

An Open Innovation Framework for collaborative food product design & manufacturing

Panagiotis Tsimiklis, Charalampos Makatsoris

Department of Mechanical, Aerospace and Civil Engineering, College of Engineering, Design and Physical Sciences, Brunel University London, UK

harris.makatsoris@brunel.ac.uk

Abstract. One of the most debated topics in actual global literature is Open Innovation. However, there are still many questions that have not been answered respecting the modern industry. One of them is the link between the corporate Open Innovation practices and the industrial structure of mature industries. Specifically, the food industry is a mature industry where its profit margins are thin and its R&D failure rate for new products is very high. Both facts indicate that a decent return on development investments cannot be provided and that the food industry still cannot rely on its traditional way of thinking and innovating. In addition, this sector recently perceived its end-users to be wary of radically new products and changes in consumption patterns. Hence, the main aim of that industry is to design new food products that consumers will buy and at the same time ensure that these products will reach them in time and at adequate quantity. Through a proposed conceptual framework which integrates a collaborative and shared knowledge framework based on “Open Innovation approaches”, we propose to work with both customers’ data and selected partners to design new food products that offer an integrated sensory experience of food and packaging, encompassing customization, healthy eating, and sustainability.

Keywords. Food Industry, Collaboration, Conceptual Open Innovation Framework, New Product Development, Supply Chain.

1 Introduction

The food industry is a relatively mature and slow-moving industry, which exhibits relatively low levels of R&D investment and is conservative in the type of innovations it introduces to the market (Sarkar and Costa, 2008). A key difference between firms in the food industry and other manufacturing industries is that the products supplied to them, and often also delivered from them, are materials or ingredients, rather than, components (Frishammar et al., 2012). However, recent changes in the nature of both food demand and supply, coupled with an ever-increasing level of competitiveness and due to the high volatility of global markets, have changed innovation into a compulsory activity, as it is vital for the overall profitability and survival of any organization (Wu and Barnes, 2010).

Furthermore, within the next fifty years, the biggest challenge that the food industry is going to face is that it is expected to produce more food than it has produced in its entire history (UK Cabinet Office, 2008; Keating et al., 2010).

But, even if the food industry could be seen as one of the most active industries, with roughly 3,500 new products reaching the UK retailer shelves every year, at the same

time it suffers from massive Research & Development (R&D) failure. About 80% of those new products are expected to fail within the first two years since their launch into the market (UK Cabinet Office, 2008). A key reason is that traditional Product Development techniques do not include the external collaboration and knowledge, which can be obtained from consumers and suppliers (Sawhney and Prandelli, 2000; Laursen and Salter, 2006; Annique Un et al., 2010; Henke and Zhang, 2010; Garriga et al., 2013; Mäkimattila et al., 2013; Pellegrini et al., 2014).

In the recent literature, we can find various examples in more “open mind-set” industrial sectors where the external collaboration and knowledge have been recognised as having large innovation potential for their New Product Development (NPD) processes (Sawhney and Prandelli 2000; Chesbrough, 2003b; Rometty, 2007; Slack et al., 2007).

To that respect, in this paper, we argue that by using Open Innovation models, we can create a collaborative environment in both NPD and Supply chain where we can understand customers’ needs and can act upon them by integrating a new Information & Communication Technology (ICT)-based product development framework with production and business systems. A new information conceptual framework can be generated, as well as, smart and on-demand manufacturing networks’ configurations demand allocations. By obtaining that, we can respond to those market segments by providing new food products in a rapid, cost-effective and sustainable manner.

The structure of this paper is described as follows: in section 2, Open Innovation Approaches in Food Industry are provided, including Definition of Innovation and a review on Food Innovations. In the same section, an overview of Open Innovation and ICT characteristics is provided. Then, in sections 3, we explain our conceptual framework and the underlying challenges the New Product Development (NPD) process entails and how the latter can be re-engineered. Furthermore, in the same section, we describe the most appropriate supply chain model for our framework. Next, in section 4, a case study is presented illustrating the use of the proposed conceptual framework. Finally, in section 5, we elaborate on our concluding remarks and recommendations for future research.

2 Open Innovation Approaches

2.1 Definition of Innovation

According to Baregheh et al. (2009), there is a vast diversity in the possible definitions of innovation in the literature.

The first definition of innovation was presented by Schumpeter in the late 1920’s (Hansen and Wakonen, 1997, p. 350) who stressed the novelty aspect and summarized innovation as ‘doing things differently’. Later on, Thompson’s definition proposes (Thompson, 1965, p. 2): “Innovation is the generation, acceptance and implementation of new ideas, processes, products or services”.

Then, according to Damanpour (1996, p. 694), newness is also associated with change and thus the definition of innovation proposed by Damanpour (1996, p. 694) is quoted as follows: “Innovation is conceived as a means of changing an organization, either as

a response to change in the external environment or as either as a pre-emptive action to influence the environment". Hence, innovation is here broadly defined to encompass a range of types , including new product or service, new process technology, new organization structure or administrative systems, or new plans or program pertaining to organization members.

Other variations in the definition of innovation arise from knowledge management and according to Plessis (2007, p. 21), it is quoted as follows:

"Innovation is the creation of new knowledge and ideas to facilitate new business outcomes, aimed at improving internal business processes and structures and to create market driven products and services. Innovation encompasses both radical and incremental innovation".

To that respect, a distinction between incremental innovation and radical innovation has to be made. Bessant and Tidd (2007, p. 15) have defined that difference as "Doing what we do better" vs. "New to the world". In order to examine whether a product is really new-to-the-world, Makrides and Geroski (2005, p. 4) posed two conditions which have to be met:

1. They offer new value propositions that radically change existing consumer habits and behaviour.
2. The markets they create undermine the competences and complementary assets on which competitors build their success.

Furthermore, radical innovation causes marketing and technological discontinuities on both a macro and micro level, meanwhile, the incremental occurs only at a micro level and causes either a marketing or a technological discontinuity, but never both (Garcia and Calantone, 2002).

Hence, organizations, often, have to go through a period of trial and error in order to learn how to obtain knowledge and specially how to gain knowledge from an external source. It requires extensive effort and time to build up an understanding of all the norms, habits and routines of different external knowledge channels (Laursen and Salter, 2006; Saguy and Sirotinskaya, 2014).

When IBM conducted a Global CEO study (Rometty, 2007) on innovation based on interviews with 750 of the world's top CEOs, 76% of those CEOs think that external collaboration with business partners and customers is key to innovation. But, only half of them believe their organizations are collaborating beyond a moderate level. Similar data have also been presented in a most recent survey, involving companies from three countries (UK, Italy and Spain) in the Food and Drink industry (Lazzarotti et al., 2012). This is because collaboration is a discipline (Rometty, 2007).

It is therefore obvious that whatever the actual or future definition of Innovation is, it must form part of the culture of any organisation and its main driver should be an organised and well established process for innovations targeting excellence in the implemented process (Lynn et al., 1999; Hoholm and Strønen, 2011; Mäkimattila et al., 2013; Pellegrini et al., 2014).

2.2 Food Innovation status

The food industry is a mature industry and is typically very conservative with the level

of investment in new technology (Bigliardi and Galati, 2013). The European food industry particularly invests much less in R&D compared to other industries and radically new products are rare (Costa and Jongen, 2006; Bigliardi and Galati, 2013). They make up only 2.2% of the total launches of new products and the risk of failure is high (Costa and Jongen, 2006; Bigliardi and Galati, 2013).

On the other hand, we must not forget that the food industry was traditionally focused on the minimization of cost production, having, thus, paid little attention to customer needs by developing new products according to customers' specifications (Lienhardt, 2004). In addition, in the majority of food companies, their new product development processes are still based on internal innovation – although a limited but growing number of food companies are starting to develop their new products adopting some success factors and best practices that reside outside their corporate boundaries (Sarkar and Costa, 2008; Huizingh, 2011; Wikhamn, 2013; Marques, 2014; Saguy and Sirotinskaya, 2014; Pascucci et al., 2015).

Moreover, research outcomes of extant literature, show that companies, which have a disciplined and step-wise new product processes, are more successful compared to those firms that have had the same processes in place for a longer time (Cooper and Kleinschmidt, 1995). However, management of innovation is the process of bringing monetary value to technological knowledge and creativity, and in recent years, a particular model of doing so has been named “Open Innovation” (Van der Meer, 2007).

Based on the Open Innovation (OI) paradigm, a firm can use an external idea, as well as, an internal one to develop a new product (Chesbrough 2003b; Huzingh, 2011; Monsef et al., 2012; Wikhamn, 2013; Marques, 2014). On the other hand, closed innovation is the traditional paradigm in which a firm generates its own ideas and then develops them internally (Chesbrough, 2003a; Sarkar and Costa, 2008; Huzingh, 2011; Bae and Chang, 2012; Wikhamn, 2013; Marques, 2014).

On the other hand, the need for new food products is driven by “five dominant forces” (Fuller, 2005) and their nature is a mixture of inside and outside boundaries aspects. Hence, when looking inside them by using an Open mindset, a clear advantage is provided versus the traditional innovation. The “dominant forces” are the following:

1. All products have a life cycle.
2. New products promote growth.
3. New markets may be created; e.g., functional foods, e-commerce, etc.
4. New knowledge and technologies may offer new opportunities, such as, nanotechnology, internet, social media, aseptic and long-life products, etc.
5. Changes in legislation, health and labelling regulations, agricultural policies, international social pressure movements such as SAVE FOOD, etc.

For that reason, in today's globalised competitive business environment, the Food manufacturing organizations have begun to realize that in order to gain and sustain the competitive advantage they have to deliver the best customer value at the lowest possible costs (Bigliardi and Galati, 2013; Hudnurkar et al., 2014). The customer is increasingly becoming highly demanding with respect to faster response time, shorter product cycle time, customised products and services (Bigliardi and Galati, 2013; Hudnurkar et al., 2014).

On that account, food firms are looking outside their organisational boundaries for

opportunities to collaborate with supply chain partners so as to ensure efficiency and responsiveness of the supply chain as well as to leverage the resources and knowledge of both their suppliers and consumers (Flint, 2002; Menrad, 2004; Chesbrough and Crowther, 2006; Bigliardi and Galati, 2013; Hudnurkar et al., 2014; Saguy and Sirotninskaya, 2014; Pascucci et al., 2015).

2.3 Open Innovation & ICT collaborative tools with consumers for the Food Industry

Contrary to the traditional definition of closed innovation, Open Innovation (OI) has initially been defined as the paradigm in which:

“... valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well” (Chesbrough, 2003a, p. 43).

Then reflecting on what was learned from the practice of OI, the definition was adapted to emphasize the intentionality of the knowledge flows inside and outside the firm (Chesbrough, 2006).

Most recently and according to Chesbrough and Bogers (2014), OI's definition has been as follows:

“OI is defined as a distributed innovation process based on purposively managed knowledge flows across organisational boundaries, using pecuniary and non-pecuniary mechanism in line with the organization's business model”.

Therefore, that mixture of knowledge can speed-up the time-to-market process, enrich the internal innovation environment and expand any company's market frontiers, far beyond, to new market segments (Chesbrough, 2003a). OI has been initially associated with fast-growing industries, like the information and communication technology sector or the pharmaceutical industry, but, there is increasing evidence that this concept may also prevail in more traditional and mature industries such as the food industry (Morcillo, 2007; Sarkar and Costa, 2008; Huizingh, 2011; Bigliardi and Galati, 2013; Theyel, 2012; Wyncarczyk et al., 2013; West et al., 2014).

The current application of Innovation in the Food Industry mainly relates either to the closer engagement and relationship between food manufacturers and retailers (Ferne and Sparks, 2009) or to the closer engagement and involvement of suppliers in corporate R&D (Park et al., 2010).

But, in the era of OI, researchers, as well as, consultants ask for more active engagement of customers into NPD than traditional market research allows (Sawhney and Prandelli, 2000; Chesbrough, 2003a; Rizova, 2006; Saguy and Sirotninskaya, 2014). As a consequence, new methods are needed towards that direction (Lilien et al., 2002; Füller and Matzler, 2007; Bjelland and Wood, 2008; Christiansen et al., 2013; Mäkimattila et al., 2013; Saguy and Sirotninskaya, 2014; Pascucci et al., 2015). For that reason, open communication and collaboration patterns can be established in order to improve that missing communication with consumers which can be based on existing solutions combined with modern ICT tools (Kano, 1984; Füller and Matzler, 2007; Karantininis et al., 2010; Christiansen et al., 2013).

Digital technologies are impacting any type of world-wide businesses and their impact

is conducted in unprecedented ways (Harrington, 2000). The proliferation of industry specific ICT, increased availability and accessibility of social media and interactive technologies including a wide range of smart gadgets, such as, mobile and tablet technologies and related applications, is a digital revolution that can affect any business, adding credence to this argument (Coleman, 1997; Harrington, 2000; Fitzgerald et al., 2013; Rodgers, 2013).

Over the last years, the world has witnessed continuous growth of ICT services. An analysis of Internet user statistics reveals some of the key challenges and opportunities that need to be addressed in order to bring more people online in developing countries. The ICT for development debate is witnessing an obvious shift: the focus is no longer on the mobile-phones development, but on the need for high-speed broad band Internet access. The affordability of ICT services is a key trigger to bringing more people into the information age (Coleman, 1997; ITU, 2011).

Thereupon, we propose the use of Internet as an interactive and multi-media-rich technology with low cost of mass communication that allows consumers to virtually experience new products and offer new simplified modes of large scale interaction between producers and consumers (Füller and Matzler, 2007). Customers should be seen as Source of Ideas, as Co-creators/Validators and as End-Users (Füller and Matzler, 2007; Saguy and Sirotinskaya, 2014).

Harvesting attitudes and perceptions from customers by using ICT should be the most important subjects to be investigated by any firm and to that respect we propose the integration of “the open innovation funnel” with an ICT platform to capture those initial ideas and perceptions directly from them. When customer value is assessed in the early concept stage of the innovation process the next benefits can be obtained (Füller and Matzler, 2007):

- a. Reduction of market uncertainties
- b. Identifications of future needs
- c. Greater variety of ideas
- d. Contacting new potential customers
- e. Increased customer retention
- f. Broader decision basis for the NPD team of a firm.

Users should not only be asked about their opinions, wants and needs, but they should be invited to contribute with their creativity and problem solving skills by generating and evaluating new product ideas (Sawhney and Prandelli, 2000; Lilien et al., 2002; Djelassi and Decoopman, 2013). There are various models to achieve such kind of interactions and some of them are hereby presented as follows:

- a. By creating different types of web blogs, searching for customers’ needs and wants,
- b. By using specific “web questionnaires” posted on Intranets (we must not forget that the employees of a food company are also consumers who can express their valuable opinion and vote the best new food ideas too) and corporate website,
- c. Or even, the traditional customer-interview questionnaires and idea generators next to the shops but, based on an Idea Management System where any idea can be analysed, checked and voted by expert teams within an “Open” firm.

By reviewing the literature, we have managed to discover that Intranet is defined as an internet network utilizing internet and web protocols located within an organisation's information technology (IT) security domain and is primarily intended to be used by the organisation's members (Slyke and Belanger, 2003); in particular for organisation applications such as:

- a. Dissemination of corporate documents, e.g. annual reports, corporate information and documents, health and safety and emergency procedures/manuals;
- b. Searchable directories, e.g. keeping organisational directories up-to-date with easy traceability;
- c. Providing departmental or divisional web pages information to all employees within an organisation who need access to information about their department or division;
- d. Facilities for software distribution, licensing and accelerating the process of distributing software updates; and
- e. Collaborative applications, such as, e-mail, chat facilities and conferencing; applications can be accessed via the intranet for managerial, administrative and team working tasks.

Furthermore, extranet has the potential to fill the gap that exists between internet and intranet networks (Finch, 2000). It allows project partners to exchange information securely by providing an authorized means of access to a portion of a company's intranet or by using a common network that links all partners. The penetration of internet, intranet and extranet technologies into the Information Technology workplace has already resulted in dramatic improvements in terms of quality and quantity, as well as, seamless integration in business processes (Gloor, 2000; Christiansen et al., 2013).

Still, it has also been identified that by using the Kano model (Kano, 1984; Löfgren and Witell, 2005) which is often used by firms to identify customer needs in NPD, customers have difficulties in articulating their needs (Füller and Matzler, 2007). This is because customers' expectation toward product and service attributes can be grouped into 3 categories: a) basic factors, b) performance factors and c) excitement factors (Füller and Matzler, 2007).

Consumers clearly state performance factors and specify their level of requirements but, the innovation level of such products is rather incremental (Prahalad and Ramaswamy, 2002; Prahalad and Ramaswamy, 2004). In radical innovations where customers extract high value from the emotional meaning of the product, their input is of limited value. They are unable to express their needs and state a clear preference (Pascucci et al., 2015). Hence, they do not come up with solutions; as they are not experts for that part of innovation process (Matzler and Hinterhuber, 1998). It is the task of the NPD team to deal with this inability of the customers to come up with the needed solutions.

3 Challenges of the conceptual Collaborative Framework in NPD process

3.1 Developing a collaborative NPD framework

In this section of the paper, we are going to present a framework for New Product Development using a workflow, which encompasses the “Open Innovation funnel” and the “Double Diamond 4D Design” design frameworks (see Fig.1). This framework is intended to be used by food companies which are seeking to use Open Innovation approaches in their product development loop when designing new food products. As suggested in the literature (Karantininis et al., 2010; Saguy and Sirotinskaya, 2014; Pascucci et al., 2015), business environment can push towards collaboration in innovation activities. The proposed framework is cross cutting as it extends beyond New Product Development by integrating processes designed to use that information to directly drive the development of new product recipes and subsequently drive product specification and ultimately production within a collaborative environment.

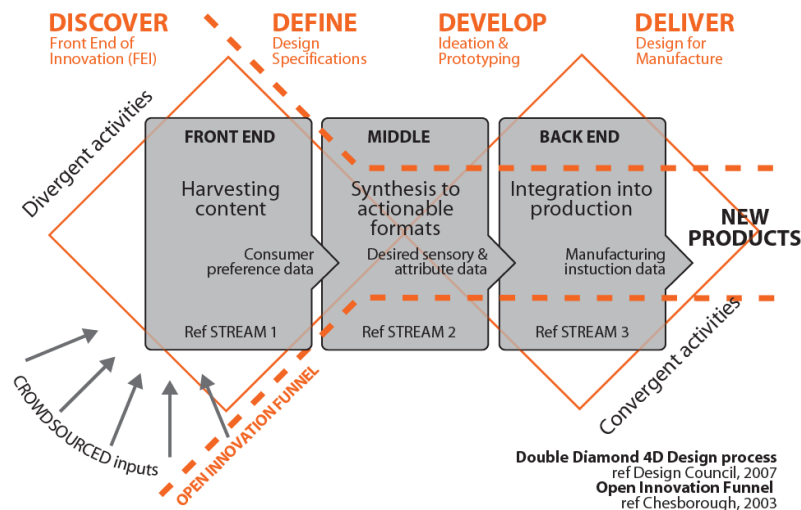


Fig. 1. The relationship of open innovation with the double diamond 4D design process model, reprinted from (Tsimiklis et al., 2014, p. 6).

The Double Diamond 4D Design diagram (UK Design Council, 2005) describes the design process in a simple graphical way. That process is divided into four distinct phases: Discover, Define, Develop and Deliver, and it maps the divergent and convergent stages of the design process. By looking inside those four distinct phases, we can see the following:

- Discover: This is the first stage of the model where the project starts. It begins with an initial idea or inspiration, which is often sourced from a discovery phase in which user needs are identified. These include:
 - a. Market research;
 - b. User research;
 - c. Managing information; and

d. Design research groups.

- Define: it is the second stage and represents the definition part where interpretation and alignment of these needs to business objectives is achieved.
- Develop: it is the development stage where design –led solutions are developed, iterated and tested within the company.
- Deliver: it is the final stage where the resulting product is finalised and launched in the relevant market.

However, the research cost for the Discover stage of the previous processes is very high (Nambisan, 2002; Füller and Matzler, 2007; Henten, 2012), as well as, the needed time for investments in this stage.

In parallel, we have identified the Double Diamond 4D Design diagram as a discipline process to develop and bring new products to a relevant market (UK Design Council, 2005).

According to Monsef et al. (2012, p. 7), a problem is that traditional NPD is risky due to alarming failure rates and the large amounts of venture capital required. When investigating the reasons for the low success rates, studies concluded that failed product innovators did not fully understand customer needs, or they designed products that cannot be repeatedly manufactured, or even, they launched products without taking into consideration the realities of those who will use the product (Dougherty, 1992).

Open Innovation provides an approach to involve consumers in the loop of a New Product Development process (Chesbrough, 2003a; Chesbrough, 2006; Chesbrough et al., 2006; Saguy and Sirotinskaya, 2014) and enable the design and production of food products that are desired and will be consumed.

To that respect, we propose to use an information workflow in order to re-configure the whole innovation process by using Open Innovation techniques. The information workflow follows the patterns presented on Figure 1. Particular functional blocks that control those information flows are presented and discussed below (Fig. 2).

The “*HARVESTING CONTENT*” area is composed of an external data sourcing interface for harvesting attitudes/perceptions from final consumers or even retailers, suppliers and other external data information systems of a firm.

The second area named “*SYNTHESIS TO ACTIONABLE FORMAT*” is crucial for mapping the raw and abstract inputs from consumers or even retailers to actionable customer requirements. The main idea at this point is the transformation of all these inputs into customer requirements and hence, into Market Business Plans (MBP).

In our case, the key elements come from an expert and a reconfigurable internal team that participates to the NPD process. It is not a fixed team and is highly dependent on the nature of the project. That team is capable of creating the new product specs, the product’s Bill-of-Material (BOM) and the specs of the machinery and the installation to be used for producing the new product. Then, that team can work with selected suppliers to facilitate the availability of that product.

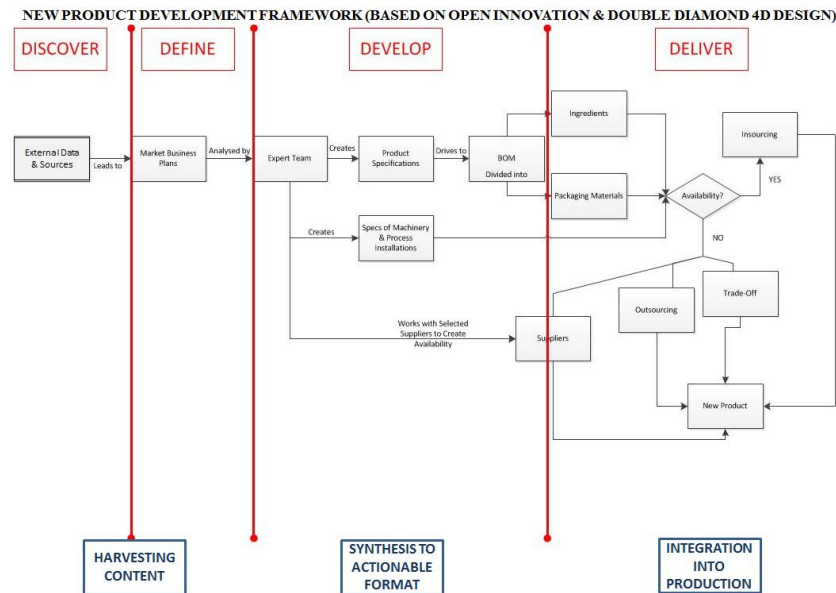


Fig. 2. Overview of new product development framework workflow, adapted from (Tsimiklis and Makatsoris, 2015, p. 5).

The last area of our model is related to the “*INTEGRATION INTO PRODUCTION*”. It is a How mechanism to fulfil the What’s of any Market Business Plan. These mechanisms are best stated as design requirements or as *the technical characteristics of solutions*, rather than as specific solutions. They transform consumers’ requirements into product specifications and finally manufacturing instructions.

As it is presented in our conceptual model (see Fig. 2), the BOM sufficiently creates the required information to check the insourcing availability of the needed ingredients and packaging material needed for the new product. On the other hand, the specs of the machinery and installation to be used for the production of the new product, deal with the internal availability of it.

The selected suppliers – experts on their subject and their selection is highly dependent on the nature of the project – can be used by the internal expert team to help them develop either the internal availability or the external one of the product (by outsourcing or by making trade-offs).

3.2 Challenge I: Barriers and Opportunities of the conceptual framework in the Food Industry

But, is it an easy task for any firm to incorporate Open Innovation in the NPD Process? It is known that production decision-making in the food manufacturing industry has not changed enough so as meet the nowadays volatile challenges (Calantone et. al., 2002; Bigliardi and Galati, 2013). In many western companies, manufacturing management still takes a subordinate role in strategic terms to the marketing and finance functions. It continues to be primarily concerned with short-term issues (Christopher, 2000). In addition, marketing-led strategies in the food industry are usually based on the principle

of growth through extending the product range. Invariably what happens is that new products are manufactured on existing processes and almost always within the same infrastructure. The logic for this is based on the principle of the economies derived from using existing plant capacity, where possible, and being supported by the existing overhead structure (Hoholm and Strønen, 2011). Over time the incremental nature of these marketing changes will invariably alter the manufacturing activity. The result is complexity, confusion and worst of all, a production organization which lacks focus and strategy (Christopher, 2000).

Furthermore, many executives are still unaware that, what appears to be one of the routine manufacturing decisions, it frequently limits the corporation's strategic options, binding it with facilities, equipment, personnel, basic controls and policies to a non-competitive posture, which may take years to turn around (Laursen and Salter, 2006; Hoholm and Strønen, 2011; Garriga et al., 2013). The reason for this is that companies having invested inappropriately in process and infrastructure cannot afford to reinvest to put things right. The financial implications, system development, training requirements and the time it would take to make the changes would leave it seriously disadvantaged.

To avoid the above mentioned hurdles, companies need to be aware of and learn from the mistakes of their past mistakes (Cohen and Levinthal, 1989; Garvin, 1993; Akgün et al., 2006). The product development process is itself a form of problem-solving activity and associated search processes that involve investments in building and maintaining links, networks and communities with users, suppliers and a wide range of institutions inside the innovation process (Laursen and Salter, 2006). Those organizations that invest in broader and deeper search may have a greater ability to adopt, to change and therefore, innovate (Laursen and Salter, 2006; Garriga et al., 2013).

Furthermore, given that search strategies must be rooted in the past experiences and future expectations of managers, they should have been well documented, while at the same time the future expectations should be clearly managed, chosen and notified (Akgün et al., 2006; Laursen and Salter, 2006; Garriga et al., 2013).

In this frame of reference, changes must be driven top down and the whole management team must be totally committed to the changes (Chesbrough and Crowther, 2006). In addition, one of the toughest challenges for managers today is to get people focused on adaptive change to meet the demands of rapidly changing environments. Many problems have no ready-made solutions and require people throughout the company to think in new ways and learn new values and attitudes. This requires a new approach to management and a new kind of organization (Garvin, 1993; Sawhney and Prandelli, 2000; Rometty, 2007).

This new type of organization structure can be defined as one in which everyone is engaged in identifying and solving problems, enabling the organization to experiment, change and improve continuously and thus increase its capacity to grow, learn and achieve its purpose. The essential idea is problem solving, in contrast to the traditional organization designed for efficiency (Garvin, 1993; Sawhney and Prandelli, 2000; Rometty, 2007; Karantininis et al., 2010; Mäkimattila et al., 2013; Saguy and Sirotninskaya, 2014).

An important value in such an organization is the collaboration and communication across departmental and hierarchical boundaries (Karantininis et al., 2010; Mäkimattila et al., 2013; Saguy and Sirotnskaya, 2014; Pascucci et al., 2015). A majority of successful innovations is developed through the collective efforts of individuals in NPD teams. NPD teams are organisational workgroups where individuals from diverse personal and organizational backgrounds come together for a limited time and work in close collaboration towards creating, designing, developing and marketing a new product (Pinto, 2002). Self-directed teams are the basic building blocks of a collaborative organisational structure (Mäkimattila et al., 2013). That multi-functional expert group is normally formed by people from different functional departments such as Production, Marketing, Logistics, Finance, Engineering, Quality, R&D, Food Safety, Nutrition and Purchasing. These people on the team must be given the skills, information, tools, motivation and authority to make decisions central to the team's performance, while responding creatively and flexibly to new challenges.

Resuming the above points, we can say that the next figure (Fig. 3) can represent a scenario of a collaborative framework using Internet/Intranet networks to speed up the information flow in a product development cycle and realize reduced development times and costs.

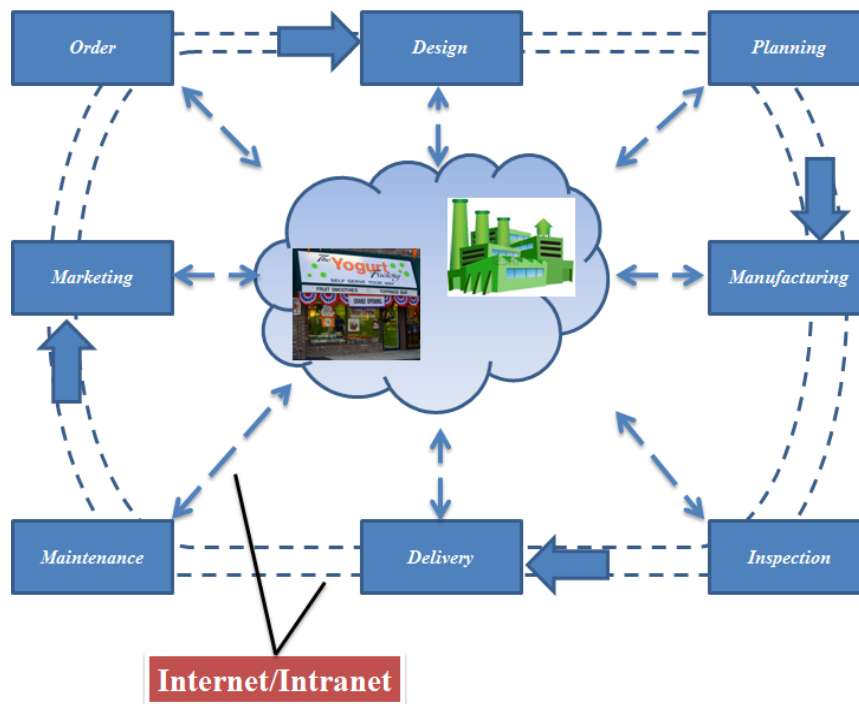


Fig. 3. A scenario of using Internet/Intranet to support information flow in product development cycles, reprinted from (Tsimiklis et al., 2014, p. 5).

Hence, the previous mentioned MBPs (see also figure 2) can be analysed by that multi-functional expert team and the obtained data are the initial product specifications that

can finally be transformed into orders of purchases. The orders of purchases can be created by a clear characterization and specification of Bill-of-Materials (BOM) of the new products. These BOMs are either related to the Ingredients of the new product or the materials used for its packaging or both. The final list of BOM is compared to the free capacity, existing installations and existing ingredients and materials to identify the most convenient decision between in-sourcing or out-sourcing or even trade-off situations.

A trade-off situation involves a sacrifice that must be made to obtain a certain product, service or experience, rather than others, that could be made or obtained using the same required resources. Many factors affect the trade-off environment within a particular firm, including availability of raw materials, a skilled labour force, machinery for producing a product, technology and capital, market rate to produce that product on reasonable time scale, and so on. Such kind of situations can only be identified by having a clear list of BOM and their specifications.

Returning to our framework (Fig. 2), it is often the lead time of in-sourcing that limits the ability of a manufacturing organization to respond rapidly to consumers' requirements. For that reason, in order to obtain the most accurate decision on the previous situation, it is vital to include as much suppliers' information into the decision loop as possible and it is therefore crucial to have a suitable supply chain approach following the Open Innovation mindset (Anniq Un et al., 2010).

3.2 Challenge II: Re-thinking and redesigning the Supply Chain

Operations Strategy is concerned with choosing the strategic decision making patterns and actions, which determine the role, objectives and activities of the organizations. There are the five basic performance objectives and they apply to all types of organisation (Slack et al., 2007):

3. Quality: consistent conformance to customers' expectations.
4. Speed: the elapsed time between customers requesting products and their receiving them.
5. Dependability: delivering or making available products when they are promised to the customer.
6. Flexibility: the quality of being adaptable or variable.
7. Cost.

Agile operations management aims at addressing these five performance objectives and this is a central component to our framework. Agility (Christopher, 2000) is defined as the ability of a system to rapidly respond to change by adapting its initial configuration. It is the ability that combines and adopts any business system to any of all those 5 objectives.

Agile Manufacturing (AM) is a company-wide strategy, which aims at responding well to unexpected change in all aspects of a company's operations. We can define it in two contexts (Christopher, 2000):

- *Externally*, as perceived by customers: (AM) means responding to those customers' needs by rapidly designing and manufacturing products customized to those requirements.
- *Internally*, in terms of a company's own operations, (AM) focuses on reducing

the lead times for all tasks in a company, resulting in improved quality, lower cost, and of course, quick response.

However, up to now, the efforts surrounding an application of agile frameworks has been focused on the shortages of traditional energy sources. But, their price fluctuations and the demand for more energy-efficient products or products using alternative energy sources are clear. Opportunities exist to re-engineer many industrial products based on new ratio of energy costs and capital costs. New energy - conservation concepts and service - will be needed. The design and marketing of this range of products are challenging because of price fluctuations (Wild, 1992).

Changes in energy availability and prices are but one example of the many possible futures we face. The many changes to the status quo present problems for unchanging organisations but represent real opportunities for those organisations that adapt and evolve with new market offerings. The organisations that will not just survive but thrive will use a learning organisational concept with which will examine their role in society and our continuously changing environment. One of the important rationales for their existence is based on innovation and agility to fill societal and customer needs (Christopher, 2000).

Furthermore, it is known that a supply chain describes the series of linked activities amongst companies that may contribute to the process of design, manufacture and delivery of products. Its main objectives are (Yusuf et al., 2004; Waller, 2013):

- a. customer enrichment ahead of competitors,
- b. achieving mass customisation at the cost of mass production,
- c. mastering change and uncertainty through routinely adaptable structures, and
- d. leveraging the impact of people across companies through information technology.

An agile supply chain should extend to the highest levels within all participants of the NPD process (internal and external ones) and local teams of employees should think globally and take virtual initiatives with teams in other companies within the supply chain of a new product (Yusuf et al., 2004).

Returning to our framework in Figure 2, it is often the lead time of in-sourcing situation that limits the ability of a manufacturing organization to rapidly respond to consumers' requirements. Accordingly, obtaining the most accurate decision on the previous situation is vital to include the maximum amount of suppliers' information into the decision loop (Annique Un et al., 2010).

But, how can we guarantee the selection of the most appropriate supplier? There are 3 conditions that have been identified for obtaining a success relationship and collaboration with the selected suppliers (Christopher, 2005; Park et al., 2010):

1. It is obvious that the supplier base of any firm must be rationalized. The firms have to identify a limited number of "strategic" suppliers with whom they can work with as partners through linked systems and processes. While the dangers of single sourcing need to be recognized, the advantages of having a network of key suppliers able to synchronize their production and deliveries with the requirements of the company are considerable.
8. To achieve the previous advantages, it is necessary to dispose of a high level of shared information. In particular, there has to be a clear visibility on the

downstream demand; data on real demand needs to be captured, as far down the chain as possible, and shared with upstream suppliers, as well as, the information systems technology to make the transfer of information possible.

9. Finally, the biggest challenge from the suppliers' empowerment is the need for a high level of "connectivity". This implies not just the exchange of information on demand and inventory levels, but multiple, collaborative working relationships across the organizations at all levels. This last point proves for another time how necessary the use of an ICT network, which can cover and connect the inside and the outside boundaries of a firm, is.

It follows that, collaborative behaviour and activities in supply chain have gained considerable importance (Hudnurkar et al., 2014). The supply chain collaboration has been defined in different ways by different authors (Hudnurkar et al., 2014). A summary of relevant and available definitions is provided:

2. Collaboration is a cooperative strategy of supply chain partners with a common goal of serving customer through integrated solutions for lowering cost and increasing revenue (Simatupang et al., 2004).
3. Collaborative relationship as one in which an organization initiates and implements a knowledge creation endeavour, and a collaborating organization shares the expense and benefits of newly created knowledge, including its joint ownership through patents and licenses (Samaddar and Kadiyala, 2006).
4. The ability to work across organizational boundaries to build and manage unique value-added processes to better meet customer needs (Fawcett et al., 2008).
5. Collaboration describes the cooperation among independent, but related firms to share resources and capabilities to meet their customers' most extraordinary or dynamically changing needs (Simatupang and Sridharan, 2008).
6. A partnership process where two or more autonomous firms work closely to plan and execute supply chain operations toward common goals and mutual benefits (Cao and Zhang, 2011).

4 Example Case: On-demand yoghurt manufacturing

4.1 Introduction to the case study

The central part of an innovation process involves the search for new ideas that have commercial potential. Thus, firms invest considerable amounts of time, money and other resources in the search for new innovative opportunities. Such investment increases the ability to create, use and recombine new and existing knowledge, external or internal knowledge available to a firm, or both (Laursen and Salter, 2006). All recent models of innovation have highlighted the interactive character of the innovation process, suggesting that the more innovative firms rely heavily on their interaction with users, suppliers and with a range of institutions inside the innovation system (Brown and Eisenhardt, 1995; Szulanski, 1996).

The Open Innovation Project of the Dairy Company, presented in this section, had precisely this aim: to identify and filter yoghurt product ideas that can be successfully brought to market as there is a clearly recognised and unmet need by a specific market

segment. At the same time the project aimed at maximising the usage of existing resources, as much as, possible with minimal additional investment. One key risk is that the degree of product innovation/differentiation does not lead to increasing returns but rather remains stagnant no matter how big the investment is (Sarkar and Costa, 2008). The open innovation approach, at the core of our proposed framework, mitigated that risk by allowing the market to be a crucial component in the development loop of the new yoghurt product by directly influencing development priorities and at the same time maximising innovation impact.

4.2 Harvesting Content

The mentioned project is a complex multi-dimensional project that requires many considerations and compromises to be made. Here, we summarize those initial considerations: Taste, Texture, Flavour, Appearance, Size/Volume of primary packaging, Consumption, Production, Distribution. A key target is to achieve sufficient differentiation compared to competition and this is embodied not only in the formulation of the product itself but also in the packaging, distribution and the design of the manufacturing and packaging processes themselves.

Initially, it is a “must” point to start such a kind of project by using the internal knowledge of the firm and to identify in a map where the actual business strategy of the firm is today and where it will need to be in the future when incorporating that new product (Slack et al., 2007).

An important value in an organization is the collaboration and communication across departmental and hierarchical boundaries. Self-directed teams are the basics building blocks of the internal knowledge of a firm. These teams are made up of employees with different skills who share their experience and knowledge to produce an entire product. The idea is to empower the well-known “Cross-functional teams”. That multi-functional expert group is normally formed by people from different functional departments such as Production, Marketing, Logistics, Finance, Engineering, Quality, R&D, Food Safety, Nutrition and Purchasing. These people on the team must be given the skills, information, tools, motivation and authority to make decisions central to the team’s performance, while responding in a creative and flexible manner to new challenges. This type of team has been used to create the information needed to initially communicate with both customers and suppliers.

Then, a well-defined market investigation based on a qualitative research of concept and product, followed by a volumetric concept testing (on line or even next to the shops) can be used to indicate the appropriateness of the idea (Sawhney and Prandelli, 2000). The main points to be covered on such researches should follow the above mentioned considerations. Thus, those harvesting attitudes and perceptions from customers are then the important subjects to be investigated by our proposed model.

For that reason, all that we propose is the integration of “the open innovation funnel” with the “double diamond” 4D design process described above. That is linked to the *Front End* of our model and we can propose some of them:

- a. By creating different types of blogs and questionnaires focusing on customers’ needs and wants, posting them on social websites (developed by a multifunctional team as described above),

- b. By using specific “web questionnaires” posted on Intranets and asking firm’s employees for new ideas or even, to vote new ideas (developed by a multifunctional team as described above),
- c. It is worth mentioning that there are approx. 56,900,000 blogs which are exclusively dedicated to yoghurt. In these blogs, various characteristic words or indicators can be obtained, which express clear consumer necessities.
- d. Then, there are many scientific and collaborative websites dealing with “yoghurt” as their topic of interest or its ingredients.
- e. Finally, the traditional customer-interview questionnaires next to the shops are still useful to obtain information that can be transformed into knowledge.

Furthermore, the voices of the retailers and the distributors of the products can provide a lot of information for preparing both the strategic and tactic actions for a particular business; it is well known as a Market Business Plan and it is integrated within the Master Business Strategy of a firm (Szulanski, 1996). We have to mention that the ability to exploit external knowledge is a critical component of innovative performance (Cohen and Levinthal, 1989).

Along these lines, the framework presented above (in Fig. 2), allows a direct interaction with consumers and lead users. One of the possible approaches to this interaction involves the design of the correct questions to crowd source and obtaining their responses. Consumer preferences and opinions were harvested by a mixture of on-line and off-line versions of the questionnaires, which focused on product appearance, taste and packaging, Fig. 4, 5 and 6, show examples of questions that have been used to establish the needs of consumers by engaging them in the process. The questionnaires have been designed in such a way that those above the initial considerations could be addressed by the New Product Development Team and later on by the Manufacturing Process Development Team. For example, the key characteristics of the new yoghurt product that was under development included “Light”, “Fresh”, “Longer Life”, “Ecological”, “Bio” and even “Lactose Free”. All these characteristics were also identified by the consumers; an initial sample of 500 consumers of the company’s products was used in that investigation. Those have been indicators of high priority to the consumers involved. Overseas consumers were engaged in the process by the extensive distribution network of the company, which was responsible for the collection and sorting of the data; a smaller sample of 50-100 persons was used in that part of investigation and the majority of them were not company’s consumers. Other important indicators that were identified included the following:

- Desire for flexibility
- Save Food
- Conserve natural resources
- Substitution behaviour
- On the go solutions
- Friendly use packaging
- Product appearance
- Recycled & “Green” Packaging aspects
- Nutrition & Health Aspects and information.

Area of Residence <input type="checkbox"/> City <input type="checkbox"/> Town <input type="checkbox"/> Village	Post Code _____	Age <input type="checkbox"/> Under 18 <input type="checkbox"/> 18-25 <input type="checkbox"/> 26-35 <input type="checkbox"/> 36-45 <input type="checkbox"/> 46-55 <input type="checkbox"/> 55-65 <input type="checkbox"/> Over 65	Sex <input type="checkbox"/> Female <input type="checkbox"/> Male	Are you a member of a family? <input type="checkbox"/> Yes <input type="checkbox"/> No	Who normally goes for shopping? _____
--	---------------------------	---	--	---	---

When you buy a product what is the first thing you look for?	Less Important	1	2	3	4	5	6	More Important
<i>Brand Name</i>								
<i>List Of Ingredients</i>								
<i>Quantity/Volume/Weight of Product</i>								
<i>Nº of calories</i>								
<i>% Fat</i>								
<i>Conservatives or Not</i>								
<i>Expiry Date</i>								
<i>Production Date</i>								
<i>Ways of conservation/Use</i>								
<i>Country of origin</i>								

Are you interesting in products with messages like?	Less Important	1	2	3	4	5	6	More Important
Light								
Fresh								
Long Life								
Ecological								
Bio								
Lactose Free								

How many are the members of your family?

2
 3
 4
 5
 Over 5

Do you prefer?

National Products
 EC Countries Products
 Any other Countries' products
 No matter

How many different yoghurt brand names have you tasted so far?

1
 2
 3
 more than 3
 all available at local market

Where do you buy yoghurt?

Super Stores
 Super Market
 Mini Local Market
 Anywhere else, please specify

Fig. 4. Obtaining Consumers' & Lead Users' inputs, reprinted from (Tsimiklis et al., 2014, p. 8).

When you buy yoghurt, you buy it due to:

	Less Important	1	2	3	4	5	6	More Important
<i>Packaging</i>								
<i>Brand Name</i>								
<i>% Fat</i>								
<i>Ingredients</i>								
<i>Expiry Date</i>								
<i>Country of origin</i>								
<i>Contain fruits</i>								
<i>Publicity</i>								
<i>Natural food</i>								

Do you prefer the brand names of yoghurt to the general ones?

Don't Agree 1 2 3 4 5 6 Strongly Agree

Do you think that the price of yoghurt is a fare price?

Don't Agree 1 2 3 4 5 6 Strongly Agree

I consume yoghurt due to

	Don't Agree	1	2	3	4	5	6	Strongly Agree
<i>Its taste</i>								
<i>Its aroma</i>								
<i>Ecological product</i>								
<i>Its vitamins</i>								
<i>Its density</i>								
<i>Form part of my diet</i>								

Do you prefer your yoghurt in?

Cups
 Pet Bottles
 Glass Cups
 Flexible Packaging
 Anywhere else, please specify

How often do you consume yoghurt?

Daily if daily, Once Twice Various times

3 x per week

2 x per week

once per week

What is your favourite part of the day to consume yoghurt?

Breakfast
 Lunch
 Dinner
 Any time

What type of yoghurt do you prefer?

Fresh
 Long Life
 Any

On your opinion, what is the adequate temperature to conserve any yoghurt?

Fridge
 Cool
 Ambient Temperature
 Warm

Fig. 5. Obtaining Consumers' & Lead Users' inputs, reprinted from (Tsimiklis et al., 2014, p. 8).

I prefer my yoghurt from

	Don't Agree			Strongly Agree		
<i>Cows</i>	1	2	3	4	5	6
<i>Sheeps</i>	1	2	3	4	5	6
<i>Goats</i>	1	2	3	4	5	6
<i>Mix cows/sheeps</i>	1	2	3	4	5	6
<i>Mix sheeps/goats</i>	1	2	3	4	5	6
<i>Any other, please specify:</i>	1	2	3	4	5	6

I prefer my yoghurt to be

	Don't Agree			Strongly Agree		
<i>Plain</i>	1	2	3	4	5	6
<i>Stirred</i>	1	2	3	4	5	6
<i>Long Life</i>	1	2	3	4	5	6
<i>With Fruits</i>	1	2	3	4	5	6
<i>Low Fat</i>	1	2	3	4	5	6
<i>Full Fat</i>	1	2	3	4	5	6
<i>Lactose Free</i>	1	2	3	4	5	6
<i>Full Vitamins</i>	1	2	3	4	5	6

I prefer the size of the packaging of my yoghurt to be

	Don't Agree			Strongly Agree		
<i>100gr</i>	1	2	3	4	5	6
<i>125gr</i>	1	2	3	4	5	6
<i>150gr</i>	1	2	3	4	5	6
<i>200gr</i>	1	2	3	4	5	6
<i>250gr</i>	1	2	3	4	5	6
<i>500gr</i>	1	2	3	4	5	6
<i>1Kg</i>	1	2	3	4	5	6
<i>5Kg</i>	1	2	3	4	5	6
<i>Any other, please specify:</i>	1	2	3	4	5	6

Fig. 6. Obtaining Consumers' & Lead Users' inputs, reprinted from (Tsimiklis et al., 2014, p. 8).

4.3 Synthesis to actionable formats

All those previously mentioned inputs represent what consumers value most. The responses are compared against existing practices, current knowledge of consumer preferences and market segmentation.

On the production and supply sides, knowledge of available processes, manufacturing and distribution capability, ingredient types and availability of them are taken into account. All these inputs and current knowledge are grouped together and mined for new relationships between the data that could reveal new desired product attributes and market segments.

All those considerations lead to the following key product targets:

1. The product should be available in an individual format.
2. The size of the primary packaging of the product should be small.
3. The design of the primary packaging should be developed in such a way that consumers always perceive a high quality product.
4. All legal information must be on the primary packaging in different languages.

The following table explains the relationship of the above points:

Table 1. A Synthesis Table, reprinted from (Tsimiklis and Makatsoris, 2015, p. 14).

Initial triggers	How addressed	OUTCOME
1. Intentional Financial Crisis	Individual Format and small packs or group of packs	Small Size (PP) polypropylene material with (IML) in-mould-labelling
2. The mean number of members of a family is getting less	Small primarily packaging and small group of packs	Format size: 100gr & 125gr
3. The “single” consumers prefer ready-to-use products in individual formats	Individual format and ease of use	Type of pot: On-the-go with spoon
4. Consumers of undeveloped countries cannot afford to buy huge format packs	Individual Format and small primarily packaging	Sell individually or in pack of 4
5. The new international labelling system requirements for the primary packaging	Legal information on primarily packaging	The label with legal information embodied on the pot
6. The necessity for a more flexible world-wide distribution	Legal information on primarily packaging in different languages	6 main languages to sell all over the world: EN, SP, FR, AR, CH, AR
7. The demand for more and more sustainable products without losing quality	Sustainable type of packaging and product	PP with IML Long life product (9 months) Fridge conservation is not needed

For that reason, the outcomes of the above synthesis, in combination with the inputs obtained from the crowd, lead to a set of basic technological requirements that can be used further. Figure 7, shows the technological requirements of a new yoghurt product.

<p>Initial Technological Requirements: Flexible primary packaging: Material, Design, Capacity, Usage, etc. Material: PS or PP (with sleeve or IML, in-mould-labelling/without sleeve or IML) Shape (Design): round, cylinder, rectangular, truncated cone, etc. Split cups (with jam, honey, etc.) Capacity: min., 100g., 125g., 150g., 175g., 200g., max. Cups diameter/Cups Height Other Features: Cups with snap-on-lid Filling Flexibility: product viscosity, temperature of filling, etc. Fruits, mix of fruits, etc. 0%, 5%, 10% M.G., Creamy products, etc. Extra Calcium, without lactose, etc. Soy products? (Allergens?) Aseptic Hygienic Design (FDA, etc.) Production Capacity: Not so high, but high flexibility 20.000-35.000 unidades/h Format change-over: rapid and highly optimised (1-2h max.) Flavour change-over (flavours, mix, fruits, etc.) – rapid and highly optimised (20/30 min.) Cleaning procedures SIP/CIP, etc – rapid and highly optimised (20/30 min.)</p>

Fig. 7. Basic initial Technological requirements, reprinted from (Tsimiklis et al., 2014, p. 9).

Initially, the key development activities for the product itself were conducted in a laboratory/pilot plant and those initial samples were evaluated by the NPD team. Then, product prototypes were replaced by test runs in full-scale production, where test batches for customers' evaluation were made and the adequate process conditions specified.

The design of the primary packaging with all accessory components and characteristics was also defined by 3D virtual prototypes and finally by foam prototypes. The machinery to process such a kind of packaging and product was also defined by industrial trials and all other aspects, such as, additional formats, promotional formats, trays, palletizing patterns, etc. that were related to consumers' needs were clearly defined and prototyped. Furthermore, a trial test with end users was carried out to verify the grade of acceptance of the prototypes. By doing this, the company could understand if the initial MBP was still accurate enough and where corrections had to be done before launching the new product.

It is clear that at this stage, manufacturing, R&D and marketing should work together as it is vital to have a fluent and harmonised communication among those three principal players within any NPD process (Calantone et al., 2002), even during the trial tests with the end users. Again, the use of an ICT network for rapid communication and data exchange should prove to be vital for such a kind of relationships among different departments, even within the same company.

On that account, manufacturing processes need to be developed that are scaled to meet market demand, not the demand of prototypes. Manufacturing can therefore provide essential inputs concerning what is feasible to produce, as well as, develop the expertise needed to move beyond current capabilities.

At this stage, coupling the external knowledge of selected lead machine and materials suppliers with the timely, open information sharing between them (Laursen and Salter, 2006; Garriga et al., 2013) proved to be a big advantage for reducing the product's time to market.

Furthermore, it is important to mention that agility is a key component for success because all types of production machinery should be selected by having a reduction of the time to market in mind.

All those aspects were implemented with lead selected machine suppliers as their external knowledge was used by the firm to obtain a better innovation performance and easier conditions for integrating a new system into existing operations (Laursen and Salter, 2006). Following this, the BOM before the initial production of the yoghurt example was defined as follows (considering that the weight of the cup of the yoghurt of our example is 100gr):

Table 2. Bill of Materials, reprinted from (Tsimiklis and Makatsoris, 2015, p. 16).

Ingredients	Packaging
Milk (90% - 7.4% fat)	Cups with IML presentation (1 piece per 100gr)
Starch (1.5%)	Lids (1 piece per 100gr)
Sugar (8%)	Snap-on-Lids (1 piece per 100gr)
Gelatine (0.49%)	Trays (24 cups per tray) - (225 trays per EuroPallet)
Lactic ferments (0.01%)	
Pieces of Fruits or Aromas (Optional but, different %)	

4.4 Integration into production

The requirements were used to drive product development, the design and the execution of the supply chain operations. The framework in Figure 2 embodies the tools for the design and operation of a smart manufacturing network that ultimately can drive on-demand manufacturing, where demand allocation and the configuration of the network itself can be determined dynamically, as product requirements and demand evolve. At the design stage, simulation assesses possible manufacturing network configurations and planning algorithms project future execution. The outputs are then set points for manufacturing execution that conventional enterprise resource planning tools can plan against and feeding back actual manufacturing execution progress and exceptions. The next figure (Fig. 8) shows an example scenario of how a demand of 15,000 cups of yoghurt is handled by our framework.

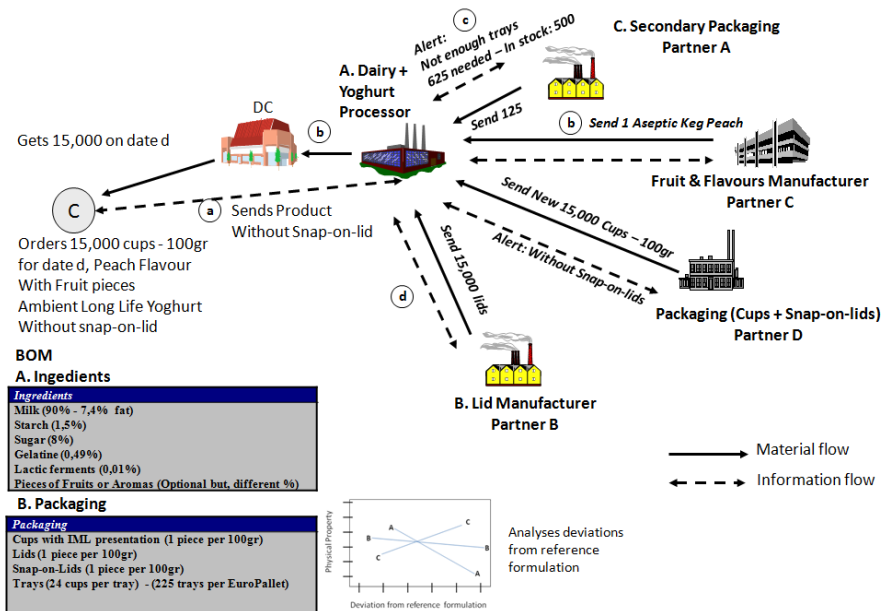


Fig. 8. Example Scenario of a smart on-Demand Yoghurt Manufacturing Network, reprinted from (Tsimiklis and Makatsoris, 2015, p. 17).

The customer (C) in Fig. 8 has sent an order of 15,000 cups of 100gr., to be received at a particular date, with the exact and specific requirements of a yoghurt product. The specific details and information of the order is directly received by the dairy processor and that piece of information is directly shared with the packaging and ingredients partners. By having centralised the formulation of the ordered product, the necessity of ingredients and their deviations are analysed from the reference formulation. Alerts of clear necessities are generated and immediately they are directly transmitted to the ingredients partners. The information is shared in a similar way with the packaging partners.

It is therefore the common information network that can provide a real on-demand manufacturing and a fast response to the customers' demands. In our case study, such a common information network with suppliers is still under development due to license matters and confidentiality aspects that need to be solved. Meanwhile, the internal communication network for any NPD (New Product Development) process has already been developed and it has been in use for almost two years.

As a real case study, it is worth mentioning the following obtained project results:

1. A better primarily packaging has been designed thanks to the points presented below:
 - i. The yoghurt recipients' appearance and characteristics have been improved (see Figure 9 and 10). The primarily packaging has an improved visual appearance due to technology; It no longer uses Polystyrene (PS) but Polypropylene (PP) with an IML (in-mould-labelling) resulting in a packaging with an excellent balance of mechanical properties, chemical resistance, colour stability and moisture barrier properties (see also Table 3). Due to its opacity, (PP) provides better protection and resistance to sunlight.

Table 3. Comparison Chart (AIMPLAS, 2009; Alpha Packaging, 2011).

Material	Clarity	MVTR*	O2**	CO2**	Impact Strength	Recycle Code
PP	Poor	0.5	3,5	7	Fair	5
PS	Excellent	10.0	6	18,7	Poor	6

*MVTR stands for Moisture Vapour Transmission Rate in g-mil/100in. 2/24hr. MVTR is a measure of the passage of gaseous H2O through a barrier. The lower the rate, the longer the package protects its contents from moisture and ensures the moisture content of the product remains the same.

**O2 and CO2 stand for Oxygen Transmission Rate (OTR) and Carbon Dioxide Transmission Rate (COTR) in cm3-mil/m2/24hr. OTR and COTR are measures of the amount of gas that passes through a substance over a given period. The lower the readings, the more resistant the plastic is to letting gasses through.



Fig. 9. Initial and Final Design, reprinted from (Tsimiklis et al., 2014, p. 10).

- ii. The labelling of the packaging has improved (from a quality point of view and at the same time it consists of six different languages with all the legally required information).
 - iii. The packaging has gained on versatility and use as it has been transformed to “on-the-go” pot thanks to its size, shape and spoon that has been attached on its snap-on-lid. The pot is available in two formats: 100gr and 125gr and both formats maintain the same diameter at their top so they can be filled by the same filling machine with minor change-overs (approx. 20 minutes).
 2. A better and more versatile product thanks to the advantages of its primarily packaging and the product itself also improved thanks to the next two points:
 - i. The shelf-life of the product is 9 months when other yoghurt products’ shelf-life is between 1 to 2 months (Cruz et al., 2010; Mataragas et al., 2011).
 - ii. The product can be transported and stored at ambient temperature, so it can be sold all over the world, even at places where there is no electricity, transport refrigeration and domestic or commercial refrigerators.
 3. So far, sales have been improved by almost 10%, the cost of quality has been reduced by almost 8-9% and transportation costs have been reduced by 5%.

5 Conclusions and recommendations

In this paper, we presented a collaborative conceptual framework based on ICT, which can be used to re-engineer any New Product Development process and, which encompasses consumer-centric Open Innovation and the more traditional design frameworks, such as, the Double Diamond 4D Design. Key features to our overall approach are a collaborative framework for innovation that extends beyond the boundaries of individual organisation and the subsequent mitigation and sharing of innovation risk not least because of the direct involvement of the consumer in the New Product Development loop. Although the present study had a geographical focus, there is no evidence to suggest that geography would restrict the applicability of our approach in any way. On the contrary, in the literature (Lazarotti et al., 2012; Mäkimattila et al., 2013; Saguy and Sirotinskaya, 2014) it has been shown that , the country factor is

irrelevant to cross border collaboration on New Product Development and Innovation activities, de-risking the process though even further. Furthermore, by embracing Open Innovation within a company's strategy framework is far more important than just addressing day-to-day competitive pressures as it allows for better response to long term business challenges and market demands through the establishment of a culture of Innovation. With this motivation in mind, our framework targets all food companies seeking to apply Open Innovation in their New Product Development efforts.

In particular, the consumer-centric Open Innovation approach suggested in this paper, with crowd-sourcing as its key feature for consumer engagement, places end customers in the New Product Development process with the additional benefits of:

1. Discovering new market segments and understanding their needs.
2. Enabling the design and production of food products.
3. Supporting the needless consumption of energy and resources because the real demand and use of the products can be guaranteed.

Therefore, we think that such a kind of conceptual framework can help any food company empower its internal knowledge and talent by absorbing selected external information and knowledge. The application of new technology which supports the access, exchange, sharing and use of information is vital for the achievement of the previous statement. When all that enriched knowledge forms part of the culture and heritage of the company, at that moment, the organization will have "acquired" a big data system. It is therefore obvious that the development of a common information network and its limitations should be an interesting future work.

Furthermore, we also explained that in order to achieve everything listed above, any food manufacturing system and its whole supply chain should rapidly respond to change by adapting its initial configuration.

However, we think that as a further research, we should study simulation and optimisation models and techniques which can be used by expert users to discover the manufacturing capacity of any available installation, configure manufacturing networks and processes, select appropriate suppliers and assess risks associated with particular process and network configuration decisions.

In addition, agile processes are essential for a correct implementation and final success of such a manufacturing model. To a significant degree, the success of an Agile Manufacturing Unit or even the whole enterprise depends on the application of new technology, which comprehensively supports the access, exchange, sharing and use of information, while speeding up the information and work flow in the product development cycle. Agile materials, capacity planning and control systems are a must. A mechanism to achieve agility is the ability to provide forecasts throughout the supply chain of forthcoming demand without the buffering encountered in current supply chains; expired products and waste of food can be avoided. We think that this last part is also an interesting study for future research.

6 Acknowledgements

This work has been conducted as part of a UK Engineering and Physical Sciences Research Council (EPSRC) research grant with number EP/K014234/2. The authors

would like to fully acknowledge and thank EPSRC for their support.

6 References

- AIMPLAS, Instituto Tecnológico del Plástico (2009). *Guía de buenas prácticas para diseñadores de productos fabricados con materiales plásticos*, (pp. 104-128). ISBN: 978-84-612-9594-4.
- Akgün, A. E., Lynn, G. S., & Yilmaz, C. (2006). Learning process in new product development teams and effects on product success: A socio-cognitive perspective. *Industrial Marketing Management*, 35(2), 210 – 224.
- Alpha Packaging (2011). Accessed 1st December 2011. Web site: <http://www.alphap.com>.
- Annique Un, C., Cuervo-Cazurra, A., & Asakawa, K. (2010). R&D Collaborations and Product Innovation. *Journal Product Innovation Management*, 27(5), 673–689.
- Bae, Y., & Chang, H. (2012). Efficiency and effectiveness between open and closed innovation: empirical evidence in South Korean manufacturers. *Technology Analysis & Strategic Management*, 24(10), 967–980.
- Baregheh, A., Rowley, J., & Sambrook, S. (2009). Towards a multidisciplinary definition of innovation. *Management Decision*, 47(8), 1323-1339.
- Bessant, J., & Tidd, J. (2007). *Innovation and entrepreneurship*. John Wiley & Sons Inc., Chichester, England.
- Bigliardi, B., and Galati, F. (2013). Models of adoption of open innovation within the food industry. *Trends in Food Science & Technology*, 30(1), 16-26.
- Bjelland, O. M., & Wood, R. C. (2008). An Inside View of IBM's "Innovation Jam". *MIT Sloan Management Review*, 50(1), 32-40.
- Brown, S. L., & Eisenhardt, K. M. (1995). Product development: Past research, present findings and future directions. *Academy of Management Review*, 20(2), 343–378.
- Calantone, R., Dröge, C., & Vickery S. (2002). Investigating the manufacturing-marketing interface in new product development: does context affect the strength of relationships?. *Journal of Operations Management*, 20(3), 273-287.
- Cao, M., & Zhang, Q. (2011). Supply chain collaboration: Impact on collaborative advantage and firm performance. *Journal of Operations Management*, 29(3), 163–180.
- Chesbrough, H. (2003a). *Open Innovation: The new imperative for creating & profiting from technology*. Harvard Business Press.
- Chesbrough, H. (2003b). The Era of Open Innovation. *MIT Sloan Management Review*, 44(3), 35–41.
- Chesbrough, H. (2006). Open innovation: a new paradigm for understanding industrial innovation. *Open Innovation: Researching a new paradigm*, 1–12.
- Chesbrough, H., & Crowther, A. K. (2006). Beyond high tech: early adopters of open innovation in other industries. *R&D Management*, 36(3), 229–236.
- Chesbrough, H., Vanheverbeke, W., & West, J. (Eds.) (2006). *Open Innovation:*

Researching a new Paradigm. Oxford University Press.

- Chesbrough, H., & Bogers, M. (2014). Explicating open innovation: clarifying an emerging paradigm for understanding innovation. *New Frontiers in Open Innovation*. Oxford: Oxford University Press, Forthcoming, 3-28.
- Christiansen, J. K., Gasparin, M., & Varnes, C. J. (2013). Improving design with open innovation: A flexible management technology. *Research-Technology Management*, 56(2), 36-44.
- Christopher, M. (2005). *Logistics and supply chain management: creating value-adding networks*. Pearson education.
- Christopher, M. (2000). The agile supply chain: competing in volatile markets. *Industrial marketing management*, 29(1), 37-44.
- Coleman, D. (1997). Collaborating on the Internet and Intranets. In *System Sciences, 1997, Proceedings of the Thirtieth Hawaii International Conference on* (Vol. 2, pp. 350-358). IEEE.
- Cohen, W. M., & Levinthal, D. A. (1989). Innovation and learning: the two faces of R&D. *Economic Journal*, 99(397), 569-596.
- Cooper, R. G., & Kleinschmidt, E. J. (1995). Benchmarking the firms critical success factors in new product development. *Journal of Product Innovation Management*, 12(5), 374-391.
- Costa, A. I. A., & Jongen, W. M. F. (2006). New insights into consumer-led food product development. *Trends in Food Science & Technology*, 17(8), 457-465.
- Cruz, A. G., Walter, E. H. M., Cadena, R. S., Faria, J. A. F., Bolini, H. M. A., Pinheiro, H. P., & Sant'Ana, A. S. (2010). Survival analysis methodology to predict the shelf-life of probiotic flavored yogurt. *Food Research International*, 43(5), 1444-1448.
- Damanpour, F. (1996). Organizational complexity and innovation: developing and testing multiple contingency models. *Management Science*, 42(5), 693-716.
- Djelassi, S., & Decoopman, I. (2013). Customers' participation in product development through crowdsourcing: Issues and implications. *Industrial Marketing Management*, 42(5), 683-692.
- Dougherty, D. (1992). Interpretive barriers to successful product innovation in large firms. *Organization Science*, 3(2), 179-202.
- Fawcett, S. E., Magnan, G. M., & McCarter M. W. (2008). A three stage implementation model for supply chain collaboration. *Journal of Business Logistics*, 29(1), 93-112.
- Fernie, J., & Sparks L. (2009). Retail logistics: changes and challenges. In J.Fernie and L.Sparks (eds). *Logistics and retail management: emerging issues and new challenges in the retail supply chain*, 3rd Edition, 3-37.
- Finch, E. (2000). *Net gain in construction: Using the Internet in the construction industry*. Butterworth-Heinemann.
- Fitzgerald, M., Kruschwitz, N., Bonnet, D., & Welch, M. (2014). Embracing Digital Technology: A New Strategic Imperative. *MIT Sloan Management Review*, 55(2), 1-12.

- Flint, D. J. (2002). Compressing new product success-to-success cycle time Deep customer value understanding and idea generation. *Industrial Marketing Management*, 31(4), 305–315.
- Frishammar, J., Lichtenthaler, U., & Kurkkio, M. (2012). The front end in non-assembled product development: A multiple case study of mineral-and metal firms. *Journal of Engineering and Technology Management*, 29(4), 468-488.
- Fuller, G. W. (2005). *New Food Product Development: From Concept to Marketplace*. CRC Press, Boca Raton, FL.
- Füller, J., & Matzler, K. (2007). Virtual product experience and customer participation – A chance for customer-centred, really new products. *Technovation*, 27(6), 378–387.
- Garcia, R., & Calantone, R. (2002). A critical look at technological innovation typology and innovativeness terminology: a literature review. *Journal of Product Innovation Management*, 19(2), 110-132.
- Garriga, H., Von Krogh, G., & Spaeth, S. (2013). How Constraints And Knowledge Impact Open Innovation. *Strategic Management Journal*, 34(9), 1134–1144.
- Garvin, D. (1993). Building a learning organization. *Harvard Business Review*, 71(4), 78–91.
- Gloor, P. (2000). *Making the E-business Transformation*. Springer Publishing Company, Incorporated, London.
- Hansen, S. O., & Wakonen, J. (1997). Innovation, a winning solution?. *International Journal of Technology Management*, 13(4), 345–358.
- Harrington, L. H. (2000). Collaborating on the Net. *Transportation and Distribution*, 41(2), 8-15.
- Henke, J. W. Jr., & Zhang, C. (2010). Increasing Supplier-Driven Innovation. *MIT Sloan Management Review*, 51(2), 41-46.
- Henten, A. (2012). Innovations from the ICT-based service encounter. *Info (Cambridge. Print)*, 14(2), 42-56.
- Hoholm, T., & Strønen, F. H. (2011). Innovation, strategy and identity: a case study from the food industry. *European Journal of Innovation Management*, 14(3), 345 - 363.
- Hudnurkar, M., Jakhar, S., & Rathod, U. (2014). Factors affecting collaboration in supply chain: A literature Review. *Procedia - Social and Behavioral Sciences*, 133(1), 189 – 202.
- Huizingh, E. K. R. E. (2011). Open innovation: State of the art and future perspectives. *Technovation*, 31(1), 2–9.
- ITU: International Telecommunication Union (2011). *Measuring the Information Society*. ITU, Place des Nations, CH-1211, Geneva, Switzerland (ISBN: 92-61-13801-2).
- Kano, N. (1984). Attractive quality and must be quality. *Hinshitsu (Quality)*, 14 (2), 147–156 (in Japanese).
- Karantininis, K., Sauer, J., & Furtan, W. H. (2010). Innovation and integration in the

- agri-food industry. *Food Policy*, 35(2), 112-120.
- Keating, B. A., Carberry, P. S., Bindraban, B., Asseng, S., Meinke, H., & Dixon, J. (2010). Eco-efficient Agriculture: Concepts, Challenges and Opportunities. *Crop Science*, 50(S1), 109-119.
- Laursen, K., & Salter, A. (2006). Open For Innovation: The Role Of Openness In Explaining Innovation Performance Among U.K. Manufacturing Firms. *Strategic Management Journal*, 27(2), 131–150.
- Lazzarotti, V., Garcia, M., Manzini, R., and Sanchez, M. 2012. The Open Innovation in Practice: a Survey in the Food & Drink Industry. *The XXIII ISPIM Conference – Action for Innovation: Innovating from Experience*, Barcelona, Spain, Issue 23, 1-29.
- Lienhardt, J. (2004). The food industry in Europe, statistics in focus-industry, trade and services. 39/2004. *Luxemburg: Eurostat, European Communities*.
- Lilien, G. L., Morrison, P. D., Searls, K. L., Sonnack, M., & von Hippel, E. (2002). Performance assessment of the lead user idea-generation process for new product development. *Management Science*, 48(8), 1042–1059.
- Löfgren, M., & Witell, L. (2005). Kano's theory of attractive quality and packaging. *Quality Management Journal*, 12(3), 7-20.
- Lynn, G. S., Abel, K. A., Valentine, W. S., & Wright, R. C. (1999). Key Factors in Increasing Speed to Market and Improving New Product Success Rates. *Industrial Marketing Management*, 28(4), 319-326.
- Marques, J. P. C. (2014). Closed versus Open Innovation: Evolution or Combination? *International Journal of Business and Management*, 9(3), 196.
- Mäkimattila, M., Melkas, H., & Uotila, T. (2013). Dynamics of Openness in Innovation Processes - A Case Study in the Finnish Food Industry. *Knowledge & Process Management*, 20(4), 243-255.
- Makrides, C., & Geroski, P. A. (2005). *Fast Second – How smart companies bypass radical innovation to enter and dominate new markets*. John Wiley and Sons, San Francisco.
- Mataragas, M., Dimitriou, V., Skandamis, P. N., & Drosinos, E. H. (2011). Quantifying the spoilage and shelf-life of yogurt with fruits. *Food Microbiology*, 28(3), 611-616.
- Matzler, K., & Hinterhuber, H. H. (1998). How to make product development projects more successful by integrating Kano's model of customer satisfaction into quality function deployment. *Technovation*, 18(1), 25–38.
- Menrad, K. (2004). Innovations in the food industry in Germany. *Research Policy*, 33(6), 845-878.
- Monsef, S., Khairuzaman, W., & Ismail, W. (2012). The Impact of Open Innovation in New Product Development Process. *International Journal of Fundamental Psychology & Social Sciences*, 2(1), 7-12.
- Morcillo, P. (2007). *Cultura e Innovación Empresarial*. Thomson Editores, Spain.
- Nambisan, S. (2002). Designing virtual customer environments for new product development: toward a theory. *Academy of Management Review*, 27(3), 392–

413.

- Park, J., Shin, K., Chang, T.-W., & Park J. (2010). An integrative framework for supplier relationship management. *Industrial Management & Data Systems*, 110(4), 495-515.
- Pascucci, S., Dentoni, D., & Mitsopoulos, D. (2015). The perfect storm of business venturing? The case of entomology-based venture creation. *Agricultural and Food Economics*, 3(1), 1-11.
- Pellegrini, L., Lazzarotti, V., & Manzini, R. (2014). Open Innovation in the Food and Drink Industry. *Journal of Agricultural and Food Industrial Organization*, 12(1), 75-94.
- Pinto, J. (2002). Project management 2002. *Research Technology Management*, 45(2), 22-37.
- Plessis, M. D. (2007). The role of knowledge management in innovation. *Journal of Knowledge Management*, 11(4), 20-9.
- Prahalad, C., & Ramaswamy, V. (2002). The co-creation connection. *Strategy and Business*, 27(2), 50-61.
- Prahalad, C., & Ramaswamy, V. (2004). Co-creating unique value with customers. *Strategy & Leadership*, 32(3), 4 – 9.
- Rizova, P. (2006). Are You Networked for Successful Innovation? *MIT Sloan Management Review*, 47(3), 49-55.
- Rodgers, R. (2013). *Digital Methods*. Massachusetts Institute of Technology, Massachusetts.
- Rometty, G. (2007). Collaboration: Leaders agree it's key to innovation *Leadership Excellence*, 24(2), 3.
- Saguy, S., & Sirobinskaya, V. (2014). Challenges in exploiting open innovation's full potential in the food industry with a focus on small and medium enterprises (SMEs). *Trends in Food Science & Technology*, 38(2), 136-148.
- Samaddar, S., & Kadiyala, S. S. (2006). An analysis of inter-organizational resource sharing decisions in collaborative knowledge creation. *European Journal of Operational Research*, 170(1), 192-210.
- Sarkar, S., & Costa, A. (2008). Dynamics of open innovation in the food industry. *Trends in Food Science & Technology*, 19(11), 574-580.
- Sawhney, M., & Prandelli, E. (2000). Communities of creation: managing distributed innovation in turbulent markets. *California Management Review*, 42(4), 24-54.
- Simatupang, T. M., Wright, A. C., & Sridharan, R. (2004). Applying theory of constraints to supply chain collaboration. *Supply chain Management: an international journal*, 9(1), 57-70.
- Simatupang, T. M., & Sridharan, R. (2008). Design for supply chain Collaboration. *Business Process Management Journal*, 14(3), 401-418.
- Slack, N., Chambers, S. & Johnston, R. (2007). *Operations Management*. Prentice Hall (5th Edition, 2007).
- Slyke, V. & Belanger, F. (2003). *E-Business Technologies: Supporting the Net-*

Enhanced Organization. Wiley, New York, NY.

- Szulanski, G. (1996). Exploiting internal stickiness: impediments to the transfer of best practice. *Strategic Management Journal*, 17(S2), 27–43.
- Theyel, N. (2012). Extending open innovation throughout the value chain by small and medium-sized manufacturers. *International Small Business Journal*, 31(3) 256–274.
- Thompson, V. A. (1965). Bureaucracy and innovation. *Administrative Science Quarterly*, 10(1), 1-20.
- Tsimiklis, P., Qin, S. F., Green, S., Rodden, T., Baurley, S., & Makatsoris, C. (2014). Open Innovation Models for Knowledge Driven Food and Packaging Manufacturing. *KES Transactions on Sustainable Design and Manufacturing*, Vol. 1, No. 1, International Conference on Sustainable Design and Manufacturing, KES International, 28-30 April 2014 Cardiff, Wales, UK.
- Tsimiklis, P., & Makatsoris, C. (2015). An Open Innovation Framework for Market Driven Food Product Design and Manufacture. *Food Studies: An Interdisciplinary Journal*, 5(3), 1-21.
- UK Cabinet Office (2008). *Food Matters – Towards a Strategy for the 21st Century*. July 2008.
- UK Design Council (2005). *Eleven Lessons: Managing design in eleven global brands. The design process*. Accessed 10th December 2011. Web site: www.designcouncil.org.uk.
- Van der Meer, H. (2007). Open Innovation- the Dutch treat: challenges in thinking in business models. *Creativity and Innovation Management*, 16(2), 192-202.
- Waller, M. (2013). *How sharing data drives supply chain innovation*. Industry Week, Penton Business Media, Inc. and Penton Media Inc., ISSN: 00390895.
- West, J., Salter, A., Vanhaverbeke, W., & Chesbrough, H. (2014). Open innovation: The next decade. *Research Policy*, 43(5), 805–811.
- Wikhamn, B. R. (2013). Two Different Perspectives on Open Innovation–Libre versus Control. *Creativity and Innovation Management*, 22(4), 375-389.
- Wild, R. (1992). *Production & Operations Management*. Cassell (4th Edition, 1992).
- Wu, C., & Barnes, D. (2010). Formulating partners election criteria for agile supply chains: A Dempster-Shafer belief acceptability optimizations approach. *International Journal Production Economics*, 125(2), 284-293.
- Wynarczyk, P., Piperopoulos, P., & McAdam, M. (2013). Open innovation in small and medium-sized enterprises: An overview. *International Small Business Journal*, 31(3), 240 –255.
- Yusuf, Y. Y., Gunasekaran, A., Adeleye, E. O., & Sivayoganathan, K. (2004). Agile supply chain capabilities: Determinants of competitive objectives. *European Journal of Operational Research*, 159(2), 379-392.