

# Knowledge Management for Innovation and Product Development in Supply Chains

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**Abstract.** New Product Development (NPD) has been viewed as critical to a firm's competitiveness and development. This paper presents a theoretical framework that utilizes existing approaches to facilitate effective use of knowledge management techniques in the NPD process. The development of this framework is based on the integration of relevant theoretical fields such as supply chain management, and open innovation. More specifically, it has accurately reflected on the nature of existing knowledge management systems and captured the core issues of NPD in a three stage approach of knowledge audit, knowledge calibration and knowledge absorption.

**Keywords:** Customer Knowledge Management, Supplier Involvement, Open Innovation, New Product Development, Product Lifecycle Management.

## 1 Introduction

### 1.1 Background

In today's business environment, firms are continually challenged by shorter product lifecycles, faster technological changes, demanding and sophisticated customers and the abiding trends of internationalisation, globalisation and convergence of industries. In response to these changes, increasingly, innovation and new product development (NPD) has been viewed as critical to a company's success [1-2]. However, the customer's rapidly changing preferences, the heterogeneity of their demands and resulting micro segmentation of product categories [3] have severely challenged a firm's capability to introduce new products. Most importantly, due to the paucity or deficiency of internal knowledge assets, firms have to rely on external knowledge to foster innovation and to enhance their performance [4]. This is also echoed by a shift in research on open innovation, where the purposive inflows and outflows of knowledge, as the impetus of accelerating innovation process, can be effectively managed [5]. Furthermore, speeding up creative operations will rely on a firm's ability to formulate a competitive strategy, co-ordinate with the supply chain, and compensate for intrinsic deficiencies by optimally leveraging external knowledge resources [4].

Knowledge has become the primary resource for the new economy and has been advocated by some researchers that knowledge will become the only source of competitive advantage [6-8]. It is therefore becoming of strategic importance that firms

constantly improve their ability to effectively manage knowledge flows, ensure success of NPD and increase competitiveness [9-12]. However, although knowledge is a decisive element for NPD, much of that required knowledge and needed information resides outside the firm's boundaries, specifically with customers, suppliers, business partners, and even competitors [13-14]. It therefore becomes imperative for firms to identify valuable knowledge sources within both internal and external environment and foster innovation quicker than the competitors [15], provided that they can accurately identify, grasp and embody the relevant technical and market knowledge within the NPD process [16]. Specifically, the onus to collect information on customers' needs through various means, as the principal component for NPD, and improve "the ability to import knowledge from the market" lies with manufacturers [17]. Particularly, effective integration of internal and external knowledge is a way of decreasing the possibility that "knowledge could be underutilized" [18-20]. In this setup, internal and external collaboration can play a decisive role in transferring tacit knowledge and building collective know-how [5], [20], [21].

Proponents of Supply Chain Management (SCM) have argued that the change in the nature of competition is becoming the momentum which shifts the competition from individual firms to supply chains [22]. Moreover, recent research has indicated that the supply chain is becoming the major source of external knowledge, skills, ideas and added value through collaborative efforts across the chain members [23-24], simultaneously influencing the present and future [25]. Collaborative innovation, in the supply chain, is about value co-creation through effective integration of all interested parties and an established way of doing business [26-28]. This shift has urged the managerial practice to re-audit and re-build the value-adding system and forced firms to re-evaluate and re-structure their value chains networks by adopting a holistic view. It has been widely discussed and accepted that valuable knowledge could be obtained and exploited through collaboration and cooperation across SC networks and optimally add value for the end customers. In this setup, customers as the "prosumer" [29] together with suppliers have been increasingly considered as the key drivers, co-innovators, co-developers and primary resources to NPD and as external actors, are increasingly influencing the process of innovation [30]. Value co-creation, recently, as customer engagement behaviour [31], is becoming the key to NPD [18] through generation of ideas and active contributions for fulfilling customer and market needs [32-33]. Rapidly changing technologies have provided customers with more opportunities to play a greater role by exchanging information with firms in the process of value co-creation [33-34]. Additionally firms have to simultaneously acquire solution knowledge scattered within both in the internal and external environment.

Increasingly, the end-user, and particularly lead users, has also been identified as key participants in product innovation [30], and in the formation of innovative networks [35]. Lead users can provide latent knowledge on product development, as well as improvement suggestions and solutions which can be embedded into the innovative process and then embodied into the new products [36-37]. Current research efforts in utilizing KM techniques for innovation have to overcome several problems such as reconciliation of perspectives between knowledge management and innovation, heterogeneity and distribution of knowledge within and across firms, and effective balance between knowledge exploration and exploitation for innovation [38] [39]. Essentially, how to effectively integrate KM into the innovative process and

significantly increase the return on investment has increasingly been regarded as a challenge. Unfortunately, these issues have never been simultaneously discussed, particularly for NPD, or in a much broader context, and unsurprisingly there are no comprehensive and reliable theoretical reference frameworks. A number of gaps that hinder the endeavours of integrating these relevant theoretical perspectives into a creditable and reliable framework have been identified and are discussed below.

Inter-firm KM effort is increasingly becoming an emerging research field wherein the potential value of KM might be optimally explored and exploited. However, tacit knowledge extraction coupled to the intricate technical requirements of KM, even within an intra-firm context, has become a barrier in pursuing value gain from inter-firm KM implementation. In an inter-firm context KM requires a sophisticated understanding of issues in the value chain as well as of employable techniques. Integrating KM into the NPD process requires an understanding of the relationship between KM and NPD and of the means by which the firms can deal with sequential aspects of this relationship, these being:

- how to identify solution knowledge based on accurate product need information;
- how to successfully acquire that solution knowledge and embed into the existing knowledge pool;
- how to effectively exploit the embedded knowledge to develop new products and increase the ROI.

So gaps exist on how to compensate for the intrinsic deficiencies of knowledge management systems and on how to identify and employ most suitable KM techniques to facilitate innovative efforts in an inter-firm and open innovation context. The shift from closed innovation to open innovation requires firms to do more than just “open the book” and have to consider various factors emerging from the competitive business environment and complexity of synthesizing external and internal knowledge assets. Particularly, the challenges are not only to elaborate and employ reliable techniques for managing external knowledge, but also how to seek need information and solution knowledge from external actors who possess valuable knowledge, open cultures and are willing to engage in learning and knowledge creating activities with a certain degree of risk [40]. Such a process should be founded upon a clear understanding of potential innovation paths through collaboration and competition in the SC network and most importantly on the effective utilisation of KM techniques to facilitate integration. Exploring and exploiting potential innovation paths relies on effective supply chain network relationships with partners that possess sharable knowledge. Utilising this knowledge, in a relative time frame through PLM, will create knowledge loops in a SC network context. The perspectives of lifecycle management and SC networks have provided theoretical foundations as to how to integrate knowledge creation into different phases of the innovation process [41]. However the difficulty is how to evaluate the value of knowledge and the feasibility of embedding knowledge specially if there is a shift in value distribution across organisational boundaries in the SC network.

## **1.2 Aims of Research**

Following the discussion above, the design of a comprehensive and creditable approach to bridge these gaps therefore becomes a prerequisite to the harmonious

combination of these relevant theoretical fields. Although the main focus of the research is to develop and present a preliminary, theory-based framework which can facilitate the process of managing knowledge flows for NPD and outline a novel approach for innovation in a SC network context, the adopted approach to do so becomes part of the contribution of this work as well. The developed framework employs knowledge audit, knowledge calibration and knowledge absorption techniques to control knowledge flow across three collaborative innovation phases, pre-acquisition, in-acquisition and post-acquisition.

Following the introductory section, this paper is presented in six sections. Section two gives a brief overview of the adopted research approach. The results of an extended literature review, presented in section three, are followed by an evaluation of extant models and frameworks related to the integration of KM and NPD in a supply chain network context. The foundations of the proposed theoretical framework are presented and discussed in section five, explained in more detail in section six and concluded upon in the final section.

## 2 Methodology

The methodological approach, presented in (figure 1) is the result of the research aims. In order to design a theory-based framework, gaps specification has been positioned as the prerequisite of formulating the basic research aims. It is followed by a relevant literature review that highlights not only the main building blocks of extant frameworks but also uncovers potential disadvantages which need to be solved within this research. It is believed that these aspects, if explored and developed effectively, provide one approach to bridging the theoretical gaps.

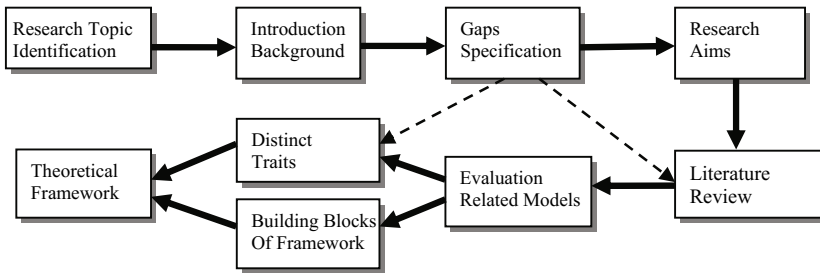


Fig. 1. Research Methodology

## 3 Literature Review

### 3.1 Knowledge Management

Increasingly, innovating firms have to improve their abilities to meet the never-ending requirements, from demanding customers and fierce competition, by effectively employing KM techniques to manage internal and/or external valuable knowledge resources. Therefore, in order to innovate, firms need to create an inventory of

knowledge assets and make it more visible, accessible, sharable and measurable [42-43]. The firms can benefit from successful KM implementation by enhancing their competitive advantage, customer focus, employee relations and development, innovation, and lower costs [43-44].

KM is a kind of strategy which involves delivering the right knowledge to the right persons at the right time (APQC). As a strategy, effective KM implementation for innovation can be solely realized by aligning with the overall business strategy not only within internal environment, but also across the external supply chain [45-47]. Accordingly, KM efforts has been understood, no longer merely as an option but rather as a core issue that has to be thoroughly dealt with for firms to surpass the global competition [48].

As a process [49], KM can improve the learning abilities and increase effectiveness and efficiency of organizational performance by systematically coordinating processes of knowledge internalization, externalization, socialization and combination [50-51]. This viewpoint about KM has been advocated by Davenport et al., [52] who place the attention on the process of “knowledge import” and “knowledge export”. The underlying principle is to “export” imported knowledge to the rest of firm for the purpose of solving problems or encouraging innovation.

KM can be seen as an effective coordinating mechanism which ultimately enables the resource to be converted into capabilities [53-54]. Similarly, Earl [55] suggests that KM can be regarded as central to product and process innovation or improvement, executive decision-making and organizational adaptation and renewal. In terms of innovation, the KM perspective of NPD is about how to seek optimal ways of controlling the valuable knowledge assets. In essence, this process is an effort of utilizing these mechanisms to coordinate the conversion process, namely from the embedded knowledge to embodied knowledge [56].

Along with the theoretical development of KM, within last two decades, there are many researches that focus on exploring and exploiting the roles of KM for NPD or innovation [56-66]. Essentially, KM has positive effects on innovation, in particular on the decisive roles of vital components of the innovative processes; namely managing (absorbing) knowledge from the external environment and exploiting the acquired knowledge based on a sound embedment [67], [17]. According to Shani et al, [58], KM and innovation configuration determines how the firm can capitalize and create knowledge by providing the organisational context wherein NPD efforts are materialised. Similarly, Plessis [20], states that the main drivers for integrating KM with innovation are a competitive advantage through collaboration and a reduction in the complexity of the innovation process. Basadur and Gelade [63] combined knowledge capture and utilization with the four phases of the KM cycle, namely generation, conceptualisation, optimisation and implementation. They place more attention on the relationship between KM and organization learning and they address ways by which the firms can become a “thinking organization.” Abou-zeid and Cheng [65] presented a modified SECI model for knowledge creation and utilization that differentiates the K-creation process, which involves tacit knowledge transfer, from the K-utilization process affected by the explicit and simple internalization and combination processes. Similarly an ontology-based methodology, to solve knowledge sharing problems in the NPD process was proposed by Bradfield and Gao [64].

Essentially, tacit nature of knowledge [69], stickiness of knowledge [70] and “knowledge that is located, embedded and invested in practice” [71-72] have been viewed as the main barriers which hinder processes of knowledge creation. It is worth noting that knowledge, as the key component of all forms of innovation [39], is rooted in organizational activities and practices and is embedded in multiple elements and sub-networks [73]. Therefore it can only be transferred when there are no barriers between senders and recipients [74]. Moreover, due to their knowledge-intensive and multi-disciplinary nature, NPD processes require KM techniques to transfer, integrate and regenerate knowledge from both the internal and external environments. More specifically, an effective combination of two theoretical fields, KM and NPD, should facilitate knowledge creation as well as identification of knowledge deficiencies, knowledge detection in the value chain and subsequent collaboration.

### 3.2 Innovation

Today’s business environment is fiercely competitive. Globalization, ever fast changing technologies and increasingly demanding customers are constantly pushing the performance bar upward. Becoming an innovator is the only way to be a winner. Unsurprisingly, successful firms have to innovate at the global frontier better than their rivals [75]. Particularly, success of NPD will help the firms to siege new opportunities and actually propel into new business fields and gain first-mover advantages or surpass the competitors in term of responsiveness or innovativeness. If companies fail to continually innovate, they die [5]. A survey conducted by the Product Development and Management Association (PDMA) has shown that successful new products contribute 50% to 60% of sales in most companies [76]. Similarly, Simth [77] states that 75% of the revenues in successful firms are generated from new products or services that never existed five years ago.

Innovation is, basically, aimed at producing new knowledge that can be developed into doable solutions for society through distinctive and idiosyncratic market acceptable products and services. [78-79]. According to CBI [23], innovation is considered as being ‘the successful exploitation of new ideas’ across industrial networks that collaborate in a SC context to stimulate the creation of these ideas. Consequently, this process will rely on the decision to exploit and develop the power of effective KM implementation to support innovation and creativity [25]. By doing so, firms become much more prepared to innovate and perform successfully to meet the requirements from the customer and market faster and better than the competitors. DTI [80] also concluded that there is a need to take a broader view of the innovatory process and to tap into a network environment, because that individual actor is seldom capable to innovate independently. Networks through establishment of “weak and strong ties” [81] and bridging of “structural holes” [82] can greatly enhance the processes of knowledge creation. This viewpoint has been advocated by Antonio who states that the knowledge needed for innovation is often a product of the configuration and combination of different fields of knowledge from heterogeneous resources [83]. Therefore, it has become a strategic attractive option to acquire knowledge from external sources to compensate for scarcity of internal resources [87]. Accordingly, open innovation [5], as an emerging innovation strategy, has been regarded as the essential element to revitalize in-house innovation or closed innovation and to accelerate the

innovation process [5], [84], [85], [86]. Gassmann et al., [88] presented three archetypes of the open innovation process:

- Outside-in: integrating external knowledge, customers and suppliers;
- Inside- out: bring ideas to market;
- Coupled processes: couple outside-in and inside-out processes and work in alliances in a complementary manner.

It is undeniable that innovation depends on knowledge [20] and the foremost purpose of KM is to facilitate innovation [89], change and product development [90-93]. Firms can engage in collaborative relationships to identify knowledge capability, knowledge reliability and richness, and develop receptors to absorb external knowledge to improve organizational competitive advantage [94], [20].

### 3.3 Supply Chain Management

SC as a value chain can offer the opportunities to simultaneously improve the individual firm's performance and increase the possibilities to achieve common goals of "growing the pie" [95]. Meanwhile, it provides firms with a way to optimally leverage core competences and unique skills and strategically outsource non-core activities to external networks [96-98]. Basically, SCM covers all business processes between vertically linked entities within three dimensions, action, relationships and processes [99-103]. The Council of Supply Chain Management Professionals (2006) concluded that SCM "encompasses the planning and management of all activities involved in sourcing and procurement, conversion and all logistics management activities. In essence, supply chain management integrates supply and demand management within and across companies."

The relation-oriented definition [104] of SCM suggests that relationships, cooperation and mutuality are vital in improving effectiveness, efficiency and overall performance. Meanwhile, the resource-based view of firm perspective explains why relationships between buyers and sellers are the most important intangible resources [105], [54]. Consequently, appropriate relationships with channel members are not only the antecedent of successful "outsourced activities" but also the consequence of fruitful collaboration. Therefore, it is core to improve the abilities and create a mechanism, by which the intricate relationship can be enforced [99], [106].

SCM presents the effective integration of key business processes that add value to end-customer, from upstream suppliers, manufacturers, distributors and retailers [107]. So it can be seen as means to coordinate functions and processes and respond to the requirements of customers through effective management of information and knowledge across the network [108]. Cooper et al. [100] state that SCM encompasses three closely inter-related elements: the SC network structure, the SC business processes, and the SCM components as depicted in figure2. Such a configuration provides the basis to identify and consider all exogenous and endogenous variables related to NPD and create strategically [110-112], operationally and technologically long-term stable relationships [104].

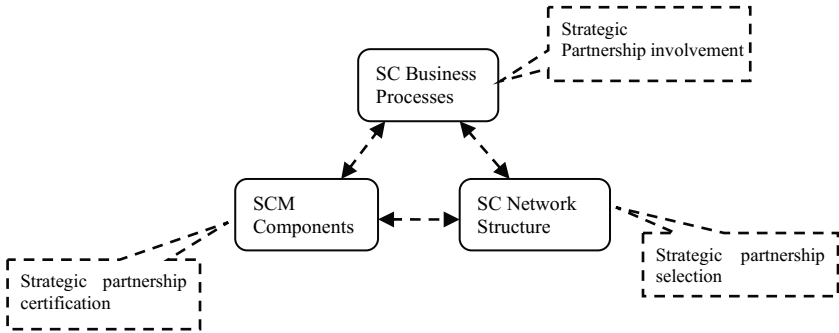


Fig. 2. SCM Framework (adapted from [185], [100])

Based on the extant literature, it is widely accepted that the suppliers’ innovative capabilities are the major determinants for collaboration. More specifically, Burton [113] argues that suppliers accounted for approximately 30% of quality problems and 80% of product lead-time problems. Increasingly, the suppliers’ role, particularly for NPD, has shifted from simple component providers to systematic development partners that possess and can provide manufacturers with valuable knowledge related to the final product. Recently, most research in this field focuses on the timing of supplier’s involvement. Petersen et al., [114] state that early supplier integration is an important coordinating mechanism for decision making that links product design, process design and supply chain design together. Moreover, early supplier involvement (ESI) in product development has been increasingly regarded as the vital means by which the manufacturers will be able to leverage the maximum value of the suppliers’ knowledge assets, cut down development risks and ensure the success of innovative activities [115].

Supplier-involved Collaborative Product Development (CPD) is viewed as an effective way to create wider collaborative networks and absorb external knowledge. Essentially, supplier integration into NPD process is a social [116-117] and systematic process [114]. Traditionally, research on supplier-involved CPD addresses the key factors, such as, collaboration method, platform, tools and standards [119-122]. However three elements are critical in supplier integration: (1) the extent to which the supplier influences decision-making; (2) the amount of control the buyer retains over the design; and (3) the frequency of design-related communications [114], [123]. Meanwhile, the compatibility, reputation and fit between parties are also critical elements [124-127]. Supplier integration offers a number of advantages. It provides “sticky” information regarding new ideas and feasibility, and supplementary product and process solutions [128-130], reduces the complexities and risk of the innovation process [129-132], and it facilitates communications, information exchange through networks and quality improvements [133-129]. Notably, a few researchers believe that there is no link between supplier involvement and key innovative performance [134] and argue that it is difficult to accomplish the “seemingly positive outcomes” of supplier involvement in NPD [135-137]. However, negative arguments and lack of studies on this process do not diminish the significant roles of suppliers in the innovative process.



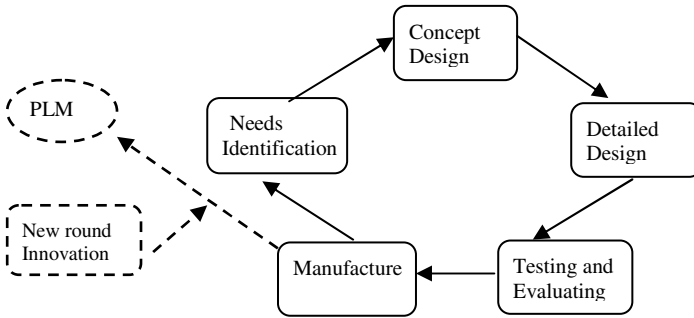


Fig. 3. Product introduction process (adapted from Jenkins [200])

### 3.4 Customer Knowledge Management

Traditionally, a NPD project (see Figure 3) needs to effectively coordinate R&D and marketing, to identify potential product opportunities, market requirements and configure an operational capability to produce. This combination can be regarded as the process of leveraging complementary knowledge resources. Success of NPD projects requires companies to develop competences by creating an external knowledge sharing ecosystem, which can not only ensure the success of NPD, but also it is hard to simulate [138]. In practice the rate of failure of NPD is high, estimated to be between 40-75% [139], with lack of a fit between new products attributes and customer requirements being a major cause [140-141]. Integrating the identification of customer needs in the product development efforts is a prerequisite to successful NPD [142], [3]. Accordingly, capturing customers and market requirements along with knowledge for solving problems is becoming an imperative for innovating firms. Absorbing customer knowledge through customer integration into the NPD process strengthens a company's core competences [143], as customers will cooperate and creatively contribute to the different phases of the innovation process [144]. Particularly in a B2B business environment, customers are becoming co-producers [145] and "customer relationship management" is becoming an attractive and academically interesting mechanism, for knowledge creation and innovation [146], [147], [30]. Customers, in the 21st century, are not anymore passive recipients of NPD but they are demanding to play a more active role [159].

Customer knowledge, as an important knowledge asset for an organization, can be broadly defined as the combination of external consumer knowledge and supply chain knowledge [148-149]. According to Wallace [150], to manage customer knowledge is to capture knowledge in need and solution information [151-152], as such knowledge will contribute to the development of the "right" products [152]. However, "sticky information" [91], could jeopardise such a process, as customers are often not able to express their requirements [153-154]. Customer involvement affects all phases of NPD and influences the effectiveness and efficiency of the NPD process [146], [155]. This process is referred to as "interactive value creation" [152] or "value co-creation" [144] in an open innovation context [5]. According to Prahalad et al., [147] effective interaction with customers is a prerequisite to value co-creation and the means of encouraging customer involvement in innovation [156-157]. Meanwhile, leveraging

external knowledge effectively and proactively, through KM based inter-firm collaboration, is becoming a *sine qua non* for a firm's development [13].

Recently, customer involvement has been widely discussed as customer knowledge management (CKM), a compelling approach to harness valuable customers' knowledge and capability [159-161]. Generally, CKM is described as ongoing process of generating, disseminating and re-using customer knowledge to satisfy consume requirements [162]. Similarly, CKM refers to processes of involving customer into innovative performance improvement activities by sharing valuable knowledge within the network environment. This process actually increases the firms' competitive advantages by encouraging a two-way exchange of knowledge that benefits both parties [163]. However this process is considered to be relatively passive and even tacit by most of researchers and practitioners and the challenge is to create mechanism for managing the relationships [159], [161], [164]. According to Gibbert et al, [161], there are five styles of CKM:

- Prosumerism that stems from the expression "prosumer" [29] and indicates that customers can play the key roles as co-innovators, as in Bosch and Mercedes-Benz, Quicken, IKEA practice [161].
- Team-based co-learning that focuses on embedding customer knowledge into a platform which can facilitate the process of embodying the shared knowledge into new product or service, Amazon and Toyota as the most typical examples.
- Mutual innovation, initially identified by Von Hippel [128] that describes the end-user's decisive role in innovation. Rider Logistics is a quoted example; a trucking company that developed to a logistics solution provider through mutual innovation with its customers [161].
- Communities of creation that differ from traditional communities of practice and where interaction of customer groups achieves the common goal of knowledge creation [28]. Examples are Beta created by Microsoft and Netscape and Antenna shops from Sony and Panasonic.
- Joint Intellectual Property is the most intense form of cooperation between companies and their customers that share ownership of NPD [161]. For example, Skandia Insurance and Kooperativa Forbundet.

### 3.5 Users as Innovators

Since at least Adam Smith's example (1776) of "a boy's innovation for saving his own labour", we have witnessed a significant transition on the role of users in innovation documented by expressions such as "users play an important but peripheral role" [165-166], "users are the sources of innovation, not just a helper" [128] and more recently, "users as innovators" [158], [167]. The concept "users as innovators" has been investigated through cases in open-source software development [168-169] where they are "user-entrepreneurs" [170-171]. Other studies include the "Collective Customer Commitment" method [3] successfully employed by companies such as Threadless, and Enos's [181] research in oil refining; Freeman's [179] study in chemical industry; Hollander's [180] report on DuPont's rayon plants and von Hippel's [151] research in scientific instrument innovation process. These studies have shown that knowledge from users or customers [172], [174] and customer knowledge

management are indispensable for developing innovative products [173]. More recently Cooper and Dreher [199] conducted a survey of 150 firms and concluded that the Voice of Customer (VoC) has been adopted as the most popular and the most effective source of new product ideas.

### **3.6 Product Lifecycle Management**

Improvements relating to the effectiveness and efficiency of NPD across the product lifecycle are becoming key business factors [175-176]. Moreover, CKM has been positioned as an effective approach which is closely linked to and supported by Product Lifecycle Management (PLM) [177]. According to Stark [178], PLM is “the activity of managing a company’s products all the way across their lifecycle (from cradle to grave) in the most effective way”. In essence, PLM is the starting point of the innovative process which consists of continual knowledge identification and knowledge acquisition from customers or market. Therefore, the effectiveness of PLM will dramatically influence further processes of knowledge creation and ultimate success of NPD projects. Gathering information and knowledge from the customer and market therefore will be the key start of efforts in synthesizing knowledge loops for successful NPD. Particularly, in terms of managing knowledge across the product lifecycle, different approaches may be required in the different stages of the cycle [177]. There are a number of issues that arise and need to be addressed and these are discussed later in the presentation of the framework.

## **4 Evaluation of Extant Frameworks**

According to the extant literature, there are numerous studies, (a comparison is presented in Table 1) which have focused on developing the methods of integrating customers or suppliers into the NPD process by utilizing KM techniques [30], [130], [114], [134], [94], [182], [13], [164], [119], [183], [184], [58], [115], [187], [188]; [189]). Although, these studies have shown idiosyncratic understanding and provided various means by which the firms might link KM with NPD process, the common characteristic is that the firms need to effectively leverage knowledge from external actors and then optimally internalize and exploit that knowledge within the innovative processes. What is additionally evident is that most of these frameworks do not address a number of issues:

### **1. Lack of Studies about KM Techniques for Inter-firm Knowledge Flow’s Control in NPD Activities**

Most commonly discussed and employed KM techniques are not problem-free and impose challenges in an intra-firm KM context and unsurprisingly will directly affect inter-firm KM activities. What kinds of techniques can be suitable for managing knowledge across organizational boundary? Can the SECI (socialization, externalization, combination, and internalization) processes occur easily within inter-firm KM activities? Therefore, a requirement will be to explicitly analyze the relationship between NPD and KM and elaborate on feasible and reliable techniques which can embody the essential and vital linkages between these two fields.

## **2. Lack of a Holistic View of Knowledge Flows for NPD**

In essence, KM based NPD is about control of knowledge flows. Accordingly, the key as to formulating a comprehensive framework is to identify knowledge sources, create knowledge flows and effectively manage them. The starting point is the identification of need information. This is followed by retrieval of solution knowledge that needs to be effectively embodied into new products or services. However, most frameworks offer one-sided solutions by focusing on either the customer side [30], [182], [184] or the suppliers side [114], [115], [130].

## **3. Lack of Discussions on How to Formulate Knowledge Flows in a Supply Chain Context**

Although, there are a few studies which have been focused on expanding knowledge flow formulation into a supply chain context, such as [13], [164], [115], [119], they merely provide a basic outline which addresses the importance of integration. More specifically there is a need to effectively understand and conduct NPD in a more systematic and comprehensive manner by considering the intrinsic elements of relevant theoretical fields. Therefore the framework has to focus on how to effectively leverage the potential value of external actors by creating a closed knowledge loop for NPD to bridge need information and solution knowledge.

## **4. Lack of Studies of Multidimensional Factors for Control of Knowledge Flows**

The main components of the framework should focus on not only indentifying and grasping the need information and along with solution knowledge, but also paying attention to the techniques as to how to effectively and efficiently internalize and exploit the solution knowledge to improve the quality of products and services. Accordingly, there are various factors, which will actually affect this process and need to be deeply investigated, in creating a reliable framework. However, most research has overlooked or failed to closely explore what will influence the process of embedding solution knowledge into an existing knowledge pool without any chaotic consequences and little attention has been focused on the process of embodiment of embedded knowledge.

# **5 Foundations of a Theoretical Framework**

Just as discussed above, this paper aims to expand NPD into a SC context by utilizing KM techniques. Accordingly, it is vital to structure a workable framework based on effective combination of the NPD, SCM and KM concepts. Inspired by the strategic supply chain model [185], [100] this theoretical framework is constructed into three phases, pre-acquisition, in-acquisition and post-acquisition. Moreover, in order to embrace open innovation strategy [5], [143], the framework especially focuses on two aspects: firstly analyzing internal and external knowledge assets regarding to internal availability and external complementary credibility (collaborative sharing). This process is extraordinarily linked with Knowledge (Management) Audit Approach [186] and has to be conducted within the pre-acquisition phase. Secondly, as a process of transferring embedded knowledge to embodied knowledge [56], innovation is

**Table 1.** Relevant models and frameworks

Models	Authors	Main characteristics	Description of Models
A new approach to developing customer products	Thomke and von Hippel (2002)	<ul style="list-style-type: none"> <li>♦customer-as-Innovator;</li> <li>♦forward the interface location between supplier and customer;</li> </ul>	It forwards the location of interface between supplier (manufacturer) and customer and the trail-and-error iterations by employing Customer-as-Innovators Approach.
Supplier integration based model	Ragatz et al., (2002)	<ul style="list-style-type: none"> <li>♦exogenous variables: needs and alignment; technology uncertainty;</li> <li>♦endogenous variables: integrative strategies and team processes;</li> </ul>	It focuses on synthesizing two exogenous and two endogenous variables that affect successful supplies integration into the NPD process.
Customer as Innovators Approach	Thomke and von Hippel (2002)	<ul style="list-style-type: none"> <li>♦form a user-friendly toolkit;</li> <li>♦increase the flexibility of production process;</li> <li>♦customer selection;</li> <li>♦evolution of toolkits;</li> </ul>	They develop a Customer as Innovators Approach and present five steps for turning customers into innovators.
Conceptual model for NPD organization knowledge system	Mohrman et al., (2003)	<ul style="list-style-type: none"> <li>♦contextual organizational elements;</li> <li>♦knowledge worker behaviours;</li> <li>♦knowledge outcomes;</li> <li>♦knowledge effectiveness;</li> </ul>	Organization knowledge system consists of four constructs, namely contextual organizational elements, knowledge worker behaviours, knowledge outcomes and effectiveness.
A new business model for collaborative product services	Ming et al., (2003)	<ul style="list-style-type: none"> <li>♦knowledge resources come from stakeholder, customer, manufacturer and suppliers;</li> </ul>	The model focuses on synthesizing the knowledge resources from stakeholder, customer, manufacturer and supplier into a Collaborative Product Services pool which is controlled by developer.
Three steps for systematic process of involving supplier into NPD	Petersen et al., (2003)	<ul style="list-style-type: none"> <li>♦deep and accurate understanding about suppliers knowledge;</li> <li>♦effective communication with suppliers;</li> <li>♦fully exploit the value of supplier's knowledge and capability;</li> </ul>	There are three steps to fully exploit the value of suppliers' knowledge and capability. Furthermore, they develop a simplified structural equation model that integrates the major activities required for integrating suppliers into the NPD process.
Contingency factors for supplier involvement	Wagner et al., (2006)	<ul style="list-style-type: none"> <li>♦contingency factors on the organizational level;</li> <li>♦contingency factors at project level;</li> </ul>	It is vital to match the product architecture and the type of design based on effective interaction with "right" suppliers, from "none" to "black box" supplier integration. Meanwhile, criteria for selecting suppliers, enhancement of buyer-supplier relationship, timing of involvement etc.
Knowledge-based Product Model for NPD	Dutt (2006)	<ul style="list-style-type: none"> <li>♦reacting with response from customer and market;</li> <li>♦knowledge based product;</li> </ul>	The model focus on creating organizational memory, which possesses embedded knowledge and embodies learning, to satisfy dynamic needs and requirements from customers through reaction with response from customer.
Strategic contingency model	Ju, Li and Lee (2006)	<ul style="list-style-type: none"> <li>♦knowledge management;</li> <li>♦knowledge characteristics;</li> <li>♦organizational learning and innovation;</li> </ul>	They present a strategic contingency model which mainly focuses on the effective integration of knowledge management, knowledge characteristics, organizational learning and innovation.
Marketing and KM based framework	Kohlbacher (2007) (2008)	<ul style="list-style-type: none"> <li>♦relationship with supply chain;</li> <li>♦customer relationship management</li> <li>♦product development management and marketing research;</li> <li>♦knowledge co-creation with customer;</li> </ul>	The framework depicts the relationship between supply chain management, market research, customer relationship management and product development management. It addresses the vital roles of relationship between marketing process and customer, supplier and partners etc, particularly knowledge co-creation with customer.

**Table 2.** Relevant models and frameworks

Models	Authors	Main characteristics	Description of Models
Conceptual model for adopting internal and external resources	Tessarolo (2007)	<ul style="list-style-type: none"> <li>◆internal cross-functional organizational structure;</li> <li>◆externally involving customers and suppliers;</li> </ul>	It addresses that both internally adopting cross-functional organizational structures for development and externally involving customers and suppliers into the process can be powerful drivers.
An alliance oriented framework	Jiang and Li (2009)	<ul style="list-style-type: none"> <li>◆KM for innovation within alliance context;</li> <li>◆the broader scope of alliance and the greater opportunity for sharing knowledge;</li> </ul>	It portrays the relationships between KM and alliance characteristic in term of innovative performance. They investigate and conclude that the broader scope of alliance and the greater opportunity for interaction of sharing knowledge.
Conceptual framework of Consumer Co-creation	Hoyer et al., (2010)	<ul style="list-style-type: none"> <li>◆importance of theoretical synthesis;</li> <li>◆introduce four phases new product introduction;</li> <li>◆three vital factors for consumer co-creation;</li> </ul>	Theoretical integration along with degree of co-creation is the central of four-phase of NPD, namely ideation, product development, commercialization and post-launch. Meanwhile, it highlights three vital factors for this process, namely consumer motivators, firm stimulators and firm impediments.
Five phases based continuous innovation process	Xu et al., (2010)	<ul style="list-style-type: none"> <li>◆idea generation ;</li> <li>◆ research and development;</li> <li>◆implementation;</li> <li>◆commercialization</li> <li>◆internalization;</li> <li>◆ notably it address the phases about pre-creation and post usage;</li> </ul>	They develop five-stage NPD process and propose a macro model of KM for continuous innovation and depict knowledge lifecycle phases: pre-creation, creation, intermediate, usage and post usage. And it can fit into knowledge assets from physical view, human view and technological view for the purpose of NPD.
A socio-technical systems based framework	Shani and Sena (2010)	<ul style="list-style-type: none"> <li>◆business environment cluster;</li> <li>◆social subsystem;</li> <li>◆technological subsystem;</li> <li>◆KM system;</li> <li>◆NPD processes and outcomes</li> </ul>	It portrays sustainability of NPD process through effective combination of five aspects, namely business environment cluster, social subsystem and technological subsystem, knowledge management system etc.
Supplier-involved collaborative product development framework	Wang et al., (2010)	<ul style="list-style-type: none"> <li>◆collaborative business model;</li> <li>◆collaborative process model;</li> <li>◆collaborative operation model;</li> </ul>	Essentially, three models respectively focus on the strategic analysis regarding with collaborative strategy, market information analysis and target product status analysis; on coordination and integration of customer and supplier in CPD; on the detailed activities at operational level.
Conceptual framework	Akram et al., (2011)	<ul style="list-style-type: none"> <li>◆integrate KM with technology, KM activities and human capital into NPD;</li> <li>◆collaboration between internal and external environment, learning and culture etc;</li> </ul>	It focuses on integrating KM and other factors, such as technology, KM activities, knowledge assets, human capital etc. It positions SECI model as the central of the innovation and is supported by collaboration between internal and external environment, learning and culture etc.
Knowledge flows oriented model for NPD process	Assimakopoulos and Chapelet (2012)	<ul style="list-style-type: none"> <li>◆key factors are people, technology, systems and products;</li> <li>◆knowledge flows control is to identify knowledge source, obtain knowledge and exploit knowledge;</li> </ul>	The model puts technology, systems and products at the central and depicts NPD cycle: design phase, analysis phase, development phase and full launch. Notably, it is based on the knowledge flows control, namely identify knowledge source, obtain knowledge and exploit knowledge.

subject to coordination of the two actions. In its essence, Knowledge embedding can be matched with Knowledge Calibration [190] and ultimate knowledge embodying will be closely linked with Knowledge Absorption and absorptive capability [191]. Subsequently, as key drivers of innovation, these two KM techniques can be utilized to facilitate the process of knowledge embedding and knowledge embodying across two phases: in-acquisition and post-acquisition. In fact, this framework might compensate for the deficiencies of existing Open Innovation studies and expand the related research into a broader context

## 6 Preliminary Theoretical Framework

Based on the literature review, a preliminary theory-based ACA (Audit, Calibration and Absorption) framework (See Figure 4) is formalized as following:

### 6.1 Pre-acquisition and Knowledge Audit

Audit Approach is a critical part of a KM framework and an effective first step of internal KM efforts [186]. Effectiveness of Knowledge Audit is a determinant which directly affects the decision “can I do it” (Knowledge Management Audit) and further activities related to managing knowledge resources. Essentially, it can provide an outline by systematically investigating and evaluating the “health” of a firm’s knowledge and ability and readiness of further KM implementation. Most importantly, it encourages two fundamental and philosophical conversions; from we do not know what we know to know what we don’t know and from know what we don’t know to know how to know. The main objectives of Knowledge Audit or knowledge management audit in the pre-acquisition phase are:

- What we know and what we don’t know (knowledge and abilities gaps identification)
- Who knows and can we cooperate (partnership selection)
- How to make it happen (knowledge loop creation)
- Are we ready to embrace activities of KM? (ability audit)
- To formulate an innovative strategy (outside-in, inside-out or coupled model);
- To analyze data or information from customers and market (need information)
- To locate and evaluate the valuable external knowledge assets and select strategic partnerships;
- To create and disseminate strategic goals through mutual collaboration and cooperation;

### 6.2 In-acquisition and Knowledge Calibration

According to Pillai & Goldsmith [190], knowledge calibration is a measure of the degree of agreement between knowledge accuracy and confidence within the knowledge acquiring and embedding processes. Meanwhile, capability to calibrate knowledge acts as a facilitator or a valuable catalyst which can support firms to make judgement about strategic partners in term of abilities, characteristics, potential

development and criteria of meaningful interaction. The main objectives in this phase constitute the requirement for the following actions:

- Building up trustworthy relationships and enhancing mutuality;
- Addressing shared goals and consistently improving routine activities;
- Harmoniously integrate and optimally utilize IT-based hard infrastructure and people-based soft mechanisms;
- Improving leaning awareness and abilities;
- Cooperative Chain Culture Creation (C4);

### **6.3 Post-acquisition and Knowledge Absorption**

Employing KM techniques will aim to facilitate not only sharing of knowledge between providers and receivers but also embodiment or absorption of the acquired knowledge into the new products or services. Accordingly, there are numerous factors that will affect the success of knowledge absorption, but amongst them, absorptive capability and the learning processes are the decisive determinants [191-192]. Absorptive capability is the ability to use prior knowledge to recognize the value of new knowledge and to assimilate and apply it to create new knowledge and capabilities [191]. Cohen & Levinthal [191] described “absorptive capacity” as a key factor in the innovative process. Generally, it refers to the ability not only to acquire and assimilate information, but also to exploit it [191], [193]. Improvement of “absorptive capacity” is closely linked to interaction with the external environment [191] and therefore interaction and openness have become the determinants which affect the effectiveness and efficiency of the knowledge creation [194]. Interaction, at individual level in particular, at inter-firm level is critical to articulate and amplify knowledge [7] and to establish channels for embedding and embodying knowledge flows for innovation. Openness may also speed up the pace of innovation by effectively leveraging outside sources of cognition and competence in the development of new products or services.

The learning processes are the mechanisms and key impetus that effectively compensate for the firms’ ability deficiencies [192]. The capability of a firm to absorb external knowledge and information has been viewed as one of the pillars related to transformation of knowledge and its conversion into new products [195]. How to benefit from the dynamic interaction with external actors, in increasingly competitive market, has been regarded as the bottleneck that influences new products and services but also the development of the firm itself. According to Souitaris [196], there are two aspects which affect the interaction process: scanning for external information and cooperating with external firms. In a dynamic environment, focusing on continuous leaning to enhance the organizational knowledge capability and strengthen the knowledge transformation process will improve quantity and quality of knowledge accumulation [197], enhance the organizational knowledge base and the ability of knowledge creation [198]. The key issues of this phase should be addressed as following:

- Continuously improve the strategic partnership;
- Evolve from knowing firm to learning firm( encouraging individual creative activities; indirectly or directly customer involvement etc);



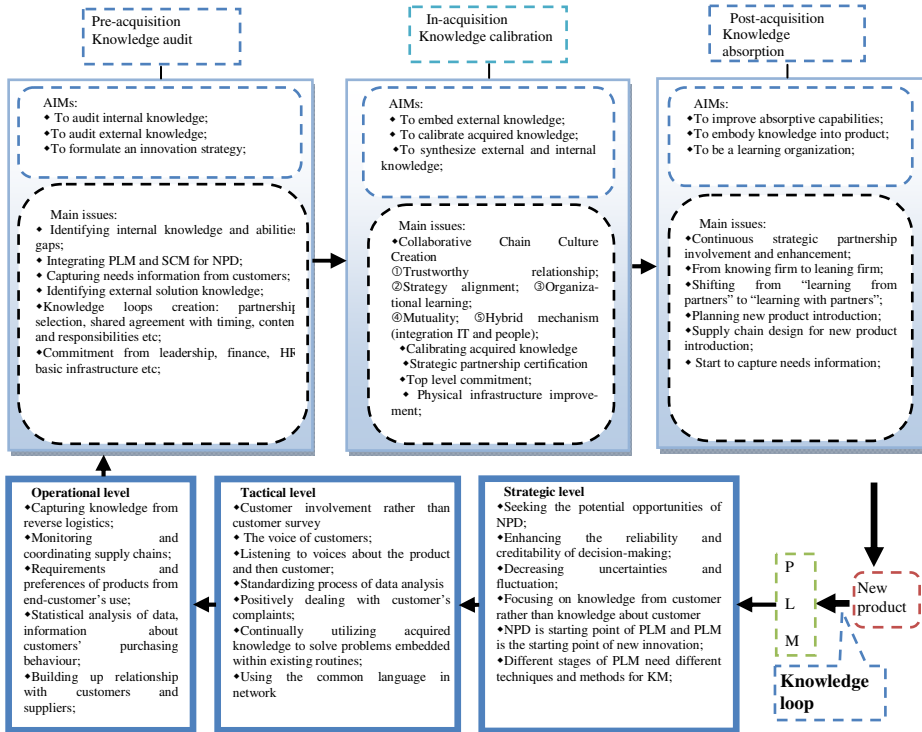


Fig. 4. Preliminary ACA framework

- Migrate from learning from partners to learning with partners (acting with suppliers as a whole by joint activities and optimal use of knowledge to reduce uncertainties);
- Embody technology knowledge and market knowledge into NPD and plan product introduction ( integrating related factors, such as distributors, retailers, inventory and marketing etc);

## 7 Concluding Remarks

As part of a wider research project, this paper mainly focuses on presenting a theoretical framework which can be considered as a reference model for further research. The proposed framework focuses on systematically synthesizing relevant theoretical fields and utilizes existing approaches to facilitate effective use of knowledge management techniques in the NPD process in a supply chain by adopting an OI strategy. More specifically, it has accurately reflected on the nature of existing knowledge management systems and captured the core issues of NPD in a three-phase approach. It logically integrates three KM techniques into the process of innovation from the wider perspective of SCM. In essence, by referencing this framework, researchers and practitioners can easily manage NPD projects in terms of optimally leveraging knowledge resources and accurately self-positioning, detecting and employing solutions in the realisation of new product or services. As a result, a firm can achieve shorter

“time to the market”, gaining from first mover advantages and satisfying the end customer requirements. At this stage, the proposed framework needs to be evaluated from a practical point of view. The process of validation will be undertaken to verify and improve the creditability and feasibility of this framework.

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