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A state-of-the-art analysis of innovation models and innovation software tools

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Abstract: This paper presents an analysis of existing innovation models and innovation software tools. An innovation model is a representation of the components and interactions that would foster the creation of novel solutions, systems or processes. Those models are mechanisms designed to help producing effective and efficient collaborations within organisations, or among large organisations (LO) and Small to Medium-Sized Enterprises (SMEs). However, although they have been often used by some LOs, their utilisation has been very limited in SMEs. This research addressed two research questions: First, investigate the components of current innovation models and their use in different organisations; and second, analyse the characteristics of innovation software tools and how they could be improved. This paper will contribute to the development of more efficient and enhanced models that can help addressing LOs' challenges and help creating new markets for SMEs by constant engagement with LOs. A qualitative analysis of 17 publications from a selection of 400 academic abstracts, and 10 innovation software tools available in the market, was carried out. Results show that innovation models have been designed to support innovation activities in sectors such as healthcare, public services, aerospace, education and businesses. The results also show that innovation software tools can provide a platform to capture, discuss, vote and rate new ideas from internal and external organisations' stakeholders. However, despite innovation models and software tools seem to be democratic mechanisms for the management of ideas crowd-sourcing, they lack a symbiotic environment that goes beyond a simple collection device, and provide improved innovation support. For example, better support to solve LOs' needs efficiently, better support in the management of the collaboration among multiple organisations and the management of organisation's knowledge, capabilities, human resources, intellectual property rights, financial resources, reputation, innovation costs and project risks. The review highlights the need to design and implement improved innovation models and software tools that empower innovation and efficient collaboration among organisations, which in turn would produce increased economic growth and jobs creation.

Keywords: Innovation model, innovation engine, innovation software tools, open innovation, SME networks, idea management.

1. Introduction

Innovation is one of the 12 pillars that determine the level of productivity and competitiveness of a country (World Economic Forum, 2014). However, 73% of chief technology officers (CTOs) surveyed in the 2014 Global Innovation 1000 Report, do not believe their companies have the tools to innovate successfully (Jaruzelski, Staack & Goehle, 2014). In this paper we aimed to investigate the state-of-the-art of innovation models and innovation software tools in order to understand what are the gaps in the literature and in innovation software implementations.

Innovation can be described as the creation of a new idea, device or process (Merriam-Webster, 2015). It can be also seen as the application of better solutions that address new market, government or social needs and requirements through new processes, services, technologies or products (Frankelius, 2009). In science and technology innovation can be represented, for example, by an original device or by original knowledge, but in economics, innovation can be represented by a novel process such as a business or a marketing model that may impact society with original ideas (Chesbrough, Vanhaverbeke & West, 2006). Innovation is also about the use of new ideas and knowledge in something that will create social, commercial or organisational value (Porter & Kramer, 2011).

Innovation can be categorized according to the organisation perspective in open or closed. “Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology” (Chesbrough, Vanhaverbeke & West, 2006). Open innovation implies working with associated partners sharing risks and rewards. There is a permeability between an organisation and its environment, where innovations transfer inward and outward. Open innovation occurs when companies need to solve their needs with the capabilities of other organisations (in-bound innovation: buying or licensing patents or inventions or Intellectual Property (IP)) or when internal inventions are translated outside the company as licensing or spin-offs (outbound innovation) (Busarovs, 2013). Open innovation fosters cost reduction in R&D, customer-centred design and potential for better synergism between organisations (Marais & Schutte, 2009). But, in open innovation collaborations organisations may need to reveal confidential information or intellectual property, and have the challenge to manage innovation internally and externally finding the best partnership (Salter, Criscuolo & Ter Wal, 2014). Innovation can also be classified according to its outcome in incremental or radical (Popadiuk & Choo, 2006). Incremental innovation happens when innovation produces an improved technology, product, service or process. It focuses on cost or feature improvements and market competitiveness. While the outcome of radical innovation is a new result, which implies higher uncertainty since it focuses in novel features and creates a remarkable change in markets and organisations (Ettlie, Bridges & O'Keefe, 1984).

An innovation engine can be a system that creates, fosters and catalyse innovation and can be the place where innovation conversations are carried out (Dvir & Pasher, 2004). For example, innovation can take place in a specialised location such as an R&D department or a University laboratory, or a common place such a particular office, a coffee shop, a museum, a restaurant or an online web site *ibid*. An innovation engine can be represented by a model that comprises the components and interactions involved in the creation of novel technologies, products, systems or processes. They are mechanisms designed to help producing effective and efficient collaborations within organisations, or among large organisations (LO) and Small to Medium-Sized Enterprises (SMEs).

This paper provides a comprehensive review of the characteristics of innovation models and innovation software tools used in different business sectors. The following sections present the methodology, results of our literature and software review and provide a discussion, conclusions and directions for further work.

2. Methodology

Our methodology was twofold: First, a qualitative analysis of 17 full publications from a selection of 400 academic abstracts was carried out by two researchers. We consulted four databases: Web of Knowledge/Web of Science, IEEExplore, Sitewise and Google Scholar and searched the following terms: Innovation model, innovation engine, innovation software tools, open innovation, closed innovation, SME networks, idea management. A thematic analysis of the literature was undertaken with Nvivo software version 10. General themes included definitions of innovation and innovation engine, innovation model description, benefits, contribution, characteristics and limitations. Other themes included the stages of the Flugle (Du Preez & Louw, 2008) innovation process: idea generation, concept definition, concept feasibility, deployment and exploitation; and themes that emerged from the data such as publication of the challenge, innovation culture, external collaboration, innovation management and intellectual property (IP). Second, two researchers reviewed 10 innovation software tools. The review included a thematic analysis of the 10 software web sites, four software live demonstrations from the vendor and three software video demonstrations available online.

3. Results

3.1 Review of innovation models

Table 1. Shows the list of the 17 full papers reviewed from the ‘innovation model’ literature. There are three main categories of papers: a) innovation models, b) innovation engines and c) innovation management.

Innovation models include for example, a system for the acceleration of innovative ideas into the market (AIM) (Sorli et al., 2002). It aims to support the gathering, storing, use and developing of ideas and knowledge to improve or create products or enterprise processes. It would potentially benefit the enterprise from reducing the innovation cycle time, reducing time and effort in solving problems, reducing waste and improving the

efficiency of the processes through systems engineering techniques. However, there is a lack of evidence of its benefits. Lawson & Samson (2001) suggested a model to develop open innovation capabilities in organisations. The model fosters the implementation of open innovation through mainstream capabilities and newstream innovation empowered by the employees that create a virtuous circle in the organisation, producing continuous growth. Nevertheless, the model lacks information about IP management and the definition and collection of ideas. Dobni (2006) presented an innovation blueprint aimed to provide organisations with an continuous capability to innovate. The model describes the manager intentions, the needed infrastructure to encourage innovation and the employees behaviours required to have an innovation culture spread all over the organisation. This model would need, however, to encourage organisations to coordinate their innovation efforts across their different areas. Fore (2003) developed an online matrix to match the capabilities of Higher Education Institutions with the Technology Needs of the National Security Institutions in the US. In this case the application supports the creation of partnerships and foster opportunities for collaboration. Nonetheless, the web site is limited to Universities and it does not have capabilities to support the management of ideas or IP. Comstock (2007) presented the NASA's Innovative Partnerships Program that match technology needs with technology capabilities. This is one of the most complete models for open innovation. It encourage partnerships, produces spinoffs that benefit the society, publish challenges in a magazine that multiple organisations may solve, offers innovation advice and provides funding and rewards for R&D projects. The utilisation and benefits of open innovation model has been highlighted by Chesbrough (2003) as an imperative approach to create and profit from technology. Marais & Schutte (2009) presented five open innovation models that assisted the Fugle (Du Preez & Louw, 2008) innovation process. The Fugle innovation process consists of six stages of innovation: Idea identification, concept definition, technical feasibility, business viability, deployment and exploitation. Each stage of the innovation process can be supported by one of the following models: Platforming (i.e., using a base product to extend their capabilities, e.g., mobile apps); Idea competitions (i.e., rewarding successful ideas and suggestions from inside and outside the organisation); Customer immersion (i.e., the involvement of customers in the development of a product); Collaborative product design & development (i.e., the involvement of customers and suppliers in the development of products); and innovation networks (i.e., partnerships among different organisations to solve a challenge with organisations' capabilities).

Table 1: Innovation models and their main components/characteristics.

Reference	Main components/characteristics	
(Sorli et al., 2002) Accelerating Innovation in Practice in New Product Design	-Innovation Repository. -Product/process knowledge base. -Collection of innovative ideas and product/process knowledge.	-Innovation Engine. -Innovation Viability Assessment. -Innovation Management System.
(Bailetti & Bot, 2013) An Ecosystem-Based Job-Creation Engine Fuelled by Technology Entrepreneurs	-Publicly Funded Services for Technology. Entrepreneurs. -Subsidise physical space. -Provide advice and run innovation workshops. -Replicate what other regions have done to generate jobs. -Operate incubators, accelerators, entrepreneurship centres, and hubs support venture capital funds.	-Invest in R&D projects and prototype development. -Provide large tax incentives. -Organize competitions and networking events that promote entrepreneurship. -Attract capitals. -Deliver innovation courses. -Pay for travel and accommodation.
(Rigby, Deane & Pritzl, 2003) Building an innovation engine	-Gather 'component' ideas: inside the organisation, among business partners, customers and suppliers and toward competitors. -Match responses to disruption realities.	-Assemble the 'Innovation Engine'. -Keep the engine running. -Plan to profit. -Attract mavericks In their early days. -Share the wealth and the wisdom. -Market your success.
(Bailetti et al., 2013) Developing an Innovation Engine to Make Canada a Global Leader in Cybersecurity	-Five entities are core to the innovation engine: an ecosystem, a project community, an external community, a platform, and a corporation.	-The five entities in Figure 1 are interdependent, and each entity relies on the other entities for the innovation engine to achieve the desired system-level results.
(Lawson & Samson, 2001) Developing innovation capability	-Holistic model of innovation capability. -The following elements are proposed to	-Organisational structure and systems. -The management of technology.

Reference	Main components/characteristics	
in organisations: a dynamic capabilities approach	exist, to some degree, within innovative firms: -Vision and strategy. -Learning from competitors -Organisational intelligence. -E-business. -Creativity and idea management.	-Innovation culture and innovation climate. -Outsourcing. -Reward systems. -Empower employees. -Communication. -Mainstream capabilities -Newstream innovation
(Weiss, 2002) Developing Tangible Strategies	Innovation engine formed by three design components:	-Desirability (human factors). -Technology feasibility. -Business viability.
(Srivardhana & Pawlowski, 2007) ERP systems as an enabler of sustained business process innovation A knowledge-based view	-Knowledge Sources. -Activation Triggers. -Organisational Knowledge/Memory. -Sustained Business Process Innovation. -Business Process Absorptive Capacity. -Industry Regimes of Appropriability.	-Social Integration Mechanisms for ERP Implementation and Use. -ERP System Constraints. -External knowledge embedded in the architecture, software vendors and partners.
(Dvir & Pasher, 2004) Innovation engines for knowledge cities an innovation ecology perspective	-Elements of the ecology of innovation: -Time to innovate. -Organisational structure. -Physical space. -Tolerance of risk. -Strategy. -Recognition and incentive systems. -Virtual space. -Structure and spontaneous processes. -Knowledge management.	-Financial capital. -Diversity. -Attention to future. -Challenge people. -Conversations as the unifying principle. -Innovation engines: Library, cafe and third places, urban events, museums, Universities, industrial districts, science parks, online sites.
(Goffin & Mitchell, 2005) Innovation Management: Strategy and Implementation using the Pentathlon Framework	-Pentathlon Framework: -Creating an Innovation Strategy. -Managing Creativity and Knowledge.	-Prioritizing and Selecting Ideas. -Implementing the Idea. -Involving people from across the business.
(Dobni, 2006) The innovation blueprint	-The innovation blueprint highlights eight areas of focus that define what is required in terms of integration of context and behaviours necessary to drive operational innovation: -Propensity and architecture. -Employee constituency.	-Employee skills and learning. -Technological and financial support . -Knowledge management. -Sphere of influence. -Empowerment and experimentation. -Co-alignment.
(Fore, 2003) Matching the Capabilities of Higher Education Institutions with the Technology Needs of the Y-12 National Security Complex-Universities providing products and services to National Security complex	-Online website matrix that helps in: -The identification of universities who would be effective partners for collaborative R&D projects. -Determination of a university's experience and knowledge base with contracts vs. grants in support of federal government and private industry solicitations.	-Review of a university's research expertise compared to the critical/essential skills needs of a company -Assessment of a university's capabilities to become an effective partner in responding to federal solicitations.
(Comstock, 2007) NASAs Innovative Partnerships Program Matching Technology Needs with Technology	-A Generalized Partnership Model. -NASA's Innovative Partnerships Program (IPP). -Publication of NASA' needs and challenges in their Tech Briefs magazine. Spinoff.	-IPP course facilitation. -SBIR funding programs. -IPP Seed Funding. -Transferring Technology to Benefit - Society. -Inwards and outwards flow of knowledge.
(Wheeler, 2002) NEBIC: A Dynamic Capabilities Theory for Assessing Net-Enablement	-Choosing Emerging/Enabling Information Technologies. -Matching Economic Opportunities with Emerging Technologies.	-Executing Business Innovation for Growth. -Assessing Customer Value.
(Chesbrough, 2003) Open Innovation. The New	-Rationale, description and characteristics of open innovation.	-Intellectual Property (IP) management.

Reference	Main components/characteristics	
Imperative for Creating and Profiting from Technology	-Multiple collaborations.	
(Sousa, 2008) Open innovation models and the role of knowledge brokers	-Knowledge brokers to mediate the collaboration between organisations. -Ability to understand innovation problems. -Ability to translate innovation problems into a structured project.	-Ability to understand the necessary capabilities, skills and knowledge to solve the problem. -Ability to identify who can better provide those same capabilities, skills and knowledge.
(Sousa, 2006) The sustainable innovation engine	-Innovation is based on knowledge. -Learning is the process by which knowledge is created. -Learning can raise knowledge depth and knowledge diversity.	-A sustainable innovation engine is based on: -Benchmarking. -Competency acquisition. -Continuous improvement. -Experimentation.
(Marais & Schutte, 2009) The Development of Open Innovation Models to assist the Innovation Process	Five innovation models are aligned with the five stages of the Fugle (Du Preez & Louw, 2008) Innovation process: -Platforming.	-Idea competitions. -Customer immersion. -Collaborative product design & development. -Innovation networks.

There are in the literature innovation engine models that may serve as frameworks to action innovation. For example, Bailetti & Bot (2013) proposed an ecosystem-based job-creation engine fuelled by technology entrepreneurs. The entrepreneurs are provided with a work space, innovation advice, business development, provide funding and a community platform. In return, businesses have to make their company growth in order to produce at least six jobs. Rigby, Deane & Pritzl (2003) produced guidelines to build an innovation engine in three steps. The first step includes the analysis of the competition, monitoring where funding is going and doing disruptive innovations (i.e., profit in a new way, enable customers and migrate upmarket). The second step is to assemble the innovation engine, collecting ideas from inside and outside the organisation, plan to profit and send the right ideas to the correct areas. The last step is to keep the engine running, thinking outside the business limits, sharing knowledge, attracting innovation experts, marketing success. Bailetti et al. (2013) created an innovation engine to improve Canada' cyber-security capabilities. The engine has five '*sparks*', an ecosystem (for global competition), a project community (focus of innovation R&D), an external community (actors operating outside the local product market) a technological platform and a corporation (directors, members and staff). This model, however, does not explain how to publish a challenge or how to manage the innovation and the IP. Weiss (2002) proposed an innovation engine based on three factors: desirability (human factors), technical feasibility and business viability. This model was specifically designed for organisations requiring innovation consultancy to improve their innovation process. But it is limited to early stages of innovation since it is a design-based strategy. Dvir & Pasher (2004) provided a set of guidelines to knowledge cities based on urban innovation engines as the pillars and ecology elements as the functional system. The ecology components of urban innovation engines are time to innovate, have a physical space, tolerance to risk, have a strategy, have a rewarding system, a virtual space, carry out knowledge management and use conversations as the trigger element in libraries, museums, Universities, science parks or industrial districts. **Sousa (2006**) explained that a sustainable innovation engine is based in knowledge, where learning is the process by which knowledge depth and knowledge diversity are created. The former is how specific is the acquired knowledge, while the latter is how many different areas knowledge is enriched from. Learning correlates with the level of innovation and competitiveness. Therefore, a sustainable engine is fuelled by benchmarking, competency, continuous improvement and experimentation. Nevertheless, common limitations of many engines are the management of IP and a lack of information about the innovation process.

The last four models are related to innovation management. Srivardhana & Pawlowski (2007) highlighted that ERP (Enterprise Resource Planning) systems can enable the innovation process despite their apparent rigidity, where knowledge capabilities such as generation, combination and exploitation of knowledge can be a source of competitive advantage. The model utilises knowledge capabilities for sustained business process innovation. Goffin & Mitchell (2005) presented the pentathlon framework. A strategy to manage innovation. It contains five elements: creating an innovation strategy, generating ideas, prioritising and selecting from these, implementing the ideas selected and involving people from all areas of the business. Wheeler (2002) created a

model to measure, predict and understand if an organisations can create customer value with the use of digital networks. It includes four elements: choosing new IT, matching economic opportunities with technology, executing business Innovation for growth, and assessing customer value. Finally, Sousa (2008) introduced the concept of open innovation models with knowledge brokers. The knowledge brokers are sought as intermediary people in charge of knowing what the organisation's core capabilities are, understanding what other capabilities are needed and using networking and collaborative skills to incorporate those other capabilities into the innovation process. These models, nevertheless, lack the proliferation of an innovation culture, the management of the IP and the creation of spinoffs.

Table 2 shows the alignment of the revised 17 innovation models to the features of open innovation specified by Chesbrough, Vanhaverbeke & West (2006). All the models aligned with external collaboration. However, only Comstock (2007) reported the publication of the challenge (i.e., their needs and requirements). Besides, only five models considered the management of IP. The management of the innovation was not a frequent feature mentioned in the innovation models. Only one model (Comstock, 2007) achieved all the open innovation features. But, the majority of the models achieved two or less features of open innovation.

Table 2: Alignment of innovation models with the features of open innovation.

Reference	Publication of the challenge	Innovation culture	External collaboration	Innovation management	IP management
(Sorli et al., 2002)	-	✓	✓	✓	-
(Bailetti & Bot, 2013)	-	-	✓	-	-
(Rigby, Deane & Pritzl, 2003)	-	✓	✓	✓	✓
(Bailetti et al., 2013)	-	-	✓	-	✓
(Lawson & Samson, 2001)	-	-	✓	-	-
(Weiss, 2002)	-	-	✓	-	-
(Srivardhana & Pawlowski, 2007)	-	-	✓	-	✓
(Dvir & Pasher, 2004)	-	✓	✓	-	-
(Goffin & Mitchell, 2005)	-	✓	-	✓	-
(Fore, 2003)	-	✓	✓	✓	-
(Comstock, 2007)	✓	✓	✓	✓	✓
(Dobni, 2006)	-	✓	✓	✓	-
(Wheeler, 2002)	-	-	✓	-	-
(Chesbrough, 2003)	-	✓	✓	-	-
(Sousa, 2008)	-	✓	✓	✓	✓
(Sousa, 2006)	-	✓	✓	-	-
(Marais & Schutte, 2009)	-	-	✓	-	-

3.2 Review of innovation software tools

The need to have the right software tools to innovate is a necessity due to the importance that innovation has in order to provide a competitive advantage to organisations.

Table 3 shows 10 innovation software tools reviewed. *Spigit/Midjet* (2014) uses social technology and behaviour science techniques, crowd analytics, crowd science and visualisation dashboards. It implements pairwise voting, gamification and mindmaps for ideas collection. However, it offers limited support to multiple organisation collaborations. *Imaginatik* (2015) offers a set of tools to launch projects, choose teams, assign tasks, and track the portfolio of ideas. It sorts and organise ideas by measures, ranging them by popularity,

thematic content or level of uniqueness. But it has limited support to multiple organisation collaborations. *Hype* (2015) is a flexible platform with an available SDK, which seems to involve multiple organisations and uses dashboards and gamification features. *Brightidea* (2015) seems to be an open, mobile, agile and interactive software. it contains dashboards and leaderboards and ideas can be submitted in five ways (text, video, audio, picture or sketch). However, it has limited support to multiple organisation collaborations and gamification. *Social Lair* (2013) collects ideas in suggestion box, has an SDK available and implements innovation campaigns by creating focus groups or contests. It uses gamification and reward techniques through virtual currency and rewards stores. Nonetheless, it has only a basic dashboard, which is not available for multi organisation collaborations. *Brain Bank* (2015) has a configurable and flexible user interface that allows collaboration and configurable tasking with gamification techniques. It has a feature that shows organisations' reputation score and 'hall of fame' ranking and offers flexible reporting. *CogniStreamer* (2015) appears to have an intuitive web portal, allows participation of different stakeholders and has some IP protection facilities. However, it is driven by a single organisation and appears to lack a strong gamification element. *Inno 360* (2015) was designed to be a cloud-based innovation management platform to support R&D groups around the world, it seems to support internal R&D organisations and build a global network of collaborators such as innovator, researchers and trusted suppliers. Nevertheless, gamification techniques are limited and innovation campaigns are driven by a single organisation. *Wazoku* (2015) targets the generation of ideas on existing challenges. It uses crowdsourcing open innovation from internal and external stakeholders. It can perform real-time analysis of the landscape around each opportunity, including patents, literature, academia and the web. However, is seems to be less flexibility to customise and the campaign is driven by a single organisation. *Crowdicity* (2015) is a platform that supports the publication of challenges, ideas collection and selection, and implements reputation rankings and leaderboards with gamification techniques. However, the collaboration with multiple organisations is limited.

Table 3. Features of innovation software tools.

	Features						
Innovation software	***Campaign design support***	***Support multiple collaboration***	***Gamification***	***Provide SDK***	***IP protection***	***Intelligent support***	***Dashboard***
Spigit/Midjet (2014)	✓	-	✓	-	-	✓	✓
Imaginatik (2015)	-	-	✓	-	-	-	✓
Hype (2015)	✓	✓	✓	✓	-	✓	✓
Bright ideas (2015)	-	-	-	-	-	-	✓
Social Lair (2013)	-	-	-	-	-	-	✓
Brain Bank (idealink) (2015)	✓	✓	✓	✓	-	✓	✓
CogniStreamer (2015)	-	-	-	-	✓	✓	✓
Inno 360 (2015)	✓	✓	-	-	✓	✓	✓
Wazoku (2015)	✓	-	✓	-	-	-	✓
Crowdicity (2015)	✓	-	-	-	-	-	✓

4. Discussion and conclusions

The results of this review have shown interesting insights about existing innovation models and current innovation software tools available in the market. On the one hand, innovation models have been designed to support innovation activities in the sector such as healthcare, public services, aerospace, education and business. Results show that the literature contains discussions on innovation models, innovation engines and innovation management. However, even though the papers reviewed explain innovation models with different aspects of innovation including innovation repository, innovation ecosystems, external community, communication and education empowerment, reviewed models appeared to be generic and may not be suitable to apply directly to the scenario of an innovation engine as an 'intelligent innovation intermediary'

that helps managing the complex interactions that may exist among multiple large organisations and SME's. On the other hand, the innovation software tools reviewed provide a platform to capture, discuss, vote and rate new ideas from internal and external organisations' stakeholders. However, despite software tools seem to be democratic mechanisms for the management of ideas crowd-sourcing, they lack a symbiotic environment that goes beyond a simple collection device and provide improved innovation support. For example, better support to solve large organisation needs efficiently, better support in the management of the collaboration among multiple organisations and the management of organisation's knowledge, capabilities, human resources, intellectual property rights, financial resources, reputation, innovation costs and project risks.

This review was limited to 17 papers and 10 software tools, but still, it has shown that there is scope for further work to design improved models of open innovation, for example, valid and reliable models are needed to improve the collaboration among SME and large organisation, for instances, with an innovation engine that fosters innovation, and helps addressing the needs of LOs with the capabilities of SMEs in order to promote economic growth and jobs creation. In addition, further work should be carried out in the design and implementation of improved software tools that empower innovation and that support efficient collaborations among multiple organisations. For example, software tools that use gamification techniques and data mining or machine learning algorithms to find the best innovation partnership and that help managing collaborations with useful visualisations. To that end, at the time of writing this paper, we are conducting participatory design workshops with innovation stakeholders in order to design a future 'smart innovation engine' that can be implemented in a software tool.

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