Considerations for Modelling Firm-Level Innovation Processes in Privacy and Cyber Security Organisations

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Abstract— **Rapid changes in technology infrastructure, the explosion of data, always-on-always-connected world, the emergence of "multiple internets" and escalating regulation and standards have and continue to offer fertile ground for the development of products and services to increase ICT and personal security. A prevalent challenge however, facing the privacy and cybersecurity (PACS) community is transitioning technical R&D outputs into commercial and marketplace-ready products and services. Compounding this, the PACS domain is deeply influenced from various themes driven by technical, human, societal, organizational, economic, legal, and regulatory concerns among others; these factors combine to create marketplace and innovation ecosystem with complex value chain relationships. In response, this paper seeks to address the innovation phenomenon at the firm-level by delineating innovation ecosystems and identifying key components for consideration in terms of assessing and in turn, (re)modelling innovation processes.**

Keywords- innovation process, innovation phases, innovation model, innovation framework

I. INTRODUCTION

The EU Cyber Security Strategy [1] coupled with Europe 2020 strategy and its flagship initiatives such as The Innovation Union and Digital Agenda all underscore the escalating importance of the Internet as a channel for commercial and personal exchange. Reflective of this, opportunities for innovators in the privacy and cybersecurity domain is increasing. Nonetheless, challenges of transitioning technology related research developments and outputs to real-world deployment are well documented: pursuing a narrow innovation process failing to incorporate the internal and external ecosystem or customer needs, an overemphasis on technology-driven bottom-up innovation, in addition to unsupportive deployment channels for research output/commercialization's hamper the transitioning of technology [2]. While much information around innovation exists, the challenge of developing effective in-firm innovation practices, models and infrastructures underpins innovation endeavors given the dominant overemphasis on technology-driven, bottom-up innovation. Indeed, understanding of innovation management and practice remains fragmented, misunderstood and untamed by practitioners and researchers [3]. Innovators operate within complex and turbulent environments, and are increasingly confronted with escalating and rapid technology developments, competitive global market competition and shorter product life cycles meaning they must be reactive and flexible to organizational, technological and market shifts [4]. Innovation therefore, does not occur within a vacuum and is impacted upon by a range of internal considerations and external contextual factors [5] [6].

Based on the foregoing, the contribution of this paper is centred upon demystifying the firm-level innovation process phenomenon, through highlighting salient consideration factors transcending innovation model phases, processes, components and framework architectures to inform innovation thinking and practice. While the context for this paper is centred on the PACS domain, its relevance and contribution is applicable to any organization or company irrespective of the domain or sector. Regarding the structure of this paper; firstly an overview of innovation models is synopsized, followed by an overview of phases, components, process flows and evolutions of innovation frameworks and culminates in the identification of key considerations for innovation modelling.

II. INNOVATION MODELS

Varying attempts have been made to articulate conceptual order on the innovation processes of organisations, in the form of innovation process models. For [7], innovation models are important because they offer a simplified external representation of a complex system to *"…assist innovators and management teams in framing, understanding, and acting on the issues which need managing"*. The variety amongst such models is the consequence of a lack of consensus as to how an innovation process should look like, given the unique contexts, environments, and purposes for which they are developed [3], [8]. While models may differ in their schematic layout, they all begin with some form of idea generation and trace the phases from selection, development through to implementation. In this vein, innovation model depictions commonly adopt a wide-scope view, encompassing the schema, phases and processes from the decision to commence research on an opportunity or problem, to development, commercialization, implementation and diffusion [9].

Reference [10] indicates that an organisational innovation model needs to support the searching for, selection of, implementation and capture of innovative ideas supported by

an overarching innovation organization and strategy. The stage-gate process [11], has the most distinctive and orderly phases which more or less prescribe that each phase can only start, if the project complied with all the requirements of the previous phase. However, the stage gate process has evolved to incorporate cyclical and feedback loops to address the limitation of a strict linear pattern [12]. In addition to the temporal phases/stages of innovation processes, [10], [13] and the Innovation Pentathlon Model [14] models underscore the organisational consideration in the form of strategy, leadership, resourcing and system and tools.

III. Phases, Components and Contexts of Innovation Process Models

In addition to general overarching innovation models, an extensive corpus of literature [5], [6], [10], [15] has accumulated documenting the range of end to end phases relating to innovation processes: idea generation, selection, development, implementation and launch, and post launch in some cases (as synthesized by [8]. A common thread emerging from the literature is that while there is logical order in these phases, the order is not necessarily linear. Typically, models start with some form of idea generation or searching stage. Secondly, a selection phase follows to determine which projects are feasible and potentially lucrative enough to be pursued. Methodologies and practice of relevance to these initial stages include innovation management, market analysis and competitive intelligence, technology forecasting [16] [10], [11]. The third step reflects the development phase where the idea is developed into a tangible product, process or service. This stage can be described differently where terminologies such as development, prototyping, manufacturing and realization are used interchangeably. Methodologies and practice of relevance to development stages include Agile, Lean Startup, Waterfall and Spiral [17], [18], [19]. The fourth phase represents implementation/launch and typically entails marketing, distribution, logistics and customer facing activities. Business modelling and product road testing [20] [21] methodologies and practices offer significant contribution for this key stage. Some authors also include a post launch phase to accommodate re-innovating, scaling and learning dimensions [10], [22].

In addition to these innovation phases, several authors acknowledge that innovation process does not occur within a vacuum, and thereby indicate a range of contextual factors which impact on the processes deployed [5], [6], [10], [23]. Innovators operate within complex and turbulent environments, and are increasingly confronted with escalating and rapid technology developments, competitive global market competition and shorter product life cycles meaning they must be reactive and flexible to organizational, technological and market shifts [4]. Such contextual factors range from organisational characteristics to societal factors and from internal factors that are controllable to external factors. These factors have been mapped by [8] into six categories which include: Strategy; Culture; Leadership; Organisational structure; Resources/Skills and links and networking links. References [10], [13] and the pentathlon model [14] underscore the organisational consideration in the form of strategy, leadership, resourcing and system and tools.

IV. Innovation Model Process Flows

Given the proliferation in research and scholarly attention afforded to innovation over the last three decades, a diverse range of innovation modelling processes exist in the literature [3], [5], [7], [8], [24]. The existing catalogue of process models of innovation can be generally subdivided into three umbrella categories: linear, phased and non-linear, coupling, cyclical models. Early models of innovation presented innovation as a linear phenomenon where each element/stage in the process was considered modular and unconnected to other parts of the innovation process [5], underpinned by a linear underpinning approach to innovation; “Technology push” and “demand pull”.

Phased models serve as a management tool to map, systemize, control and review innovation progress across the sequential phases involved in an innovation project [25]. Inputs and outputs for each phase are defined with management reviews at the end of each phase to determine the continuation of a project (“go-no-go”). The advantages of such an approach is in reducing uncertainty and promoting completion of sub stages of the innovation process. Reflecting a project management orientation focus in terms of innovation modelling, the development funnel metaphor has been incorporated by researchers to illustrate the phased process from idea to innovation execution [26]. The wide element of the funnel reflects the idea generation/concept development stage and the funnel narrows as ideas progress through corresponding development, test and release. The Stage-Gate process [11], [12] represents distinctive and orderly phases consists of a range of gates to evaluate the various stages in the innovation development journey.

Mindful of the combination of technical activities occurring in the innovation process, the external forces of the market place, as well as the complex interac tions between the various stages of the process, researchers in the field of innovation have developed more complex and inclusive models based upon the limitations of linear and phased models [27]. For example, the Chain Linked innovation model [28] combines both market pull and technology push orientations, and identifies multiple paths of innovation process incorporating feedback loops across the components of the innovaiton value chain. Relatedly, Berkhout’s Cyclic Innovation Model [29] developed in the nineties views the innovation process as more than just technical invention and describes the innovation arena by a ‘circle of change' linking changes in science and industry, and changes in technology and markets.

V. The Evolution of Innovation Framework Models

Understanding of the process of innovation at the firm-level has evolved throughout recent decades from simple linear and sequential models to increasingly complex models embodying a diverse range of inter and intra stakeholders and processes. Distinguishable by their management focus, strategic drivers, accommodation of external actors and internal and external processes and function level integration, [5] documented five shifts or generations, demonstrating that the complexity and integration of the models increases with each subsequent

generation as new practices emerge to adapt to changing contexts and address the limitations of earlier generations [30].

For [5] the evolving generation of innovation models does not imply any automatic substitution of one model for another; many models exist side-by-side and, in some cases, elements of one model are interwoven with elements of another. More recently and following on from the seminal work of Rothwell's innovation generation model typology, researchers [31] have suggested that Chesbrough's [32] open innovation model represent the latest wave of innovation models. Table 1 [24] illustrates an overview of the key characteristics of generations of innovation framework models. For a detailed overview of the various generations of innovation framework taxonomy see [5], [7], [8], [33], [34].

TABLE I. GENERATIONS OF INNOVATION FRAMEWORK MODELS

Model	Generation	Characteristic
Technology Push	First	Simple linear sequential process, emphasis on R&D and science
Market Pull	Second	Simple linear sequential process, emphasis on marketing, the market is the source of new ideas for R&D
Coupling	Third	Recognizing interaction between different elements and feedback loops between them, emphasis on integrating R&D and marketing
Interactive	Fourth	Combination of push and pull models, integration within firm, emphasis on external linkages
Network	Fifth	Emphasis on knowledge accumulation and external linkages, systems integration and extensive networking
Open	Sixth	Internal and external ideas as well as internal and external paths to market can be combined to advance the development of new technologies

The *first generation technology push era* of innovation models represents a simple linear structure which mapped innovation as a sequential process performed across discrete stages. Technology push (Fig. 1) is based on the assumption that new technological advances based on R&D and scientific discovery, preceded and 'pushed' technological innovation via applied research, engineering, manufacturing and marketing towards successful products or inventions as outputs [5].

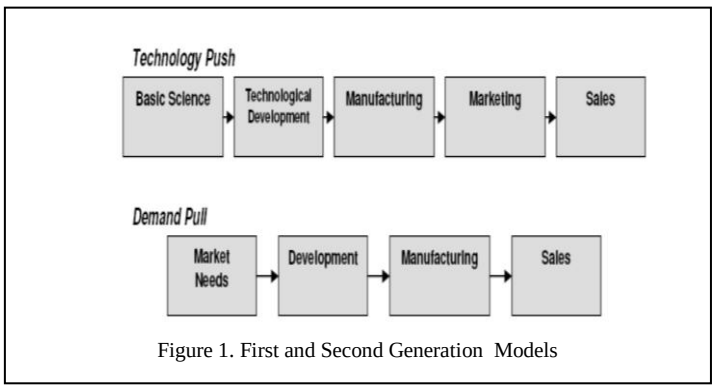

Figure 1. First and Second Generation Models

In the *second generation market/demand pull* era a linear model depiction of innovation also applies, this time prioritizing the importance of market demand in driving innovation endeavors. What distinguishes this model from its predecessor is that rather than product development originating from scientific advances, new ideas originate in the marketplace, with R&D becoming reactive to these needs [5].

The *third generation Interactive, Coupling or Chain-linked models* overcame many of the shortcomings of the previous linear atypical examples models, by incorporating interaction and feedback loops to recognize that innovation is characterized by a coupling of and interaction between science and technology and the marketplace. Consequently, the third generation models integrate multiple in-house functions and interdependent stages [5]. While third generation models are non-linear with feedback loops, a sequential nature of the stages of innovation were characterized (Fig. 2).

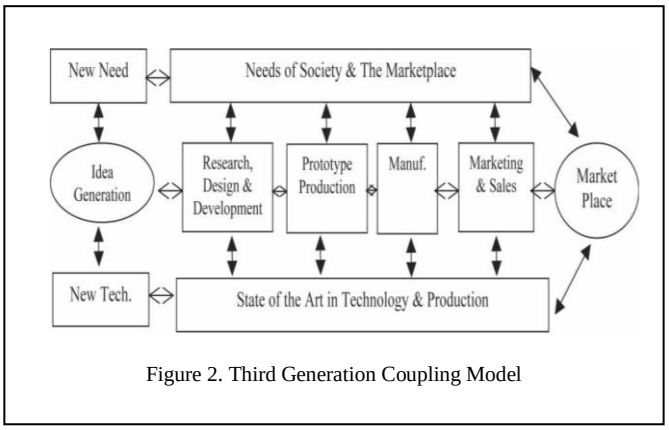

Figure 2. Third Generation Coupling Model

In response, and aiming to reflect the high degree of cross functional integration within firms, *fourth generation integrated or parallel models* reflect significant functional overlaps between departments and/or activities (Fig. 3). A further novel feature of this model is the concept of external integration in terms of alliances and linkages with suppliers, customers, universities and government agencies [5], [24].

Extending from the previous generation of innovation models, *fifth generation systems integration and networking models* emphasize that innovation is a distributed networking process requiring continuous change occurring within and between firms, characterized by a range of external inputs

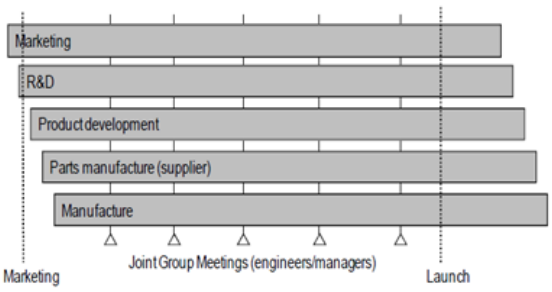

Figure 3. Fourth Generation Integrated/Parallel Model

encompassing suppliers, customers, competitors and universities [5]. Reflecting a systems thinking approach, the dominant characteristics are the integration of a firm's internal innovation ecosystem and practices with external factors in the National Innovation Environment [24]. The fifth generation models are characterized by the introduction of ICT systems to accelerate the innovation processes and communications across the networking systems in terms of raising both development efficiency and speed-to-market through strategic alliances (Fig. 4).

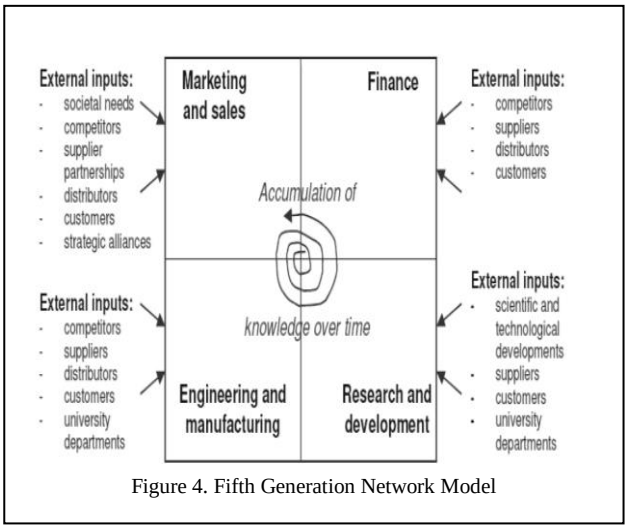

Figure 4. Fifth Generation Network Model

More recently and following on from the seminal work of [5], innovation generation model typology, researchers have suggested that open innovation [24] represents the latest wave of innovation models [31]. Reflecting a dominant orientation to the preceding network models of innovation, the open innovation approach is not limited to internal idea generation and development, as internal and external ideas in addition to internal and external paths to market (licensing, insourcing etc.) are facilitated within the innovation development chain (fig. 5).

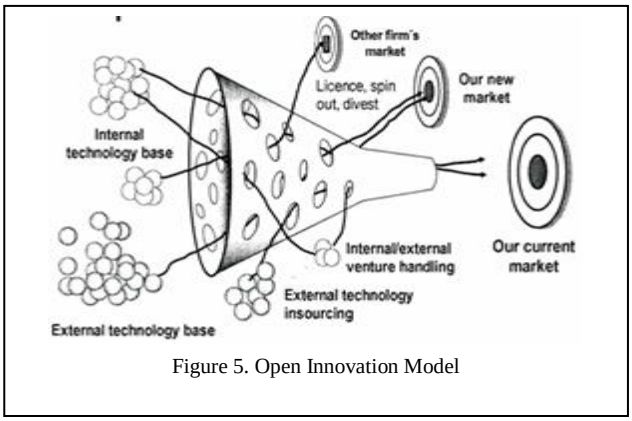

Figure 5. Open Innovation Model

Open innovation is considered as a paradigm shift whereby competitive advantage can result from leveraging discoveries beyond the confines of a single internal R&D unit (inbound open innovation) and can equally benefit from relying exclusively on their own internal paths to market through engaging with external organisations that may be better positioned to commercialize a given technology (outbound open innovation). In a similar vein, [35] identifies three core processes can be differentiated in open innovation:

(1) *The outside-in process:* which involves enhancing and extending an enterprise's own knowledge base through the integration of suppliers, customers, and external knowledge sourcing.

(2) *The inside-out process:* which refers to securing commercial/revenue benefits by bringing ideas to market faster than internal development via licensing IP and/or multiplying technology, joint ventures, and spin-offs.

(3) *The coupled process:* which combines co-creation with partners through alliances, cooperation, and reciprocal joint ventures with the outside-in process (to gain external knowledge) and the inside-out process (to bring ideas to market).

VI. Synthesis and Conclusion

Turning to the specific PACs domain, a pronounced challenge facing this innovation community is transitioning technical R&D into commercial and marketplace ready products and services [2].Responding to the need to develop a better understanding of how Privacy and CyberSecurity (PACS) market needs, innovation ecosystems and planning practice can be harmonized more effectively the contribution of this paper is centred upon the development of key innovation process modelling considerations. The degree of inclusiveness of innovation models has been refined throughout the years with each generation of model capturing academic and best practice knowledge of the time thereby serving as a foundation for the development of more sophisticated models. As synthesized in Table 2 below, based upon [5], [31], [36] the strengths and weaknesses of the successive innovation generations are presented.

TABLE II. Strengths and Weaknesses of Innovation Generations

	Features	Strengths	Weaknesses
First generation	Linear, Consecutive, Technology push.	Simple Radical innovation	No market attention No networked interactions No technological instruments
Second generation	Linear, Consecutive, Technology push.	Simple Incremental innovation	No technology research No networked interactions No technological instruments
Third generation	Linear, Consecutive, Fusion of market analysis and technology push.	Simple Radical and incremental innovation Feedbacks between phases	No networked interactions yet No technological instruments
Fourth generation	Consecutive, Parallel sub-activities, technology push,	Actor networking Parallel phases	Complexity increment of reliability No technological instruments

Fifth generation	Parallelism, Social interactions, Strong technological means.	Pervasive innovation Use of sophisticated technological instruments Networking to pursue innovation	Complexity increment of reliability
Sixth generation	Networking, Openness, Collaboration, Internal and external foci.	Internal and external ideas as well as internal and external paths to market can be combined	Assumes capacity and willingness to collaborate and network. Risks of external collaboration

The linear first and second generation models have been widely criticized for their overly simplistic linear, discrete and sequential nature of the innovation process. In response, the third generation of models demonstrates how the various business functions interact during the innovation process in addition to marrying the importance of technology push and market pull dimensions. Nonetheless, the main criticism of third generation models for is that they do not detail sufficiently mechanisms for interacting with environmental factors. Regarding fourth and fifth generation models there is a paucity of evidence to demonstrate the impact of these models. Mindful of the above, and factoring in a range of best practices within a specific historical period the notion of a generalized, prescriptive or isolated best practice approach can be misleading. More recently, the model whereby enterprises invest exclusively in research and development departments to drive innovation is eroding with the advent of open innovation. Contrasted to closed innovation, where innovation activities take place entirely within one firm, open innovation processes are characterized as spanning firm boundaries presenting opportunities to reduce risk and commercialize both external ideas and internal ideas externally.

In conclusion, there is no one size fits all solution to designing and implementing a successful innovation process as innovation engagement and management is unique to its respective organisational context. Nonetheless, there is an ever increasing general body of information around innovation practice and modelling which has direct relevance to informing firm-level innovation practice: the set of rules, models and stages involved [3], [6]; considerations for R&D, utilizing knowledge sources and responding to market forces [7] and the strengths and weaknesses of the various generations of innovation models [5], [8].

Irrespective of the firm-level context, exploring innovation models is important because they can assist management teams in framing, understanding, and acting on the issues which need managing. Such issues include, but are not limited to: the key phases in the innovation lifecycle and the activities, actors and their interrelationships. Moreover, the linkage of organisational contextual factors equally impacts upon the overarching innovation ecosystem. The imperative of developing the most optimal innovation processes and models is of paramount importance give than innovation is the means by which organisations execute in the present and adapt to the future challenges and opportunities.

ACKNOWLEDGMENT

This research is part of the IPACSO (Innovation Framework for Privacy and Cyber Security Opportunities) FP7 project, supported by the European Commission.

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