by project management students, we have collected empirical data that has been tested with ANOVA one-way, using the Levene test to verify the variables homogeneity, and the Scheffe test to verify if there were significant differences between the samples, a confidence interval of 95% has been used.

In here are highlighted some of the practices where evidences have been found to assume that there are significant differences between the samples (p-value<0,05). Using this project management practices may be beneficial to the success of R&D and Innovation projects.

Most significant differences between certified and non-certified companies are:

a. Analysis of lessons learned from relevant previous projects;
b. Project risks identification;
c. Comparing the actual project schedule and costs with the project baseline to identify any variance;
d. Collect lessons learned from the project.

These practices are more frequent among certified companies.

Most significant differences between R&D and innovation non-certified companies and the expectation of implementing project management practices by project management students are:

a. Analysis of lessons learned from relevant previous projects;
b. Carrying out an economic and financial feasibility analysis;
c. Describing contextual and operational requirements of project deliverables;
d. Definition of participative project goals with the teams that will be enrolled on the project execution;
e. Assignment of contingency reserves of time and resources to address potential risks and slippages;
f. Project risks identification;
g. Definition of quality checkpoints to verify accomplishments;
h. Definition of quality management tools to monitor and measure the achievement of project deliverables;
i. Encouragement of all project team members to participate and be creative;
j. Analysis and treatment of risks that may come up throughout the project life cycle;
k. Comparing the actual project schedule and costs with the project baseline to identify any variance;
l. Determining the causes of variation between what was planned and what was executed;
m. Analysis of the deviations impact throughout the project life cycle;
n. Definition of a project recovery plan (if required);
o. Collect lessons learned from the project.

For all these practices, project management students have greater expectations of implementing them, in contrast to the actual frequency of use by project managers in R&D and Innovation non-certified companies.

We have also concluded that there is a greater alignment between, the students expectations of implementing project management practices, and the practices applied by companies that have a certified R&D and innovation system under the Portuguese standard NP 4457 i.e. we have only found 6 practices where there were significant differences out of 107 practices under analysis, namely:

a. Assignment of contingency reserves of time and resources to address potential risks and slippages;
b. Use PERT analysis to estimate the tasks duration;
c. Prepare a probability vs impact matrix to prioritize identified project risks;
d. Analysis and treatment of risks that may come up throughout the project life cycle;
e. Creation of work instructions for critical and/or operational tasks;
f. Definition of a project recovery plan (if required).

Paying attention to these and other project management practices may help us to optimize the use of project resources, considering cost-benefit relations throughout the project, to make decisions based on facts and tangible and intangible assets valued by project stakeholders. Optimized use of project resources also implies creating the right working conditions, carrying out constructive and rewarding monitoring and evaluation practices, ensuring an adequate communication and information flow, reinforcing the development of behavioral, technical and contextual competencies[5], to enable people talent and culture within the project, in compliance with IPMA individual competence baseline (IPMA/ICB, 2015 and IPMA/NCB, 2008).

Having verified and validated the project deliverables, through actions such as, modeling, testing, experimentation and demonstration, confirming that what we have set out to do has been accomplished, the project team should be able to disclose the project deliverables to be valued through knowledge and/or technology transfer activities, which refer to the 3rd group of the conceptual model.

4.3. 3rd group: Knowledge and technology valorization

The goal of the knowledge and technology valorization process is to make project deliverables available to people and industry to derive value from its application. The model in subsection 4.4. represents some of the major actions for technology valorization and exchange. The description of this 3rd group is based in literature review and in qualitative data collected by interviews with Portuguese Technology Transfer Offices head of staff.

Technology valorization and exchange usually starts with the results disclosure to the project sponsors (the funding parts or the part that is leading the cooperation or consortium agreement) or in the case of universities to its TTO (Technology transfer Office) that usually requires a description of the disclosure novelty, inventive activity, industrial applicability and market potential. Having this information, the TTO typically schedules a meeting with the researcher or R&D team to assess the research results and market opportunity to start defining possible valorization paths.

Among the possible valorization paths are licensing or sales, the creation of a spin-off company, the establishment of a joint venture and the establishment of research and cooperation agreements e.g. CRADAs – Cooperation Research And Development Agreements, MTAs – Material Transfer Agreements, and NDAs – Non-Disclosure Agreements, that allow the institution to keep control over the technology and at the same time to access resources and knowledge from third parties, to continue or to develop new projects or R&D stages (Thalhammer-Reyero, 2008).

Among the technology assessment tools, most used by TTOs, are checklists and pre-defined evaluation models to perform a quick technological and market assessment of the disclosed project deliverables. A projection of cash-flows, despite its usefulness for some products, is not usually performed at this assessment stage. TTOs tend to make cash-flow projections when they receive a manifestation of interest by an investor as a starting point for an agreement negotiation and when there is the intent of creating a spin-off company to consider a possible monetary participation (Rocha & Romero, 2015 and Rocha, 2009).

[5] Behavioral (people oriented skills), technical (operational and management skills) and contextual (environment, strategic and perspective skills), see IPMA – ICB: International Project management Association – Individual competence baseline https://www.ipma.world/individuals/standard/, July, 2021.

When reviewing the technical solutions, TTOs also consider whether patenting is the right strategy to protect and to deliver profit from it, and typically, searching for patents is a good practice before starting and after concluding a project, the good use of patent directories may reduce the time and costs of R&D projects (Smith, 2005). Patent directories also give us information about changes undergoing in the invention field and information about related inventions and inventions aiming at similar purposes (if existent).

Patenting is a good option to grant exclusive rights for the exploitation of a technical solution and to grant future profits (Howell, 2017). Keeping an invention as an industrial secret can be a good option when the invention does not create a strong barrier to prevent others from achieving similar results using a different technical approach (Dolfsma, 2011 and Nelsen, 1998), or when the field of the invention moves so fast that patents will not grant a reasonable tangible or intangible profit, also when it is very difficult to identify that other parties may take advantage of it e.g. the use of inventions referring to production methods may be very difficult to notice (Nelsen, 1998).

To transfer technology, either patented or not, we must find an opportunity to combine its characteristics and advantages with the needs and interests of potential licensors.

The identification of potential licensors implies not only the technology and market description but also the identification of resources and skills needed for new stages of development and application. A good licensor or technology partner is the one who is able to complement our resources and skills to enable further developments and the application of knowledge and technical solutions in the relevant contexts and markets where we want to be (Speser, 2006).

When identifying what we need from potential R&D and innovation partners we must understand how the technology is going to fit into their technological space to find an alignment between the technology characteristics and the capabilities and resources held by these organizations. During this assessment, we must (Rocha, 2009):

a) Identify the technologies that have to be integrated with the new technical solution to obtain an application or product;
b) Analyse the possibility of combining the knowledge and technology with existing products and systems;
c) Determine what knowledge has to be transferred and if licensors are able to use it;
d) Analyse the possibility of reproducing the technology on a large scale and its functional reliability in different environments.

Throughout the whole technology transfer process we must be mindful that many patents are licensed not because they have an innovative technology but because there is a solution that has been demonstrated and is ready for use (Rocha, 2011).

Portuguese Universities primarily license products based on technical solutions either or not patented, patent licensing cases alone are fewer, so whenever possible, all the necessary steps must be taken to obtain the technology proof-of-concept – the development of products using the invention and the demonstration that they work reduces the risk perception of potential licensors (Speser, 2006), and for this perception, it may well be very important the TTOs role in the identification of resources that enable further developments and demonstration stages.

The case in which there is usually a greater success in technology licensing occurs when technologies are tailor made to firm needs or are developed with a firm participation (Harmon *et al*., 1997).

Projects tailor made to firm needs or with firms participation come up either from industry contacts or from the TTOs and researchers contact, and are intended not only to license or develop technology, but to develop projects to solve specific issues and to make the best of R&D and Innovation funding programs.

To transfer technology, Portuguese TTOs, also use formal and informal networks of contact to get further information regarding the technology technical and market potential, to get financial support and funding, to support the creation of spin-off companies, and to gain access to contacts to promote the technology diffusion.

The information collected from these contact networks and from the application of technology and market assessment methods is used by the TTOs to formulate the technology value proposition, which must highlight its benefits and applicability in an objective and appealing way (Lindic & Marques, 2011). The value proposition must be used to contact potential licensors.

Along with the value proposition, is important to have in the vicinity of the universities, incubators and science and technology parks, which may exert a positive influence in the creation of spin-off companies and in the absorption of knowledge and technology (Markman, *et al*., 2005). The coordination between TTOs and project management supporting services, such as PMOs (Project Management Offices), is also very important to align common strategies aiming knowledge and technology transfer.

Once an expression of interest to transfer the technology is obtained, the negotiation process begins, and the results of evaluation methods can give us a basis on which we can negotiate a balanced agreement for all parties. This agreement may include different types of payments (Rocha, *et al*., 2017):

a) The most common payment types used by Portuguese university TTOs are, running royalties, sub-licensing payments, minimums, patent maintenance fees and milestone payments;
b) Payments to provide technical and scientific support services, usually increase the revenues from licensing agreements, and have the advantage of maintaining the relationship with the technology licensor while maintaining the possibility of transferring new technology;
c) Deferred payment calculations may be included when the licensor has prior relationships with the university or when a spin-off company is created;
d) Social capital investment on spin-off companies may also be considered, universities that financially invest on spin-off companies usually obtain greater economic benefit than those that only license the technology to spin-off companies (Lockett, Wright & Franklin, 2003).

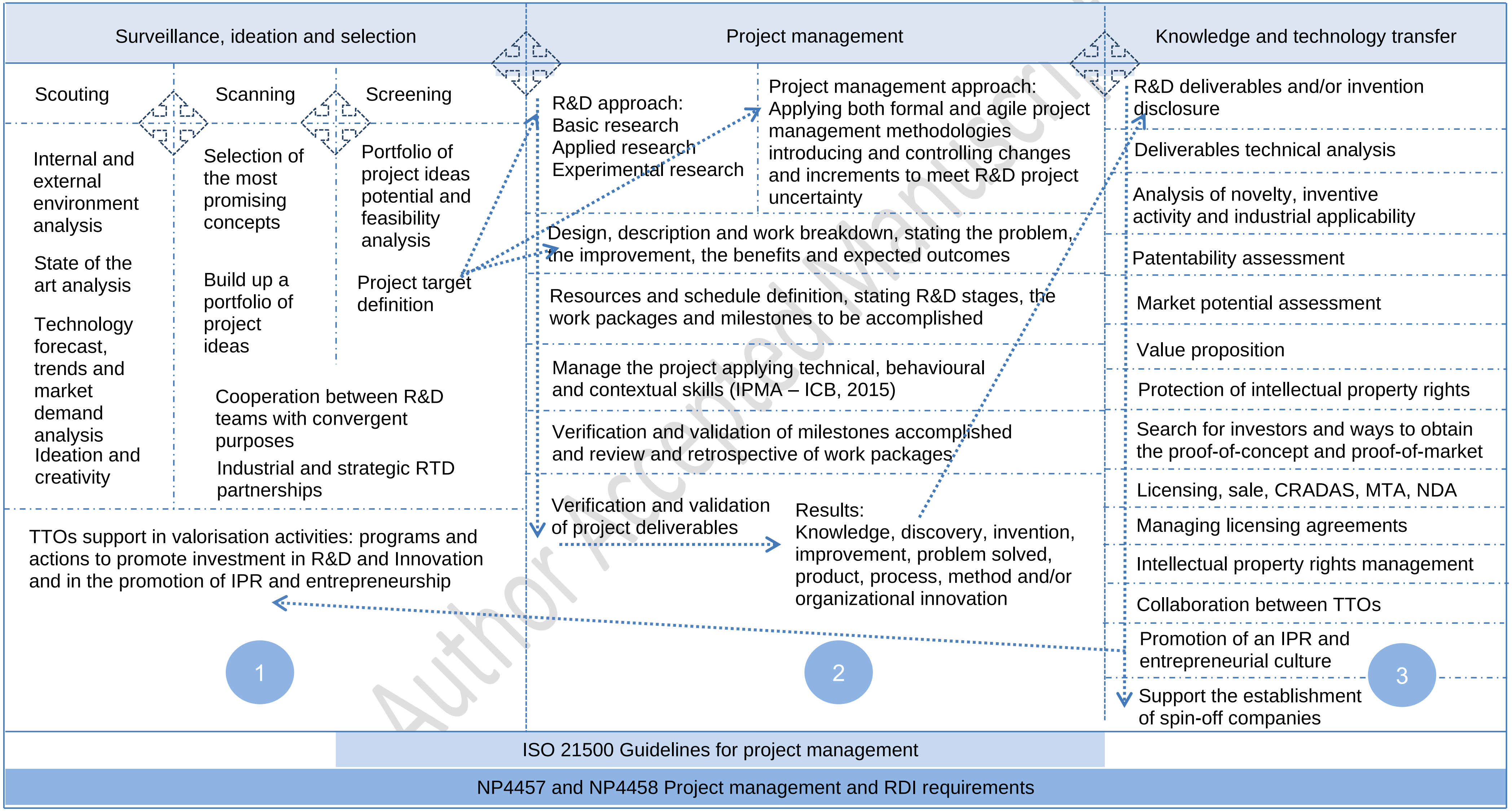
Once the transfer agreement has been established, we have to monitor and manage it to ensure its enforcement e.g. payments to be made and goals to be accomplished, and in the case of patents, management of intellectual property rights in the territories where protection has been requested and granted, and search and reaction to infringements.

As supporting activities to this 3rd group of the proposed conceptual model are the university TTOs initiatives meant to identify R&D and Innovation investment programs (to pull investment and push R&D and technology towards industry), and also to promote an intellectual property and entrepreneurial culture among researchers. In here are highlighted some of those initiatives:

a) Organization of technology briefings: forums where researchers present their results to potential investors and people who can make a relevant contribution to value and transfer the technology;
b) Identification of technological and business mentors to enhance the results utility and to support its economic and financial valorization;
c) Support in the evaluation of business ideas and in the establishment of spin-off companies;
d) Support in the pre-incubation and incubation of business ideas;
e) Identification of funding sources for R&D and demonstration projects;
f) Reception and diffusion of industry-university project proposals;
g) Addressing industry with R&D and demonstration project proposals aligned with the university research initiatives, and making the best of public funds for co-promotion projects;
h) Organization of multidisciplinary training programs, in which students and researchers from different areas of knowledge come together to develop an investment plan for a technology and/ or business idea;
i) Organization of events with entrepreneurs and promoters of knowledge in intellectual property rights and entrepreneurship.
j) Cooperation between TTOs to leverage resources and contacts to favor R&D projects and technology transfer.

These supporting initiatives, from the 3rd group of the conceptual model, have a transversal scope to support the 1st and 2nd groups of the conceptual model, namely by levering investment for R&D projects and by fostering innovation through the application of the project outcomes.

4.4. Managing R&D and innovation projects: an integrated conceptual model for technology transfer



5. Conclusion

This article presented a conceptual model that sets the stage to nurture and to drive the transformation of knowledge into innovative, competitive products and services that are critical for competitiveness, long-term sustainability and growth by establishing an interception between ideation, project management and technological innovation.

This conceptual model includes three interrelated groups, the first group focuses scouting, scanning and screening endeavors to identify and select R&D and Innovation projects, the second group focuses project management processes, and the third group focuses on knowledge and technology valorization practices to make project deliverables available to people and industry to derive value from its application.

These three groups are supported by improvement, innovation and project management guidelines and standards, namely NP 4457 that defines the requirements of an R&D and Innovation system, NP 4458 that establishes the requirements to manage R&D and Innovation projects, and ISO 21500 that establishes the guidelines for project management.

The model, primarily targets research and development projects in the context of universities or research labs or centers, but it is not exclusive and can be applied by organizations engaged in research and technology development aiming to successfully transfer project outcomes to organizations and people that can benefit from technical and service innovations or from knowledge that can advance science, people skills and future discoveries.

The model uniqueness relies on anchoring project management principles and culture to surveillance, ideation, selection and technology transfer, which is seldom clearly presented in the reviewed models and frameworks.

To validate the relevance and applicability of this model, empirical studies are needed to assess whether the knowledge and guidance provided by this model, indeed support R&D organizations in setting the stage to take the lead of innovation by strategically driving R&D projects thinking on benefits, market needs, and project outcomes that are both efficient and of the highest quality since the project inception till the disclosure of the project deliverables to the university technology transfer office to generate wealth through knowledge and technology transfer.

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