Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 138 (2016) 459 – 471

Procedia Engineering

www.elsevier.com/locate/procedia

"SYMPHOS 2015", 3rd International Symposium on Innovation and Technology in the Phosphate Industry

Managing Innovation & Technology in the Process Industries: Current practices and future perspectives

Thomas Lager*

EMINES – School of Industrial Management, Université Mohammed VI Polytechnique, 43150 Ben Guerir, Morocco

Abstract

The "family" of process industries spans multiple industrial sectors and thus constitutes a substantial part of all manufacturing industries, including petrochemicals and chemicals, food and beverage, mining and metals, mineral and materials, pharmaceuticals, pulp and paper, steel, and utilities. This article begins by reviewing methods and tools used in the process industries for effectiveness improvements, such as technology road-mapping, R&D strategy development, and portfolio balancing. Next, more efficiency-related areas of R&D like work processes and methodologies like quality function deployment, and collaboration in an open innovation approach are introduced. Both areas relate to product and process innovation from idea generation to implementation. Starting from this platform of current knowledge, future perspectives on the need for new approaches and tools for improved Management of Innovation & Technology in the process industries are reviewed and discussed.

Peer-review under responsibility of the Scientific Committee of SYMPHOS 2015

Keywords: Innovation Management, Technology Management, Process Industries

1. Background and introduction

1.1 Innovation in the process industries

The process industries span multiple industrial sectors and thus constitute a substantial part of all manufacturing industry. This "family" of industries includes, for example, petrochemicals and chemicals, food and beverage, mining

* Corresponding author. Tel.: +33 6 78080274.
E-mail address: Thomas.lager@emines.um6p.ma

Peer-review under responsibility of the Scientific Committee of SYMPHOS 2015
doi:10.1016/j.proeng.2016.02.105

and metals, mineral and materials, pharmaceuticals, pulp and paper, steel, and utilities. A key difference between companies in the process industries and those in other manufacturing industries is that the products supplied to them, and often also those delivered from them, are materials or ingredients rather than components. Additional key features are the often long supply and value chains prevailing within them and the fact that process companies are very asset-intensive and strongly integrated in a few physical locations [1]. R&D in the process industries is conducted in a laboratory, pilot plant, or production plant environment rather than at a design office. Product prototypes are replaced by test runs in pilot plants or full-scale production, in which test batches for customers or consumers are made. Development work is fundamentally experimental, and product and process development often take place in collaboration with manufacturers of process equipment and suppliers of raw materials and reagents. Moreover, both the final quality of products and intermediate product characteristics are often strongly related to available raw material properties – a fact that is further illustrated in the following section.

1.2 The downgrade/upgrade cycles of products, process technology and raw materials – a point of departure

Figure 1 illustrates how raw material properties not only influence production costs and the complexity of appropriate production process technology but also often determine the quality and the performance of final products. Thus, securing a price-competitive and high-quality raw material supply base with a long-term perspective, as well as the development of such raw materials, should be prioritized highly by firms in the process industries [2]. However, the ability to be a cost-competitive commodity producer, or a producer of more functional products, is also related to an ability to develop and introduce cost-efficient process technology in the production processes. Referring to Figure 1, lacking sufficient resources for process innovation, corporate core process technology will inevitably be downgraded to basic technology. When manufactured products with improved functional properties are introduced on the market, however, they are usually soon imitated as competitors try to produce the same type of product with the same performance; prices then gradually decline, and the functional products degenerate into commodities.

Fig. 1. A conceptual model of the downgrade – upgrade cycles for products, process technology and raw-material supply in the process industries. When proper innovation activities are lacking, all three areas will downgrade [2].

1.3 Producer of commodities or functional products? Repositioning along the company supply/value chain

As a consequence, of different competitive dimensions on the market, commodities have been differentiated in Figure 2, into “upstream” and “downstream” commodities [3]. Upstream commodities are defined in this context as primary raw material resources, like cultivated agricultural products, forest products, crude oil and so on. Products of this kind are often traded on raw material exchanges. Downstream commodities, on the other hand, are defined as upstream commodity products that are processed further, such as metals (copper, lead, zinc, etc.), structural steel, orange juice, aggregates, petrol, standard wood pulp, and so on. Such products are sometimes traded on raw material exchanges, but most often prices are set on the world market. Here one also finds commodity products that are marketed to consumers (B2C), like detergents, and food products like milk.

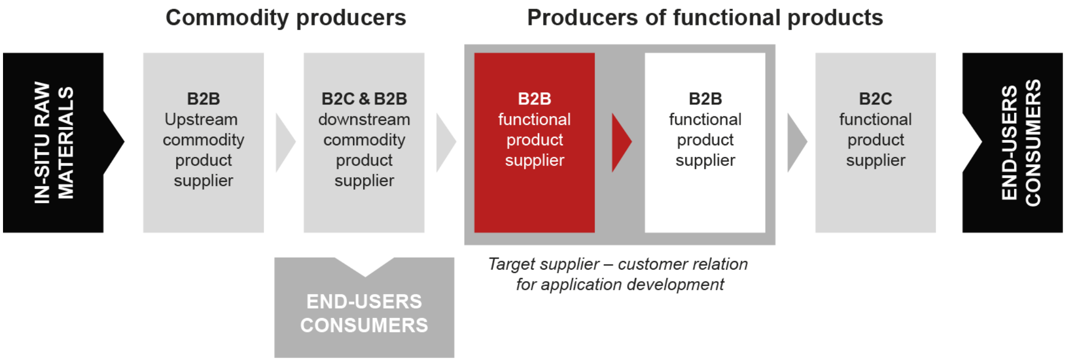

Fig. 2. The supply/value chain in the process industries [3].

The functional products have been separated into B2B (Business-to-Business) and B2C (Business-to-Consumer) functional products. In the B2B competitive perspective, it is possible to establish a long-term collaborative relation with individual customers and even to produce customized products that suit large customers' application needs (marked in red). In the chemical industry, such products are often referred to as specialty products, and customer services for and collaborative development of the customer's use of such products is more in focus. In the B2C competitive perspective, apart from functionalites, branding plays a much more prominent role in consumers' purchasing decisions. An example of repositioning along the value chain and a voluntary descent on the "functional ladder" is demonstrated by Dow Corning, where the decision was made to operate as a retailer of their more commodity-like products in addition to producing products with strong or medium product functionality. It was thus necessary to develop a better-adapted business model (and a new organizational subsidiary) that fostered a rather different culture, focusing on activities like cost-efficient supply chains and less on customer support [4].

1.4 Management of Innovation & Technology

While the production systems and R&D in the process industries are substantially different from such activities in other manufacturing industries, there are nonetheless many similarities and synergies between companies from different sectors within the cluster of process industries; moreover, it cannot be said that prior or on-going research into the management of R&D in general does not apply to the process industries. For example, as illustrated in Figure 3, Samsung uses a portfolio of currently available methodologies and tools in their innovation of new products [5]. However, the idiosyncrasies of process companies are likely to influence the conduct of R&D and innovation; as a result, there is a need for more specific or adapted tools and best practices in the topical area of management of innovation and technology in the process industries.

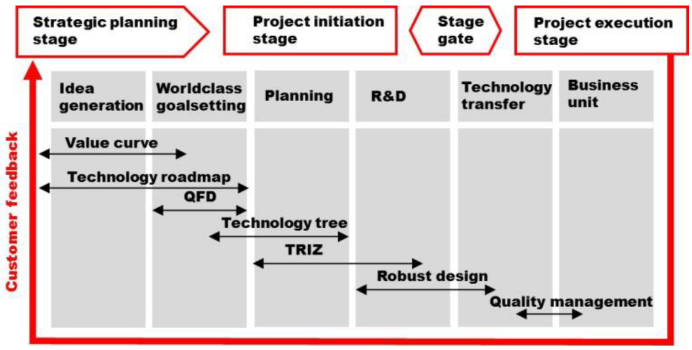

Fig. 3. Deploying a portfolio of integrated development methodologies at Samsung [5].

In this article, the following research question is thus addressed:

RQ1 What tools, methodologies and best practices are important to improve or develop in order to facilitate and guide an improved management of innovation and technology for companies in the process industries?

2. Resource allocation models: A strategic perspective on the effectiveness of R&D

From a resource allocation perspective, is pouring more money into the R&D organization the best way to achieve greater innovation? Looking at innovation through the lens of effectiveness and efficiency, the answer to this question is certainly no. The effectiveness (doing the right things) and efficiency (doing those things well) of using the innovation resources are the hidden variables that incentivize companies to use the best practices and tools in innovation.

2.1 Current practices

Technology roadmapping and portfolio balancing as a starting point

Technology roadmapping refers to translating company business strategies into innovation objectives, thus creating a "framework" for further development of innovation strategies. However, in the spirit of Minzberg [6.7], innovation strategies and activities may equally give new incentives to revise company strategies. Within such company R&D strategies the importance of a better classification of product development is gaining acceptance in industry, and the very early Booz, Allen and Hamilton product matrix (Figure 4a) can facilitate assessment of the company's product development portfolio with regard to aspects such as necessary company resources, a proper risk/reward balance for the product development portfolio and personnel qualifications needed for different kinds of product development [8].

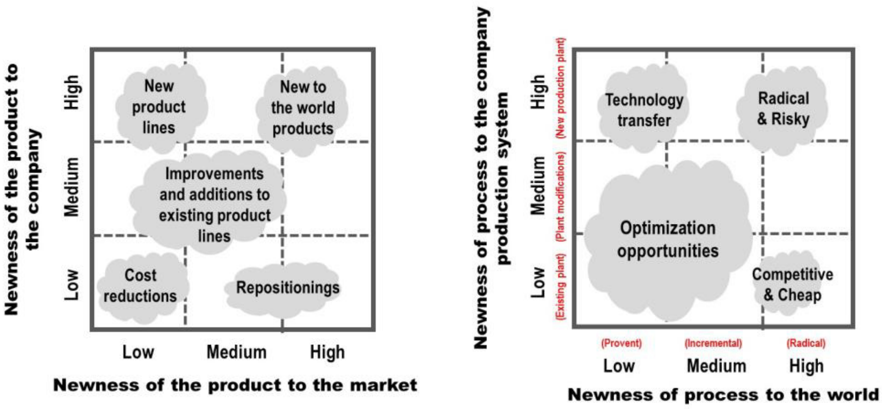

Fig. 4. (a) What is new with a new product [8]? (b) What is new with a new process [9]?

In a similar vein and in an improved classification of process innovation, the degree of newness of a process technology can sometimes be related to whether the process can be patented. Another thing that often distinguishes the process industries from other manufacturing industries is that production plants in the former are seldom easily modified, and changes in the process configuration are often costly and investment-intensive. Because of this, the newness of process technology to the company production system is another important dimension (Figure 4b) and the following scales [9]:

- *Low: The new process technology can be used in existing process plants.*
- *Medium: The new process technology requires significant plant modifications or additional equipment.*
- *High: The new process technology requires a completely new process plant or production unit.*

2.2 Future perspectives

Starting with the seemingly trivial question of "how much innovation is enough", resource allocation models for innovation are rare, if indeed they exist at all. In the overall corporate resource allocation process, the distribution of corporate total resources to different functional areas like sales and marketing, production and R&D is often based on traditional percentages and previous needs [10]. The lack of a usable and robust model for resource allocation is unfortunately particularly acute with regard to the distribution of corporate resources to innovation [3]. The different dimensions in Figure 5 illustrate well that product and process innovation in the process industries are only two of the innovation and innovation-related activities that should be considered, which in this context will be called the company's "distributed innovation intensities" [11]. In order to get a balanced allocation of company innovation resources, it would be wise not only to use this typology in R&D strategy development but also afterwards conduct an annual follow-up on how resources are spent in reality along those dimensions.

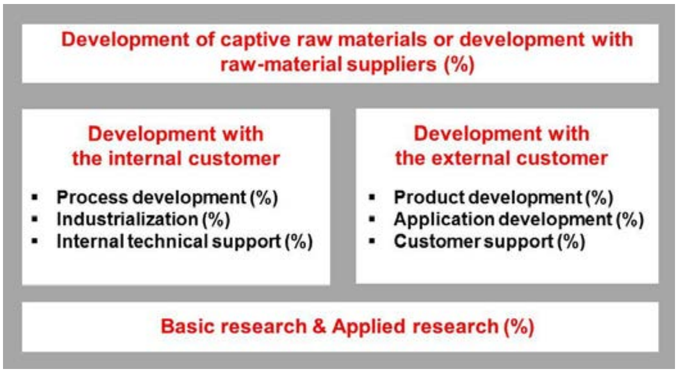

Fig. 5. A typology for innovation and innovation-related R&D activities. The percentages in parenthesis illustrate the concept of "distributed innovation intensities" and put R&D in a strategic perspective as distributing "buckets of money" to different areas of R&D [2].

3. Innovation work processes: An organizational perspective on R&D efficiency

The manufacturing/R&D/marketing triad has been a topical area of interest since a hundred years ago, when companies in the spirit of Taylor [12] started to separate into departmental organizations in order to improve their efficiency. Today, a majority of studies in this area focus on how to bridge such barriers and to use – and, further on, to revitalize – company "key business processes" [13]. The use of company formal work processes is one best practice that not only can facilitate cross-functional collaboration but also can be seen as one form of "organizational learning".

3.1 Current practices

The term "development process", is illusive, because it gives the impression of a completely ordered linear and logical process that is controlled step by step. Those who have been directly involved in industrial development activities, however, can testify that the development process is often of a very complex and sometimes even chaotic nature. However, the following statement is food for thought: *As a process engineer, you would most certainly be of the opinion that it is impossible to control or improve a technological process that lacks a proper flowsheet. As an analogue to this statement you should ask the question: "How do we control our innovation work processes, and what do their flowsheets look like?"*

Product and process development are both processes that should always begin and end with the customer [14]. However, the customers for these two types of development are different (see Figure 6), as the customer for process development is the internal customer production.

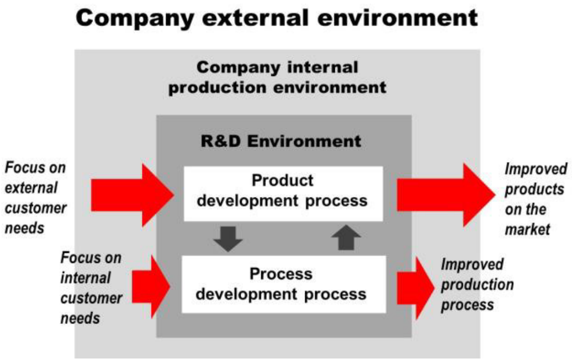

Fig. 6. Formal work processes for product and process development [14].

The Stage Gate advocated by Cooper, sometimes called the Idea-to-Launch Process, must today be regarded as a de-facto standard for a formal product development process. Cooper [15] defines this concept as follows: "A Stage-Gate process is a conceptual and operational map for moving new product projects from idea to launch and beyond – a blueprint for managing the new product development (NPD) process to improve effectiveness and efficiency" (see Figure 7).

Fig. 7. A condensed model of the product innovation work process.

3.2 Future perspectives

In his late review of the Stage-Gate system, Cooper emphasizes the importance of listening to the Voice of the Customer and undertaking a competitive analysis, but also the importance of the fuzzy front-end (pre-development) part of the system [16], which includes ideation, scoping the project, defining the product and building the business case. The Stage Gate system was recently studied in a large sample of users, and it proved to be an instrument that top-performing companies used often and well [17]. Cooper's vision of the next-generation Stage Gate system includes [18]:

- *Adaptable and flexible gates*
- *Fast-track versions of the system for low-risk and minor projects*
- *Overlapping stages*
- *Emphasis on the fuzzy front end*

A traditional model of the process innovation work process usually is a description of consecutive steps of the test work, and going from the laboratory stage to the pilot plant stage is an important step in improving the understanding of a process [14]. The large cost increase associated with pilot plant testing makes the balance between pilot plant testing and laboratory testing an important issue. Following trials in a demonstration plant are often very expensive and are carried out only when the process is of a completely innovative nature. The role of the production plant also as a source of innovation is of great importance; however, using simulation has already replaced test work in some applications and, in many respects, is expected to revolutionise process innovation in the future. Nonetheless, the above presentation of test work is not a proper description of a process innovation work process, since this is only describing the middle development part (see Figure 8). As an analogue to the product development work process, the pre-development and post-development stages must be included. Unfortunately, those stages often are the most difficult parts to manage, and experience tells that post-development activities are underestimated in companies [19,20].

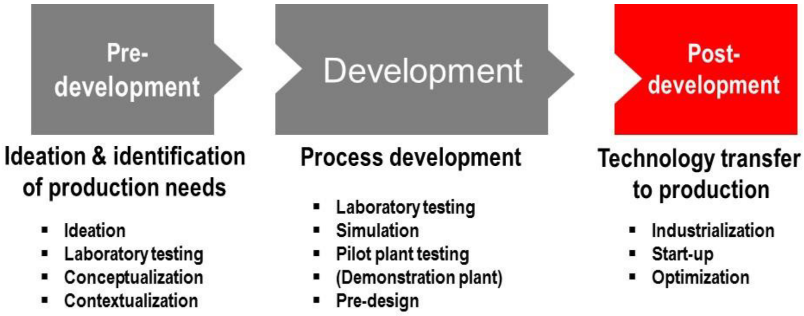

Fig. 8. The process innovation work process [14].

4. Tools and methodologies: Facilitating instruments in innovation

In all industrial undertakings today, it is necessary to use supporting methodologies and tools in order to facilitate and improve the performance and quality of such work. A large number of such methodologies are available, and the question is not really if they should be deployed but rather which, when and how.

4.1 Current practices

Figure 3 illustrated Samsung Research Centre’s use of multiple methodological tools for innovation [5]. The QFD methodology is used as the primary tool for “World Class Goal Setting” for new products in the fuzzy front end. This QFD methodology has become fully integrated into other methodologies like TQM, Design for Six Sigma, and so forth; thus, it is today not a “stand alone” development tool but rather is often combined with supplementary methodologies [21,22,23].

4.2 Future perspectives

However, in the deployment of the QFD methodology, there appears to have been a general misunderstanding about the “cause and effect” of the outcomes [24]. Using a “retrievable and accumulated company knowledge base” coupled with “improved company communication”, you will get “better decision support” assisting in the development of “better product specifications” ending up with “better products” and ultimately leading to “better overall customer satisfaction”. The development of a retrievable and accumulated platform of knowledge for innovation is thus the “hidden gem” of using the QFD methodology. Companies today cannot afford to start from a “clean sheet of paper” if they want to develop products in a reasonable time frame and unlocking the “company tacit knowledgebase for innovation” in the future is a necessity. Starting development activities from such a “knowledge platform” also has the potential to speed up related product development activities. However, in the process industries, the products and related production processes are firmly interlocked, a phenomenon best stated by industry professionals as: “the process is the product” [25]. For this reason, product and process innovation must always go “hand in hand”. Consequently, customer requirements of the product must not only first be translated into design requirements but, more importantly, must afterward also be further progressed into the production system as requirements on process capabilities and on raw-material properties. Using the mpQFD system, specially adapted to process-industrial development, is further illustrated in Figure 9, and how the matrices are used to develop an integrated knowledge platform for further development of related product and process concepts [26].

5. Co-innovation with B2B industrial customers: An application development approach

5.1 Current practices

One kind of innovation activity in the process industries lies in the area of helping business-to-business (B2B) customers to make more effective use of the supplied products and thereby assisting them in improving their processes and products [27]. This area is generally designated “application development” by industry professionals and can be defined as follows: *Application development is not product development but rather the significant development of the customer’s use of the supplying company’s products.*

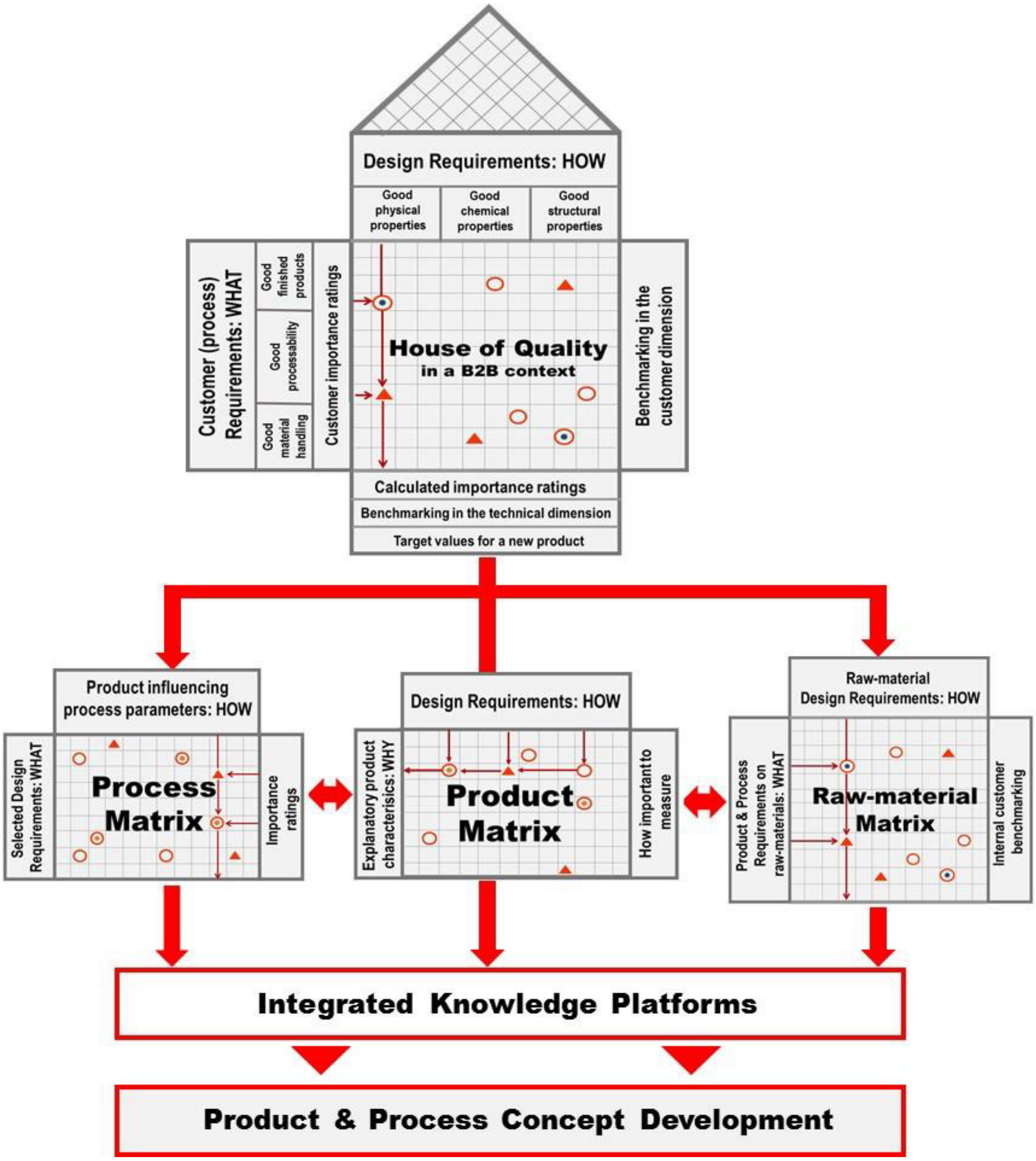

Fig. 9. The mpQFD system as a facilitating tool in product and process innovation. [26].

This kind of development is primarily intended to optimise and to improve the customer's products and/or production system. It is positioned – from the perspective of the application-developing company – at the interface between incremental product development, new business development and marketing. Application development in the process industries has thus far been scarcely researched, but the present author's own industrial experiences confirm that companies in the process industries have long since identified this area of development as one of industrial importance. For this reason, a study was initiated in order to investigate different aspects of application development and in the following, the empirical findings from a survey of major process companies in Sweden, including mineral, forest, steel, and chemical industries, are presented.

5.2 Future perspectives

The first and most obvious target for application development is, naturally, the group of immediate customers in the supply chain, but application development with the customer's equipment suppliers and end-users may be optional activities (see Figure 10).

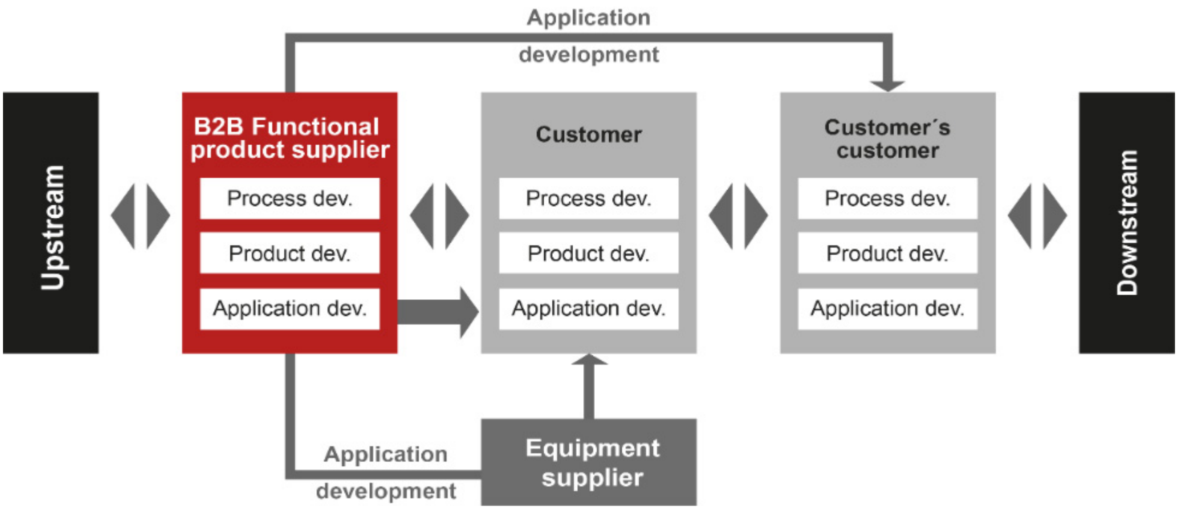

Fig. 10. Application development can be carried out directly with customers, with the customers' customers, with the equipment supplier to the customer or in a collaboration with all actors [28].

The importance of innovation to long-term corporate survival and prosperity is universally acknowledged, and this often extends to both product and process innovation. The area of application development, however, is not yet well recognized. The results from asking the respondents about the importance of this activity in their company showed that application development is an activity of strong importance to most companies in the process industries [28]. There were different motives, or drivers, for companies to engage in application development; of these, the top-ranked driver was *an opportunity to build long-term sustainable customer relationships and secure future product sales (top line growth).* The second-highest-ranked driver was *an opportunity to learn about customer needs and feedback to own product development*, which points out that application development provides important input to other development areas. The customer obtains different outcomes from application development, and the large span between 100% improved customer processes and 80% improved customer products is an interesting point for reflection. Resource allocation to application development with the customers varied between 5% and 100%, with a mean value of 31%, and those resources were mainly allocated to well-known customers and application areas. Since an average of one third of total R&D spending was allocated to application development, it can be concluded that application development was a significant and important area of R&D for most of the companies in this study. An average of 10% of company application development resources were spent on application development with the customers' customers. The majority of all companies in this study carried out application development with the customers' equipment suppliers, which indicates that collaboration between companies in the process industries and equipment suppliers is an important activity and an area of interest for further improvements [29]. This topic is addressed in the following section.

6. Co-innovation with suppliers of raw materials/ingredients

Securing a supply of raw materials for the production process has always been an important concern for companies operating in many sectors of the process industries. Some upstream industries in the process industries have a long tradition of development and use of a captive (corporate-owned) raw material supply base, see Figure 2.

6.1 Current practices

The mineral and metals, petrochemical, and forest industries are examples of industries in which maintaining a strong captive raw material supply base has proven to be a winning strategy. In the mineral industries, for example, the size of the captive raw material base is closely related to both metal prices and the extraction rate (recovery) of individual minerals or metals from each deposit. For this reason, process innovation is not only a tool to improve production economy in those industries but also a tool to improve and/or enlarge the captive raw material supply base [2]. Improved exploration of existing deposits or search for "green field" deposits is the normal way to upgrade the captive raw material supply base. However, such exploration will also often benefit from close internal collaboration and interaction with process innovation in order to find innovative process and extractive technology solutions for improved raw material utilisation.

6.2 Future perspectives

Companies located farther downstream in the material supply chain (see Figure 2) need to secure suppliers of price-competitive raw materials with desired material specifications and "processability". An external collaborative approach in the development of such raw materials is an avenue that has not yet been explored to its full potential. It is thus surprising that higher priority has not yet been assigned by companies in the process industries to securing a price-competitive and high-quality raw material supply base in a long-term perspective, as well as the collaborative development of such raw materials. In other manufacturing industries, such as the automotive industry, an intimate collaborative innovation with component suppliers in the supply chain has long proven to be a successful business strategy [30]. Suppliers taking over the development of improved components and systems is a collaboration model that was born in Japan but now has gained worldwide acceptance. In that perspective, the collaborative development of raw materials with the suppliers can still be regarded as being in its infancy in the process industries. The substitution of recycled materials for other raw materials is also likely to be of ever-increasing importance in the process industries in the future. Virgin raw materials will then be gradually replaced by recycled materials; scrap-based metallurgy, for example, is becoming more important in the steel industry, as are recycled paper products in the forest industries. This trend has also been influenced by external regulations. Further process and product innovation will determine what is to be regarded as a recyclable resource for creating new sources of raw materials in the future. The optimisation of the total raw material supply chain, including an improved functionality of other commodities and reagents for the production process, is also an area with large, but often neglected, economic potential.

7. Co-innovation with suppliers of technology/equipment

7.1 Current practices

As illustrated in Figure 11, the full life-cycle of a piece of equipment can be divided into two distinct stages: innovation of the equipment and operation of the equipment [29]. In the family of process industries, product and process innovation often take place in collaboration with manufacturers of process equipment; however, the question still remains of how such collaboration should be arranged.

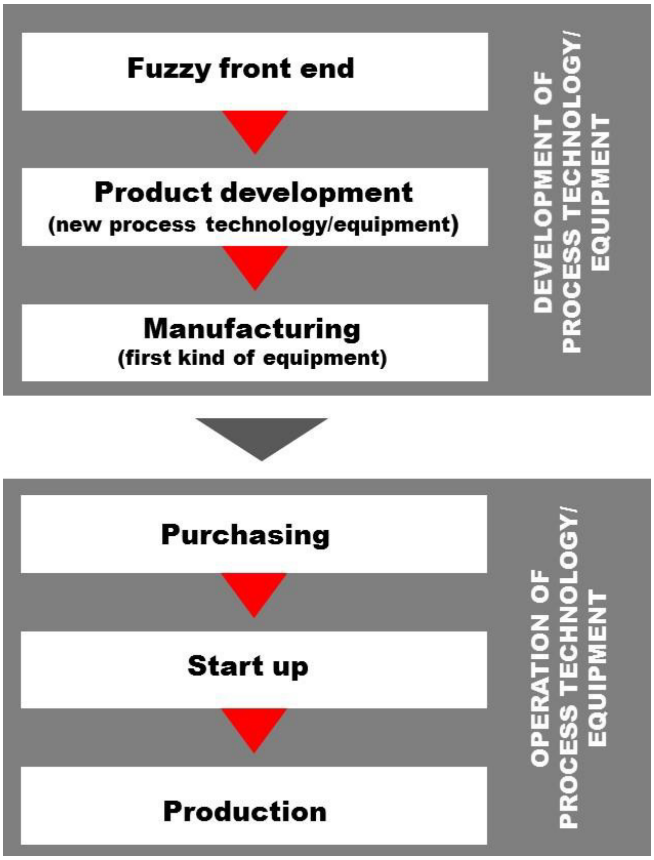

Fig. 11. The technology/equipment life-cycle in the process industries [29].

The driving forces behind collaboration between process companies and technology/equipment suppliers are not always obvious and may vary, because such collaboration involves both advantages and disadvantages for each collaborating partner. Moreover, if there is a motive to start a collaboration, the questions to be addressed are how such activities should be set up and how such commitment should be distributed during a project's lifetime in order to obtain a strong but lean collaboration process.

7.2 Future perspectives

It is initially important to determine whether a collaboration is feasible and, if so, how such a collaboration should be arranged in order to create a "win-win" situation for both parties. The desired effect may be best achieved by a stronger integration of the individual company work-processes and supply chains and improved internal and external collaboration. In a previous study of such collaborations [31], the two most important pros for the process company during the innovation stage were *speeding up the firm's product and process development* and *access to more resources.* For the equipment manufacturer, the two most important pros were *collaborating with a demanding customer often allows the supplier to improve its development capabilities and identify good development targets* and *an opportunity to develop and test prototypes in a real operating process environment setting.* The concept of "open innovation," as a development approach in innovation, may also be seen to have an analogue in production, and it has been suggested to define the concept of "open production" as *the extension of company production activities across formal organizational borders and a collaboration with external suppliers of production resources, technology or equipment* [31]. In Figure 13, such open innovation and open production in a B2B process-industrial context are further illustrated. Open innovation in this context is about integrating a customer or supplier into the process company's innovation process – or, from the other collaborative partner's perspective, integrating the process company into the supplier's or customer's innovation process. In a similar vein, open production in this context is about integrating a customer or supplier into the process company's production process – or, from the other collaborative partner's perspective, integrating the process company into the supplier's or customer's production process. From an "open production" perspective, supply chain integration is already common. However, advanced collaborative production is still in its infancy and appears to be an interesting avenue for further exploration.

8. Conclusions and research outlook

The conclusion to be reached from this study is that there certainly is a need to develop improved or new tools and best practices and to use excellence in management of innovation and technology as a lever for improved R&D and company overall performance. In light of these findings, a closer linkage between innovation management and operations management would be a fruitful avenue to follow in both industry and academia.

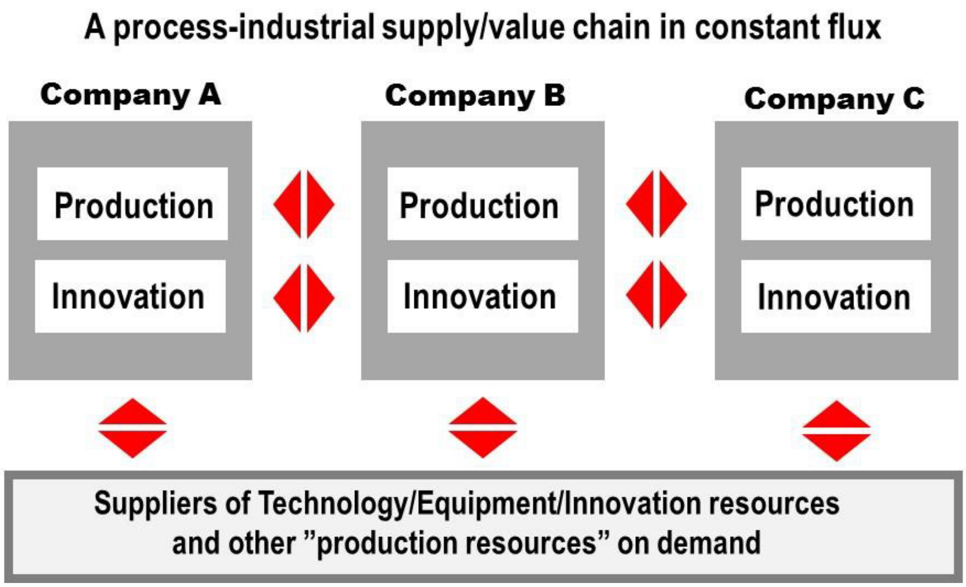

Fig. 12. The collaboration between technology/equipment suppliers and process companies in B2B collaborations [31].

9. References

[1] M. Tottie, T. Lager, QFD–linking the customer to the Pproduct development process as a part of the TQM concept, R&D Mgmt. 25 (2000.) 257-267.
[2] T. Lager, Managing Process Innovation - From Idea Generation to Implementation, vol. 17, Imperial College Press, London, 2010.
[3] T. Lager, S. Blanco, The commodity battle: A product-market perspective on innovation resource allocation in the process industries, Int. J. of Tech. Intelligence and Planning 6 (2010) 128-150.
[4] M. W. Johnson, C. M. Christensen, H. Kagermann, Reinventing your business model, Harvard Bus. Rev. Dec. (2008) 51-59.
[5] S. Park, Y. Gil, How Samsung transformed its corporate R&D center, Res.-Tech. Mgmt. Jul.-Aug. (2006) 24-29.
[6] H. Mintzberg, Crafting strategy, Harvard Bus. Rev. Jul.-Aug. (1987) 66-75.
[7] H. Mintzberg, Structure in Fives: Designing Effective Organizations, Prentice-Hall, Englewood Cliffs, NJ, 1999.

[8] Booz, Allen & Hamilton, New Products Management for the 1980s, 1982.
[9] T. Lager, A structural analysis of process development in process industry: A new classification system for strategic project selection and portfolio balancing, R&D Mgmt 32 (2002) 87-95.
[10] C. M. Christensen, M. E. Raynor, Why hard-nosed executives should care about management theory, Harvard Bus. Rev., Sept. (2003) 67-74.
[11] T. Lager, Product and process development intensity in process industry: A conceptual and empirical analysis of the allocation of company resources for the development of process technology, Int. J. of Innovation Mgmt 4 (2002) 105-130
[12] W. T. Taylor, The principles of scientific management, in: J. M. Shafritz, J. S. Ott (Eds.), Classics of Organization Theory, Earl McPeek, Belmont, CA, 1916, pp. 61-72.
[13] M. Hammer, Reengineering work: Don't automate, obliterate, Harvard Bus. Rev. (1990) 104112.
[14] T. Lager, A new conceptual model for the development of process technology in process industry, Int. J. of Innovation Mgmt. 4 (2000) 319-346.
[15] R. G. Cooper, Perspective: The Stage-Gate Idea-to-Launch Process - Update. What's New, and NextGen Systems, J Prod Innov Manag 2008; 25;213-232
[16] R. G. Cooper, How companies are reinventing their idea-to-launch methodologies, Res.-Tech. Mgmt. Mar.-Apr. (2009) 47-57.
[17] R. G. Cooper, Best Practices in Idea-to-Launch Process and Its Governance, Res.-Tech. Mgmt. March.-April. (2012).
[18] R. G. Cooper, What's next: After Stage Gate, Res.-Tech. Mgmt. Jan.-Feb. (2014).
[19] T. Lager, D. Hallberg, P. Eriksson, Developing a process innovation work process: The LKAB experience, Int. J. of Innovation Mgmt 14 (2010) 285-306.
[20] T. Lager, Startup of new plants and process technology in the process industries: Organizing for an extreme event, J. of Bus. Chem. 9 (2012) 3-18.
[21] Y. Akao (Ed.), Quality Function Deployment: Integrating Customer Requirements into Product Design, Cambridge: Productivity Press, 1990.
[22] Y. Akao, The leading edge in QFD: Past, present and future, Int. J. of Quality & Reliability Mgmt. 20 (2003) 20-35.
[23] S. Mizuno, Y. Akao (Eds.), QFD: The Customer-Driven Approach to Quality Planning and Deployment, Asian Productivity Organization, Tokyo, 1994.
[24] T. Lager, The industrial usability of quality function deployment: A literature review and synthesis on a meta-level, R&D Mgmt. 35 (2005) 409-426.
[25] T. Rousselle (Ed.), R&D Management Conference, Grenoble Ecole de Management, 2012.
[26] T. Lager, Multiple Progression - A proposed New System for the Application of Quality Function Deployment in Process Industry, Int. J. of Innovation Mgmt 9 (2005) 311-341.
[27] T. Lager, P. Storm, Application development in process firms: adding value to customer products and production systems, R&D Mgmt. 43 (2013) 288-3026.
[28] T. Lager, P. Storm, Application development in the process industries, J. of Bus. Chem. 11 (2014) 101-115.
[29] T. Lager, J. Frishammar, Collaborative development of new process technology/equipment in the process industries: In search of enhanced innovation performance, J. of Bus. Chem. 9 (2012) 3-19.
[30] K. B. Clark, T. Fujimoto, Product Development Performance: Strategy, Organization, and Management in the World Auto Industry, Harvard Business School Press, Boston, MA, 1991.
[31] T. Lager, K. Tano, N. Anastasijevic, Open innovation and open production: A case of a technology supplier/user collaboration in the process industries, Int. J. of Innovation Mgmt. 19 (2014).