

## **A NEW CONCEPTUAL MODEL FOR THE DEVELOPMENT OF PROCESS TECHNOLOGY IN PROCESS INDUSTRY**

**A point of departure for the transformation  
of the “process development process” into a formal work process?**

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In an exploratory survey to R&D managers in different sectors of European Process Industry, the importance and present use of a formal work process for process development has been studied. A new conceptual three-phase model for the “process development process”, including the identification of production needs, process development and transfer of results to production, was also tested. The results show that only 44% of the companies in the study presently use a formal work process for process development, but the need for such a process is considered to be high. Good support was given for the new conceptual model as a starting point for further development of a company-specific “process development process”.

*Keywords:* process industry, process technology, process innovation, process development, “process development process”, work process

### **Is There a Need for a Formal Work Process for the Development of Process Technology — and in such a Case, What Should it Look Like?**

Even excellent companies in Process Industry must continually improve their performance. One alternative to achieve a competitive advantage is to use product and process developments to improve the cost efficiency of production processes and the performance of delivered products. Also, companies in mature sectors of Process Industry, such as the steel industry, have proven to benefit from such an innovative strategy (Leonard-Barton, 1992). Process Industries nowadays often try to avoid being simply commodity producers and strive to produce more functional products that offer more benefits to customers with higher profit margins. When products with improved functional properties are introduced on the market, they are usually imitated before long when competitors try to produce the same type of product with the same performance (Linn, 1984). Prices then gradually decline and the functional products degenerate into commodities, which is further illustrated below in Fig. 1.

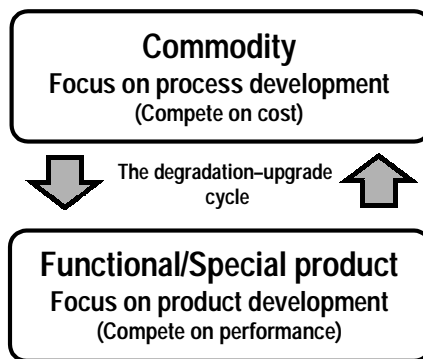


Fig. 1. The arrows illustrate the development cycle for functional and commodity products with different focus for development activities for different types of products.

Commodity products, products traded on the world market mainly competing with price, usually need a focus on process development, while more functional products often benefit from product development (Cobbenhagen *et al.*, 1990). A cost-competitive commodity producer with the desire to produce more functional products will thus need an ability in both product and process developments. Product and process developments, like all other activities in industry, call for continual adaptation to new circumstances and continual improvement (Freeman,

1990). One way to improve the performance of product and process developments might be through a better understanding of the work processes.

In other manufacturing industries, an improved performance in product development has often been achieved with new work processes, commonly referred to as “concurrent engineering”, “simultaneous engineering” or “integrated product development”. These work processes integrate the whole organisation at an early stage in the development process using multifunctional teams with a strong customer focus. In the development of new products at a faster pace and at lower cost, the formalisation of the product development process has often gone far. When Process Industry starts to formalise work processes for product and process development, it is important to learn not only from industrial experience and academic research about the “product development process” in other manufacturing industries, but also to identify the specific needs of the development environment for Process Industry.

Since the development of process technology is going to be one important area in the future (Skinner, 1992), both for commodity producers and producers of more functional products in Process Industry, the use of a more efficient work process could be a road to follow to improve the process development results. *What is the present use of a formal work process for process development in Process Industry and what does/should it look like?* In the following text, a new conceptual three-phase model for the “process development process” is first introduced. Results are presented from an exploratory survey to R&D managers in European Process Industry that includes their present use of a formal work process for process development and their estimated usefulness of the new conceptual model for the “process development process”.

## **Product and Process Development in Process Industry — A Frame of Reference and a Background**

After a definition of three important concepts in this study, a short literature review focusing on the work processes of product and process development is further presented.

### **A frame of reference**

Good definitions facilitate communication and improve the understanding of concepts. Since many different definitions are used in this area, both in industry and in academic research, it is important to explicitly state the definitions that have been chosen to avoid confusion for the respondents and to get a high validity in the research results. The three most important concepts in this study,

“Process Industry”, “process development” and “work process” will thus, first of all, be more clearly defined below.

*Defining Process Industry as part of all manufacturing industries*

The concept “Process Industry” is often used as a denomination of a group of production industries, but often without any specification of what types of industries are being referred to.

The following intentional type of definition of Process Industry characterises this industry in a descriptive manner (the main parts of this definition are published elsewhere but the author has regrettably not been able to relocate the publication).

*“Process Industry is production industry using (raw) materials to manufacture non-assembled products in a production process where the (raw) materials are processed in a production plant where different unit operations often take place in a fluid form and the different processes are connected in a continuous flow.”*

Companies are normally grouped together in clusters of similar types of industries producing similar types of products and often using similar production processes. Using the above definition of Process Industry, clusters of industries have been selected for an operational definition of Process Industry, using the NACE codes for the classification of industries in the European Community (NACE, 1996), defining Process Industry as a subset of all manufacturing industries. Such an operational type of definition, often called extentional definition, gives the possibility to define what type of Process Industry is included in a study, which gives a better opportunity to compare the research results from different projects. Industries, here proposed to be included in the group Process Industry, have been selected from the NACE system and clustered as mining & mineral industry, food & beverage industry, pulp & paper industry, chemical industry, basic metal industry, and other process industries; for further reference, see Appendix A.

*Defining the difference between product development and process development*

Even if product and process developments in Process Industry can sometimes be considered as two sides of the same coin — product development is often process development work in a laboratory or pilot plant — the lack of distinction often creates confusion both in the operational performance of industrial R&D and in academic research.

To distinguish between the two terms, “process development” has, in this study, been defined as *development driven by internal production objectives*. Such objectives may be reduction of production costs, higher production yields, improvement of production volumes, environment-friendly production, etc. In many sectors of Process Industry, process development work is mainly prompted by the needs of production (internal customers). Correspondingly, “product development” has been defined as *development driven by a desire to improve the properties and performance of finished products*, even if the nature of the practical development work is process development in a laboratory. Objectives for product development can be improving product properties, improving product quality (uniformity of composition), environment-friendly products, etc.

A combination of the two activities in a project is possible, but it is important to clarify the two different customers and objectives. A process development project can thus give opportunities for product development, just as the development of new products can be combined with process development and cost reduction in the production process.

### *Defining a formal work process*

There are many descriptions and definitions of the work process concept. In this study, a definition from AT&T (1988) has been selected.

*“A process is the set of interrelated work activities that are characterised by a set of specific inputs and value-added tasks that produce a set of specific outputs.... Processes may consist of a collection of sub-processes.”*

Many activities in industry can be looked upon as work processes. The work process must have both a customer and a supplier, and the existence of feedback loops is further illustrated in the model in Fig. 2.

Melan (1992) characterises four different types of transformations occurring in different types of work processes:

- (i) Physical — Change of state, converting raw or semifinished material, for example, assembling an automobile.
- (ii) Locational — Involving movement of objects or material from one place to another and storage, as in moving and warehousing.
- (iii) Transactional — Involving a value-implied exchange, such as banking or stock brokerage.
- (iv) Informational — Data are the input and the output consists of data converted into meaningful information, e.g. financial reports.

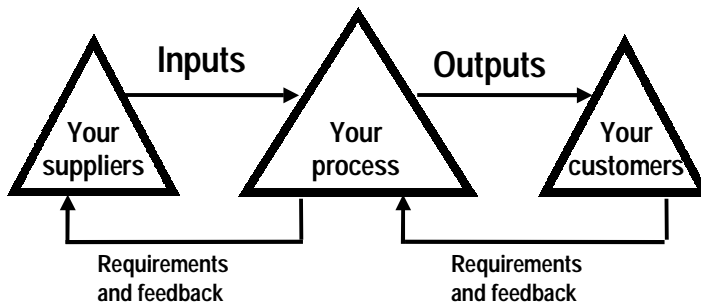


Fig. 2. A model of the work process. From AT&T (1988), *Process Quality Management & Improvement Guidelines*.

Other characteristics of a formal work process are that an “owner” of the process should be recognised and that the process should have clear boundaries, “interfaces”, to connecting work processes.

### A short literature review and background

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 development activities can however testify that the development process is often of a very complex or sometimes even chaotic nature.

In 1974, Utterback presented a simple three-phase model for the development process:

- (i) Generation of an idea, involving synthesis of diverse (usually existing, as opposed to original) information, including information about market and technology.
- (ii) Problem solving, including setting specific technical goals and designing alternative solutions to meet them.
- (iii) Implementation, consisting of manufacturing, engineering, tooling, plant start-up, and market launch required to bring an original solution or invention to its first use or market introduction.

In 1982, Booz, Allen & Hamilton presented a simple linear model of product development, including the steps; idea, preliminary assessment, concept, development, testing, trial and launch. At that time, many companies may not have formalised their product development efforts, a fact that should not *a priori* be confused with the fact that many companies had established routines and knowledge about how to develop new products.

Research in this area by Cooper and Kleinschmidt (1986), and Cooper (1988), gives a picture of both the industrial use of more formal work processes and how the work process could be designed and possibly be improved. Recognising the “product development process” as a number of activities separated by “decision points”, the “Stage Gate” model made the development process more distinct. To improve an *ad hoc* process for product development, it could be necessary to overstress the formality of a new work process to induce an organisation to change. The linear “Stage Gate” model might have served this purpose.

Later research by Cooper (1994) and other research in this area, such as Bower and Keog (1996), Kline (1985) and Schroeder *et al.* (1986) give a more complex picture of the “product development process” and indicate that future work processes must be more flexible and adapted to the individual characteristics of different development projects. This research also tends to take a more sceptical view of the “product development process” as a well-controlled linear process and also of the merits of simultaneous engineering (Hörte, 1992). Descriptive research and case studies sometimes present a picture of a very chaotic development process. This observed fact, however, does not necessarily preclude the possibility that this chaotic process could be made less chaotic and that the output from development processes could be higher if they had had a more formal structure. Cobbenhagen *et al.* (1990) present their views on future development processes in two propositions:

- (i) Innovation management depends on the way in which one is able to deal with inconsistencies.
- (ii) Innovation capability is built up in a learning organisation. Control of innovation processes therefore calls for a shift from formal planning (feed forward) towards an investment in feedback.

Pisano (1997) also recognises the importance and competitive position of the development of process technology. Several models for process development are introduced, recognising the plant as the customer to the process and the importance of letting process development go hand in hand with product development in product development projects. How much structure should the product development process have, and how formalised should the process be? The answer proposed by Norling (1997) is that it depends on the type of project that is going on and the type of organisation the activity is being performed in. Reengineering of R&D work processes can in the future probably be a powerful tool for R&D, see, e.g. Brockhoff *et al.* (1997), Hammer (1990) and Liebeskind (1998). A restructuring and improvement of R&D work processes must however start with a better definition and description of the development processes.

In the above publications, the “product development process” is much in focus. But what about the work process for process development? The work process for process development (development of process technology) has received little attention. *The first research question in this study thus relates to what such a “process development process” looks like or rather should look like?* In the following section, a formulation of the traditional industrial model for process development is first attempted, followed by the development of a new conceptual model for the “process development process”.

## **Two Models of the “Process Development Process” in Process Industry**

From the previous presentation, it can be concluded that there are a number of studies about the “product development process” in the manufacturing industry, but few about the “process development process” in Process Industry. Lacking good models or descriptions of the “process development process” both from the academia and industry, this study started with the development of two such models.

### **A traditional model of the “process development process”**

The following text and model were initially based on the author’s own practical experience with the development of process technology and on fragments from a number of publications and discussions on the subject of development and innovation. The text and the model were then discussed with R&D managers from Process Industry (see later section). In those discussions, it was understood that the concept “process development process” is still much associated with this chain of practical testwork in laboratories and in pilot plants. The discussions resulted in some modifications and refinements of this model, which was denominated the traditional “process development process” and which is a kind of descriptive picture of how practical testwork is carried out in Process Industry. The model includes the following four parts:

#### *Laboratory testing*

Laboratory testing is often considered as the starting point for process development and includes experimental work in the laboratory in batch testing or in more continuous laboratory testing. The main part of the experimental work is often carried out in a laboratory environment because of ease of experimentation and low costs. The laboratory testing part may have different objectives depending

on the character of the development work. Development methodologies can certainly be improved in laboratory testing; one important step is the introduction of methodologies for experimental design and multivariate experimental evaluation as well as other optimisation methodologies.

### *Pilot plant testing*

Going from the laboratory stage to the pilot plant stage is an important step to improve process understanding. The large increase of cost associated with pilot plant testing makes the balance between pilot plant testing and laboratory testwork an important issue. One reason for moving the development process into the pilot plant is to test the full process as a closed system and to determine the influence of circulating loads on the process results. Another reason may be production of test samples in larger quantities for further testing.

### *Trials in a demonstration plant*

Trials in a demonstration plant are often very expensive and are carried out in a major development project when the process is of a completely innovative character and existing pilot plant facilities cannot be used. The primary objective of using a demonstration plant is not as an alternative to the pilot plant, but to run trials that complement previous pilot plant testing. These objectives may be:

- (i) to test wear on the process equipment;
- (ii) to develop process control strategy and systems;
- (iii) to scale up the process to something between the pilot plant and the production plant;
- (iv) to produce larger samples of products for subsequent testing in the customer's process.

### *Production plant tests*

Nowadays, many tests are conducted directly in the production environment, giving fast feedback and reliable test results. To find a correct balance between the goals of fast process development in plant tests and minimum production disturbance is going to be an important issue in the future. Production plant trials may be undertaken to test new equipment, new process conditions, new process configurations, etc. The role of the production plant as a source of innovation is of great importance and it may also serve some other purposes

in the future integrated development work involving the production plant operational crew and the development teams. The use of the production plant for more development activities and improvement work may have future organisational implications and lead to new development models (Leonard-Barton, 1992).

In Fig. 3 below, the above four different steps in process development have been put together, giving some sort of general simplified model of the traditional “process development process”.

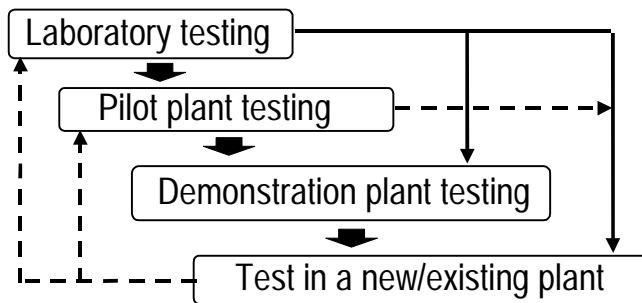


Fig. 3. Process testing in Process Industry. Process development does not necessarily involve all the steps shown nor are they necessarily performed in the order shown. Several iterative loops are common.

Process development sometimes includes only one or two of these steps, sometimes in different order and also with different types of iterative loops. Each development step serves different purposes in the total “process development process”. Short cuts can be taken; laboratory results can, for example, be scaled up and applied directly in the production plant. There are also two fundamentally different cases:

- (i) The process is to be implemented in an existing production environment or existing production plant.
- (ii) The process will be implemented in a completely new plant that must be built before production starts.

Different situations also exist if the new process is to be integrated into an existing production structure or operated as a stand-alone process.

*The above presented traditional “process development process” is however lacking fundamental parts that are often much more emphasised and articulated in the descriptions of the “product development process”.* Compared to the simplified model of the development process presented by Utterback (1974), the first and the second parts are missing since the idea generation phase and the implementation

phase are not explicitly stated. According to the author's practical experience, this is regrettably also often the case in the industrial development of process technology. In the following text, a new conceptual model for the "process development process" has thus been developed, that puts more focus on those missing parts, treating process development not only as practical testwork.

### **A new conceptual model for the "process development process"**

Two assumptions for the development of the new conceptual model for the "process development process" are given below:

- (i) The "process development process" is assumed to be somewhat unique for each company and possibly also for different types of projects. The consequence of this is that the development of a company-specific "process development process" needs a simplified structural model that can be further developed into a more detailed company-specific model.
- (ii) The previously presented traditional model of process development is lacking two important structural phases included in the model presented by Utterback (1974).

The simplified model of the innovation process presented by Utterback (1974), including the three phases, idea generation, problem solving and implementation, was considered a good structural starting point for a new conceptual model of the "process development process". This model can then be further developed in detail and customised by each company in the further development of their specific work processes. The building blocks of those detailed work processes for process development are probably different from the building blocks of the product development process. The "product development process" starts in the first phase with the identification of customer needs and ends with product commercialisation or product launch as the last phase. In the "process development process", we must instead identify "production needs" in the first phase and end up with "the transfer of development results" to the production process as the last phase. This gives the conceptual model presented in Fig. 4.

#### *Phase 1 — Identifying internal production needs*

The idea generation phase focuses on the identification of internal production needs. An analogy to the expression "listening to the voice of the external customer" in product development, is here "listening to the voice of production". This "voice of production" can possibly be developed into the same structural clarity

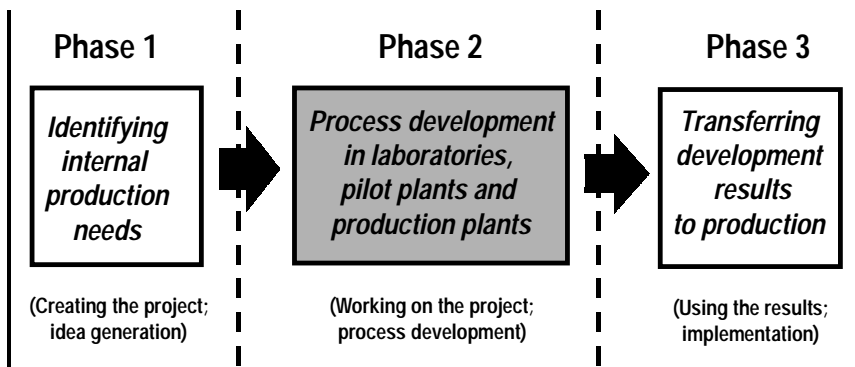


Fig. 4. A new conceptual model for the “process development process”; each phase comprises a number of sub-processes.

as the “voice of the customer” in product development, using proven QFD methodology (Tottie & Lager, 1995). The reason that this phase is often neglected is probably because it is often confused with the experimental sub-process of doing laboratory testing. A way to improve this phase in process development could be more desk research, brainstorming with production staff and workers, discussions with equipment manufacturers and reagent suppliers, structural analysis of the production process, and exploratory laboratory tests.

#### *Phase 2 — Process development work in laboratories, pilot plants and production plants*

This problem solving phase is where actual systematic testing is carried out, comprising all kinds of tests from laboratory experiments through full-scale production plant trials, often including a number of different sub-processes and iterative development loops. *This phase is similar to the previously presented “traditional model” for process development.* As such, this “traditional model” could be used as a starting point for the development of a more detailed company specific model for this phase of the “process development process”.

#### *Phase 3 — Transferring development results to production*

This implementation phase is the transfer of the results from the previous process development phase into the production environment. This phase has possibly also been overlooked or neglected in the past, yet it represents the part of the development process that sometimes makes the difference between success or failure of a process development project. Using cross-functional teams in the

process development phase or active participation of R&D personnel might improve this phase.

## **A Survey to R&D Managers in European Process Industry**

The results presented in this paper are part of a larger research project about the development of process technology in Process Industry. In this project, a survey was carried out among R&D managers in European Process Industry during 1998 and 1999. The survey included a large (eight pages) enquiry concerning different aspects of process development. The results presented in this paper are those concerning the “process development process”.

### **Research strategy and methodology**

*How important is a more formal work process for the development of process technology? What are the characteristics of such a “process development process” and, finally, how useful could the new conceptual model be as a starting point for the further development of such a work process?*

The above research questions were further developed and integrated in an enquiry in a larger survey to R&D managers in European Process Industry. Before the enquiry in the survey was constructed, the traditional model and the new conceptual model were presented and individually discussed with eight R&D managers from companies selected from different sectors of Process Industry in Sweden and Norway, in association with other unstructured interviews regarding other parts of the total research projects. The questions in the enquiry were partly derived from these discussions and partly from the previously presented literature survey.

Encouraging support from the R&D managers in this group prompted further testing of the relevance of the new conceptual model. The first objective with this part of the survey was to find out the industrial importance of having a formal “process development process” and the characteristics of such a process. The second objective was to test the usability of the new conceptual model. The task for the R&D managers was to be the “judges” and to assess the *potential* usefulness of this new model they had not previously seen or used.

The total questionnaire was pilot tested on three R&D managers before they were sent out to 327 Process Industries in Europe with a focus on Swedish Process Industries. The sample for the survey and the further conduct of the

survey are presented in Appendix A. The relevant part of the enquiry is presented in Appendix B.

**Does Process Industry already use a formal work process for process development?**

Since fairly little has been previously published about the “process development process”, it was interesting to find out the respondents’ awareness and attitude to the question: *Do you think it is important that the “process development process” is described more distinctly as a formal “work process” in the company?* The answer to this question is presented in Fig. 5 below. The importance of describing the “process development process” with a formal work process is clear.

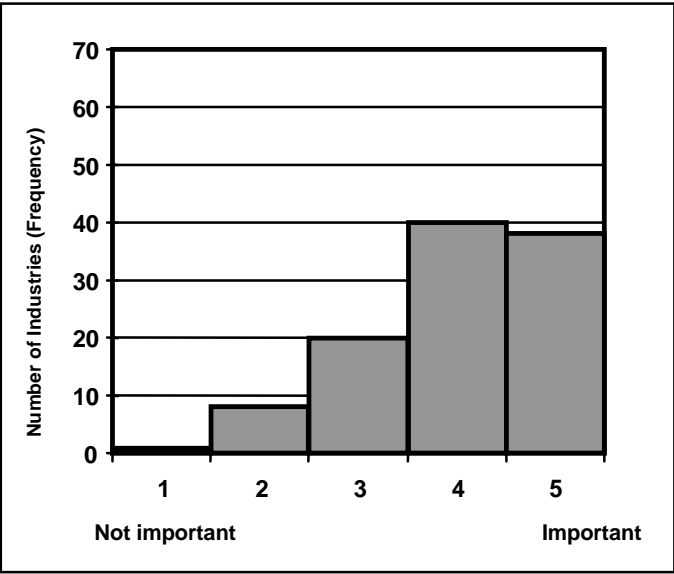


Fig. 5. Answers to the question of whether it is important to describe the “process development process” as a formal work process.

*Does your company recognise process development as a formal “work process”?*

Out of 112 answering companies, 44% already have the “process development process” as a formal work process. It must however be noted that these answers

are of a general nature insofar as they do not tell how much this process is formalised, when it is used, or what it looks like in detail.

### **What are the characteristics of the “process development process”?**

Some questions were asked concerning how the respondents characterised a “process development process”. In one question, it was proposed that the customer for the process development process is an internal customer and that, consequently, the process development process both starts and ends with the internal customer.

The bimodal distribution of the answers, Fig. 6, is influenced to a certain extent by companies included in this study that develop and sell process technology. The development activities they included as process development should have been classified as product development, using the previously stated definition. The preliminary discussions with R&D managers had indicated that process development activities often had longer lead times than product development projects. The answers to the question about lead time for process development presented in Fig. 7 tell us that this is not at all the case.

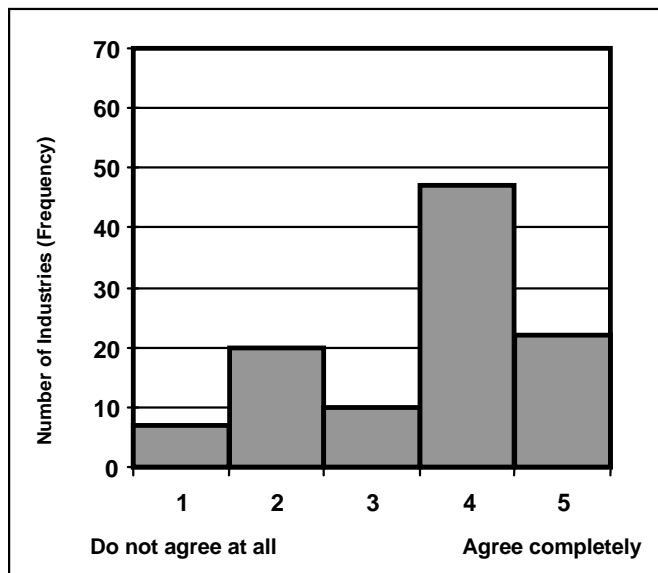


Fig. 6. Answers to the question of whether the customer for the “process development process” is internal.

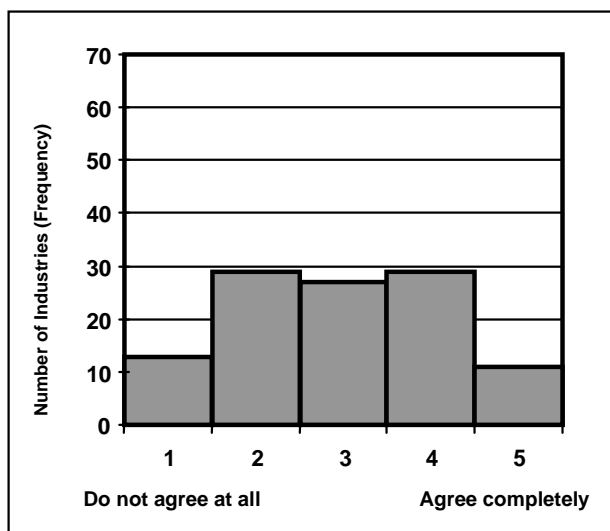


Fig. 7. Answers to the question of whether the time horizon for process development is long (3–8 years) compared to product development projects.

Some respondents agreed but many did not. The question was not very well formulated in that the answer was difficult to give since lead times often differ depending on the type of project (see next question and comments below). Some comments from R&D managers:

- (i) The time horizons depend on different sectorial affiliations in Process Industry.
- (ii) Different lead times for different types of development (0–1 year for optimisation, 2–4 years for development and 3–8 years for radical innovation).
- (iii) Must generally be shorter in the future for process development too.
- (iv) Many kinds of process development can have very short time frames.

*Do you consider that the process for process development differs according to the character and nature of the development projects?*

Referring to the comments above, the answer in Fig. 8 to some extent support the fact that the development process must be adapted to the type of project.

Not only does the lead time for the “process development process” change depending on the type of project, but so might also the total work process. A comment from an R&D manager:

- The more you move towards “breakthrough”-type process innovation, the more you need a formal work process.

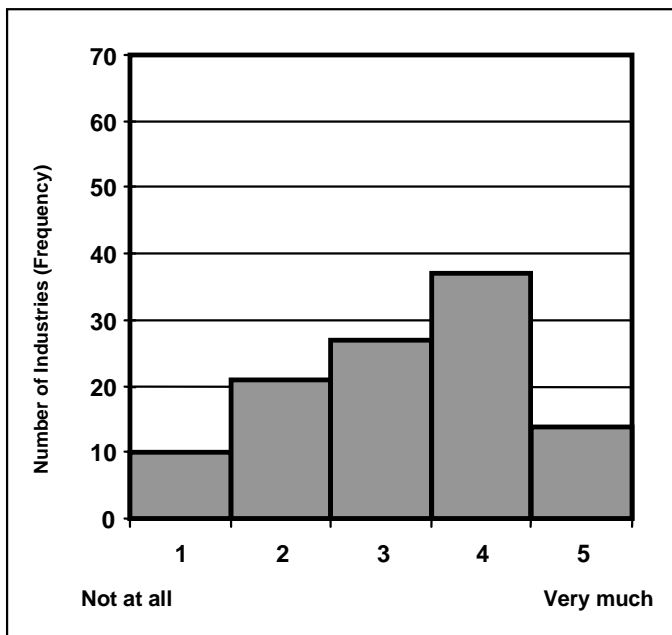


Fig. 8. Answers to the question of whether the “process development process” differs according to the character and nature of the development project.

### How useful is the proposed three-phase conceptual model as a starting point for the development of the “process development process”?

The proposed simplified three-phase model was well received (Fig. 9). The new conceptual three-phase model was presented to the respondent but not the more detailed traditional model.

Some comments from the respondents:

- (i) Different parts have different “weight” and work volume.
- (ii) Important to emphasise that the total process is iterative as a whole and in its parts.
- (iii) The process may have earlier steps and stages as well as afterwards (evaluation of project results, etc.).
- (iv) The decision points between the separate phases should be recognised and highlighted.
- (v) The phases are often not so deterministic.
- (vi) Ideas do not only come from production but also from strategic objectives and other sources of ideas.

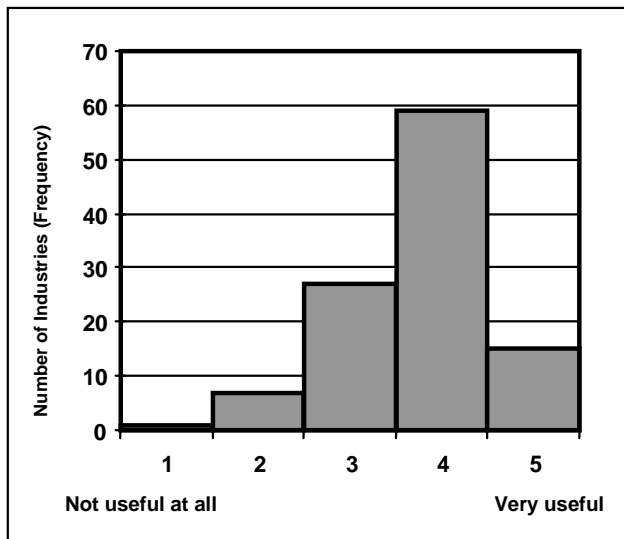


Fig. 9. Answers to the question of whether the proposed three-phase model was useful as a starting point to develop company-specific work processes for process development.

### **Some final general comments from respondents:**

- (i) It must be observed that in the implementation phase, improvement of existing plants must often be carried out while the plant is in production. This makes implementation difficult.
- (ii) Good process development work requires the involvement of many categories of people such as maintenance people, shift workers, etc.
- (iii) Process development projects regrettably do not get as much support and focus as product development projects. Often lower priority. Also, not enough members with an academic background.
- (iv) The economic objectives are easier to recognise in process development compared to product development.
- (v) Implementation sometimes incurs very high costs in new plants.
- (vi) Success rate is higher in process development projects compared to product development projects because of a more flexible final goal (goals can be more or less reached).

## **A Discussion of Research Findings and Implications for Industry and Academic Research**

The results from the survey are further discussed in the following text and the validity and the reliability of the research results are commented upon. The

interaction between the “process development process” and a “product development process” is considered together with implications for industry and academia.

### **The importance and industrial use of a formal work process for process development**

The high ranking of the importance of having a formal “process development process”, together with the fact that only 44% of the respondents already have a formal work process, stress the significance of this area for process development. The figure 44% can be considered rather high since this area has not been discussed or given much attention in previous industrial and academic publications. The answers in this study are however rather summary (the questions about the “process development process” were only one part of the total enquiry) and there are many complementary questions that should be answered to give more dimensions to this area (see section about implications for academic research).

### **The characteristics of the “process development process”**

The question about the customer to the “process development process” could have been differently phrased since, apart from production, there may be some other interested parties in the company. The support for the new conceptual model however gives evidence of production as the most important customer of the results from process development. The answers to the question about lead times in process development indicate that shorter lead times are not necessarily something that distinguish process development from product development! This question could have been complemented with questions about lead times for different types of product development since the respondents indicated in another question that the “process development process” differs for different kinds of projects. A fact that also stresses the importance of a better classification system for process development projects. One respondent stated that the lead time for process development is not short, but has to be shorter!

### **The usability of the new conceptual model**

The potential usefulness of the new conceptual model got strong support in this study which encourages industrial use and a further development and refinement of the model. Since the respondents were not presented with the traditional model, some comments indicate that they might have misunderstood the purpose

of the new conceptual model (a starting point for a further development of a company-specific work process), although they were presented with an accompanying explanatory text.

Interesting general comments were given in the final open-ended question related to the “process development process”. The comment about low priority in the company for process development compared to product development could certainly be interesting to discuss and follow up in companies. Two other comments relate to the objectives of process development. The first points out that the success of process development is easier to measure than in product development. This is obviously so since process development delivers within the company but is a fact that has not been paid enough attention. The other comment is that you can partly succeed in process development! This is an interesting comment that touches the risk/reward question in development and measures a “degree” of success in development projects.

### **The validity and reliability of the research findings**

The construct validity of the research findings are related to how well the questions and the new conceptual model have been understood by the respondents and the respondents’ ability to estimate the potential usefulness of a model they had never tried before in operational R&D. The respondents had not seen the model before but they must, on the other hand, be considered to be very knowledgeable and well acquainted with process development in their positions as directors or managers of R&D, which gives the results an estimated high validity.

Presenting a new conceptual model and asking the respondents to estimate the usability can be regarded as a “leading” question that might influence their answers. However, since the question about the usability of the model is more like an investigation of attitudes and not an opinion poll, and we are more interested in the direction of the attitudes than the absolute truth, this type of leading question can be acceptable (Himmelstrand, 1961).

The reliability of the results are certainly influenced by the respondents’ available time for this enquiry. As this was only a part of an eight-page enquiry and the respondents in their positions as R&D managers often have little time available for this type of activity (some said that they got an enquiry every week), the reliability can be influenced by this. On the other hand, the enquiries were often completed well, with few missing values. Several respondents wrote additional comments in letters indicating that the time spent with the enquiry had not been considered a pointless effort. The results should therefore be considered to be of an indicative quality.

### The “process development process” and the “product development process” — Two separate but interacting work processes

Product and process developments are sometimes looked upon as the same activity in Process Industry. It can be argued that it is not necessary to distinguish the work processes for “product development” and “process development” because product development in Process Industry also partly takes the form of process development work in a laboratory. The strongest argument against that point of view is that both processes start with different customers and end up with different customers. In Fig. 10 below, this is further illustrated.

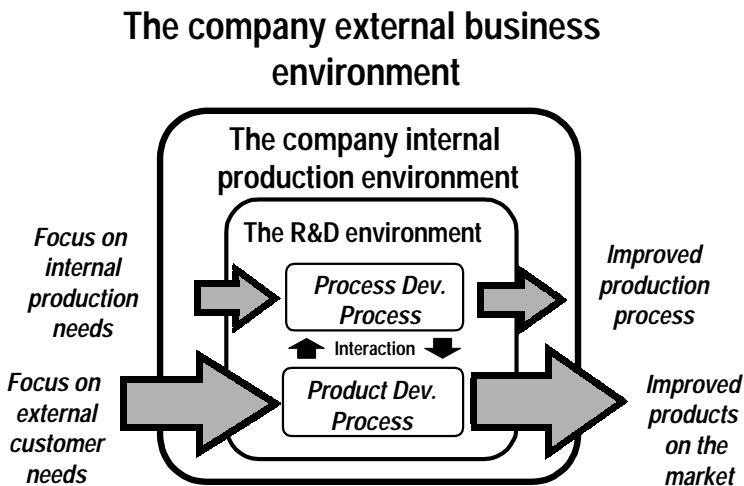


Fig. 10. A simplified model of the interaction between the “product development process” and the “process development process” in Process Industry. The large shaded arrows symbolise that the two processes start with different customers and end up with different customers. The black arrows indicate an interaction between product and process development.

Process development, using the previously presented definition together with the new conceptual model, is very much an internal company affair in the respect that the process starts and ends within the company. There is no need to interact with the “product development process”. Product development and the “product development process” will, on the other hand, include development activities that, to a considerable extent, is of a process development nature. The second phase of the new conceptual model for the “process development process” can at times probably be more or less identical to some parts of a “product development process”.

The importance of an interaction between product and process development has been stressed by Etienne (1981). To achieve this interaction, an interaction between the “product development process” and the “process development process” must be observed. Sometimes, both product and process developments are included in a development project. In that case, the work processes for product and process developments should interact, although the different objectives and customers for the individual and separate work processes should be observed.

### **Implications for industry**

Since a large number of the respondents considered a formal work process for process development an important issue, the development or the improvement of the “process development process” should be high on the agenda for an industrial R&D organisation.

The fact that only 44% of all companies in this study already have such a work process is an indication that the development of such a process in many cases will have to start from scratch. In the development of such a company-specific work process for process development, the presented conceptual model might be a starting point and serve as some sort of a structural framework.

The conceptual model should then be further developed into a more detailed formal work process, using the previously presented definitions and language for work processes (sub-processes, process interface, process owners, etc.). Lessons should also be learned from research about the “product development process” insofar that the work process should probably be flexible and adaptable to different types of process developments and to the company individual characteristics. There are yet many questions to be answered about the “process development process” and some of them possibly with further academic research.

### **Implications for academic research**

This exploratory study has only highlighted the industrial importance of this area and presented a new model which might be a starting point for the further development of the “process development process”. Many important questions need to be answered in this rather under-researched area:

- (i) What are the building blocks in a more detailed “process development process”? How should they be put together and how should the iterative loops between them be designed?
- (ii) How much does the “process development process” differ for *different types* of process developments (from optimisation to the development of breakthrough technology)?

- (iii) How company specific is the “process development process” and how specific is the process for different sectors of Process Industry?
- (iv) How should the “product development process” and the “process development process” interact under different conditions?
- (v) How should effective cross-functional teams for process development be composed?

## **Conclusions**

In an exploratory survey to European Process Industry, the importance of having a formal work process for process development, the characteristics of such a work process and finally, the usability of a new conceptual model for the “process development process” have been studied. The results from this study show that R&D managers consider a formal “process development process” very important, but so far only 44% of the companies participating in the study have such a formal work process. The proposed new conceptual model for the “process development process” received encouraging support, but it certainly takes more evidence to prove that the use of a formal work process will improve the development of process technology in Process Industry.

The results from this study of a fairly large group of different types of Process Industries however give support to formulate the following two hypotheses:

- (i) An effective “process development process” for the development of process technology in Process Industry shall include the following three phases: identification of production needs, process development and technology transfer to production.
- (ii) The use of a formal work process for process development will improve the company’s process development performance.

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## *Appendix A*

### **The Sample and the Survey**

#### **The sample and the sample frame**

The population for this survey can be classed as Process Industry “world-wide”. Since it is difficult to get direct access to R&D organisations, the sample unit is the company. The total sample was 337 companies from European Process Industry focusing on Swedish industry. For economic reasons and due to lack of a good sampling frame, the sample was not a simple random sample but consisted of industries selected according to the following criteria:

**Type of industry:** Process Industries were selected according to the previously presented definition. The types of industries were selected using existing statistical codes for European Industry (NACE). Industries from different sectors have been clustered together: Mining & Mineral Industry (NACE codes 13, 14 & 26); Food & Beverage Industry (NACE code 15); Pulp & Paper Industry (NACE code 21); Chemical Industry — including petrochemical, plastic and rubber but not pharmaceutical (NACE codes 23, 24 & 25); Basic Metal Industry (NACE code 27); Other Process Industries (NACE codes 28, 37, 40, 41 & 24.4, plus some other industries connected to Process Industry).

**Geographical location:** For reasons of convenience, most of the companies were selected from Sweden (easy to get in touch with and get information from). The total Swedish sample is 109 companies. A fairly large number of industries from other Nordic countries were also selected (Norway, Finland and Denmark). Total sample of Nordic countries other than Sweden: 80 companies. From the rest of Europe, we selected a smaller sample of industries (Germany, the United Kingdom, France, the Netherlands, Belgium, Italy, Austria and Switzerland). Total sample of European countries other than Nordic countries: 148.

**Size of Industry:** The firms contacted had at least 200 employees, often more than 500 employees and in many cases much more.

**Innovation intensity:** Some parts of the industry sectors presented above were excluded from the sample because of our estimates that the innovation intensity for this group of industries was too low; thus, meat production and concrete production, for example, were excluded from the survey.

## **The conduct of the survey**

The questionnaire was sent out to R&D managers in the respective companies. All questionnaires were sent to a specific person whom we had identified as the right respondent in the organisation. For practical reasons, the method of conducting the survey in Sweden differed from the one used in the rest of Europe.

The Swedish survey was carried out according to the following scheme: telephone contact with companies, checking the data and confirming participation – mailing the questionnaire – telefax reminder – telephone reminder – new telephone reminder – final telefax reminder. The scheme for the Nordic and the European surveys was: mailing the questionnaire – new mailings after new information (new contact persons or address) – telefax reminder – final telefax reminder.

### ***Response rate***

	<b>Sweden</b>	<b>Other Nordic Countries</b>	<b>Other European Countries</b>
Number contacted	109		
Number of mailings	99	80	148
Number of responses	78	18	16
Response rate	72%	23%	11%

The response rate is very good for Sweden, considering that the total number of respondents including those who declined to participate on the telephone before the mailing are included in the sample. For some sectors, nearly all industries were included in the Swedish sample, making it close to a census for those groups. The response rate dropped dramatically for the rest of the sample because of the different design of the survey.

## ***Appendix B***

### **The Relevant Part of the Enquiry**

#### **The process development process**

We have noticed two individual features which often characterise process development and which, to a certain extent, distinguish it from product development.

- A. The customer for process development is internal, and process development is consequently a process that both starts and ends with the internal customer.

*To what extent do you share this opinion?*

Not at all				Completely
1	2	3	4	5

- B. Process development often has a longer time horizon, often 3-8 years, whereas product development projects seldom last as long as that.

*To what extent do you share this opinion?*

Not at all				Completely
1	2	3	4	5

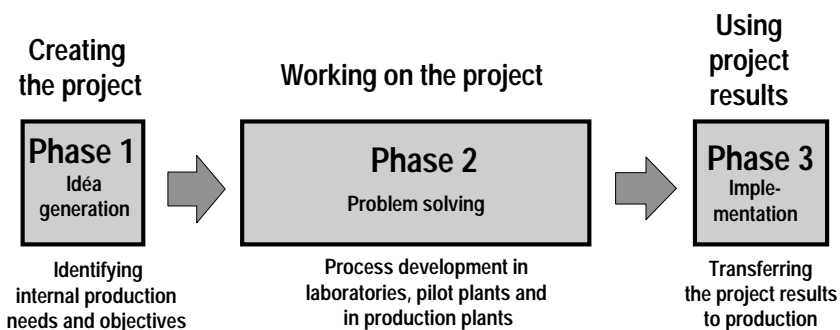
- C. What other individual features do you consider to be specially characteristic of process development?

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We have chosen to illustrate the process for process development with a simplified model comprising three principal phases: idea generation, problem solving and implementation (Utterback, 1974). We further elected to characterise these three phases as (1) identifying internal production needs, (2) process development work, and (3) transfer of project results to production. Each phase includes a number of sub-processes (often of an iterative character) which are not further described in this general model.



*Do you think it is important that the process development process is described more distinctly as a formal "work process" in the company?*

Not important				Important
1	2	3	4	5

<b>Does your company recognise process development as a formal "work process"?</b>	Yes	No
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<b>Do you regard the model presented above as a useful starting point for developing company-specific "work processes" for process development?</b>	Not useful at all	Very useful
	1    2    3	4    5

<b>Do you consider that the process for process development differs according to the character and nature of the development projects?</b> (see previous page)	Not at all	Very much
	1    2    3	4    5

**Do you have any other point of view in this matter or how would you characterise the process development process and its principal phases?**

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