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PRODUCTION DEVELOPMENT AS LEADING DISCIPLINE IN THE DEVELOPMENT PROCESS

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Abstract

For successful competition based on automatic production, it is important to eliminate the limits of this type of production by cooperation between product and production development. In this paper, the issues of leadership in such a process are studied. The work is based on former research on the improvement of the production development and on the discipline's status in the production development process. Several development situations are discussed showing the necessity of production development as leader. Based on characteristics of a concurrent development process, categories for development approaches are identified. Using these categories a matrix is built that can be employed for the identification of a suitable leadership candidate. In most cases this will be production development.

Keywords: Development process, production development, leading discipline, automation

1 Introduction

1.1 Development process

The development process includes all activities from the start of development to the start of commercial production. Different specialists are involved in the development process. Product development, production development, marketing are the most important and cited disciplines [1]. The disciplines are responsible for different tasks inside the development process and contribute with special discipline related knowledge to reach the target.

The traditional sequential development approach, first product development and then production development, has not been able to shorten the development time and reduce the iteration steps as required by the competitive market. Concurrent engineering (CE) with its parallel development approach fulfilled the requirements and entered the development scene, but cooperation between parallel working disciplines was missing. Andreasen and Hein [2] presented integrated product development that followed the parallel working approach with interdisciplinary cooperation and their required organization. Lien [3] pointed out that a parallel working approach with cooperation is important for successful shortening of the development periods. The cooperation between product and production development is important to align both understandings and to support the common goal.

Development is practized in different markets and surroundings, but the development process is still a high risk for small, large, or niche companies and a successful outcome depends on the development work done.

Based on the strong product focus in traditional development, product development has had the leadership in the development process and the other disciplines have followed and tried to realize the suggested products. But the increased importance of a product's quality and price, which relates to the chosen production process, has led to a reduction of product development's dominance and to a strengthening of other disciplines. Today the common interest of all involved development disciplines is to provide a better satisfaction of customer's demands than the competitors.

1.2 Competition in goods producing industry

The competition conditions have changed from local and national to global, where several companies, different in size, organization structure, and strategies, compete for market shares.

Two types of market are identified: a niche market for specialists and an open market. The open market requires less specialized knowledge; because of this more companies compete for customers with nearly identical offers. In the global market companies from different regions of the world compete in the same market but with different home conditions, such as the wage level, production technology, rules, which directly influence the product price. In high-wage regions companies are particularly interested in reducing the wage cost per product to be more competitive. In addition the challenge of shorter development times and the permanent necessity to act or react on market changes increase the pressure on development.

The low-product-price competition requires adjustments of the companies. They have two alternatives to act on market pressure: 1) to move their production location to a low-wage region and proceed as before or 2) to stay and redesign the product and production process for the usage of automatic equipment and to reduce manual work to remain competitive.

1.3 Survey of definitions and terms

Static product concept

The notion static product concept is composed of the terms static and product concept. In general static means 'standing or fixed in one place, characterized by a lack of movement or progression, and producing an effect of response or quiescence' [4]. In engineering design, static means to be stable, a change in condition is not expected. The meaning of product concept varies, from an abstract product formulation to a nearly finished product [5]. The product concept describes the generic idea in early phases of development to create a general picture, i.e. as a principle solution including a functional structure and working principles [6]. A concept is often presented as a verbal description or sketches.

In the 1980s Pugh used the term 'static product concept' for the first time [7,8]. In his opinion, a static product concept has reached a maturity-level, which can be seen as a plateau; changes in the concept plateau phase are not expected. A static concept in Pugh's understanding is based on the use of old solutions, which are approved and are highly reliable, e.g. static product concept of a car [7]. All the basic elements such as body, engine, gear, wheels are still in use. But the technology progress has changed the elements; the concepts have been rearranged, e.g. current car design, material change (Audi A2), or power unit (Toyota Prius). In the case of the car, the static product concept has been in use for over 100 years and will be used further.

In a static product concept not everything is fixed in detail, there is still the opportunity to make rearrangements to keep the product attractive.

Dynamic static product concept

To defend its market share a company has to present 'new' products to the customer. Often the 'new' products are not really new but are based on existing ones, differing only in exterior design and some attributes, using the knowledge and structure of a former product. In terms of Pugh's definition this means that a static product concept is used for the development of a 'new' product.

The improvement of an existing concept converges towards a mature concept – a plateau. A concept can be seen in a total aspect or in its sub-concepts. At sub-concept level not all concepts converge at the same time and to the same maturity level. In the case where the main product concept is static it is possible that some sub-concepts based on the change of boundaries get unfixed and a new process towards a new plateau status begins. This way, the static product concept gets dynamic.

A static product concept that is dynamic seems a contradiction, however, only in the first moment. The static product concept offers a profound basis for a new development process. The goal-oriented work gets eased by knowledge and information available form older concepts. As in control engineering, the identified dynamic concepts are used to adjust the output by feedback, which again adjusts the process towards the desired output. Hence companies are able to offer attractive products to the customer. A dynamic static product concept is not a contradiction but a useful tool which enables a fast response on market changes. It is not possible to give a general definition when a static product concept is dynamic. Each case must be examined individually.

Static product concept, an advantage for production development

A static product concept builds on a mature, existing concept, and knowledge exists about the production process and system, including its strength, weakness, and improvement potentials. For production development, potentials for improvement are given by the collective experience concerning production process and system, and by knowledge about new production technology. These suggestions are made with focus on the production process, e.g. to improve the quality, to ease manufacturing and assembly, and to reduce the production cost. The advantage is that the suggestions for product development are directed towards more promising solutions at early stages. Since it is possible that sub-concepts get unfixed (dynamic) changes in the production process with focus on quality improvement, ease of production, automation, and reduction of production cost can be realized in a static model.

Production systems

In the framework of this paper, the production system has to be considered along with the product concept. The production system comprises several activities and notions. The most important ones are:

Production

In this paper, production describes the change from raw material to the final product. Production is the generic term for parts manufacturing and assembly. Manufacturing denotes the forming of parts to a defined shape. Assembly is the joining of one or more manufactured parts to a larger component or product.

Production system
A production system is the entire system that is used to manufacture and assemble the desired product. The production system realizes the production process by combining operations in the production equipment in a sequence to perform the desired task. Parts emerging from the production system have form, structure, functionality, and properties according to the requirement list.

Production development
Production development is the task of development that leads to a functional and efficient production process and production system enabling production at low cost, with good quality, and sufficient flexibility enough to respond on the market demands.

Production process
The production process is a predefined sequence of manufacturing and assembly operations that an object must pass to get from raw material to the final product.

2 Discussion

2.1 Development process

The development process creates the foundation for a successful outcome for the product and the required and related production process, respectively.

The traditional development process is characterized by its sequential approach with main focus on the product development and less focus on the development of the production process. Right from the beginning the product developer has the certainty that the future parts production will be performed by human workers, who are trained for production work. The product designer has the responsibility to design a functional product where the required parts fit together. It is less important for him to consider the fabrication aspects such as reduction of the amount of production operations or ease of production tasks. The product designer is satisfied if the worker can handle the parts with his hands or by tools. Development tools are used by the designer to improve the product's attributes and to ease production such as DFM and DFA, but further work is not invested to enhance the production performance. The product developer believes that the worker’s knowledge, experience, and intelligence help to perform the tasks as required, even if production related specifications are insufficient. This can lead to unexpected production situations with difficulties. Often the traditional production developer realized the suggestions of the product developer without product improvements, except in cases that require product improvement for realization. Based on the cost calculation for production a large potential for cost savings has been identified that could be used for improvements. Successful improvements in late phases of the development process are not excluded but they are time, work, and cost intensive. Much more efficiency is possible if the improvement aspects are taken into account at earlier stages of the development process. This idea of early cooperation is the essential element of parallel or concurrent development.

The strong market competition has increased the importance of the development process. This requires improvement of efficiency in the development process to develop an attractive and good product as well as good and effective production processes and systems in shorter time.

This can be realized by a parallel development process. Additionally, the development process must implement aspects of automatic production to enable lower production costs. The focus of product development must change from the singular product focus to a focus on products and their abilities for automatic production. It is necessary to take into account that the product's design freedom is limited by automatic production technology. Hence, the product should be designed specifically for automatic production. The full benefit of product development for automation will be obtained if product and production development cooperate and adjust product and production process to enable an optimal automatic production. Production development has to design and develop the needed, effective performing of production operations for use in automatic production modules. Automatic modules have special functionalities, which require an analysis and identification of important characteristics, parameters, and potential failure situations. Based on this, the required performance characteristics must be defined to avoid stops or disturbances of the production process and system in normal production. Further the part's geometry, shape, joining technology, similarity, gripping possibilities, etc. must be evaluated with respect to the used automatic equipment. The goal is the identification of the best available realization alternative based on a complementary relation between product and production process.

Additional aspects such as investment cost for automatic equipment, utilization of equipment, sharing equipment for production of other products, and possibilities for rearrange or reuse of equipment must be discussed and solutions worked out. It is important that during the development process no possible failures due to the production process are overlooked. Failures will stop production and require costly human intervention to restore automatic operations.

2.2 Automation

Manufacturing engineers were very happy with the introduction of automation in the plants because it eased the daily work and simultaneously increased the production rate. At the beginning, single operations have been automated; later automation has been extended to small sequences. The improvement of technologies and the development of new technologies enable the increase of the amount of automatic fabrication equipment continuously. The technology progress enables the realization of more complex functions and sequences up to the full automated production process. In general, the tendency shows that production facilities in high-wage regions have a higher degree of automation than in low-wage regions. The costs of automatic production equipment are the same all over the world but the wage-costs are different. Therefore automation is used in high-wage countries to reduce the production costs and to avoid a move of production facilities into low-cost regions.

Advantages and disadvantages

The implementation of automatic production is important for future production plants. Concerning the total product life cycle the right point of time for the implementation of automation is during the development process. Then adequate and often close to optimal solutions for realization can be found. Therefore the advantages and disadvantages must be identified and integrated into solutions. Automatic production has the following advantages:

- Labour wage cost saving
- Higher production rate saves the investment in parallel production equipment and

labour

- Cycle time reduction
- Performance speed stability
- Consistent and high quality performance (precision)
- No stops due to worker fatigue
- Can run without constant supervision
- Program control for work; if the program is error free, all repetitions are error free
- Modular production automation is reconfigurable
- Performance of several tasks inside the solution space
- High production volume capacity
- Ease of work burden for manual labour

However, also disadvantages can be identified, for example:

- High investment costs of automatic equipment
- Profitable only for long production cycles with few changeovers
- Limited flexibility for performance of different production tasks
- Usage of automatic equipment is limited to the environment for which it is developed
- Need special auxiliary equipment to perform a specific production task
- Performance of production tasks must be planned in detail
- More development work needed to avoid production problems or disturbances
- Automation sets limits for the operation realization of objects / products
- Full utilization only if product and production process are adapted to each other
- Production problems or stop require help of experts
- Loss of jobs

Even if there are arguments against automation, the reduction of production costs and the increasing of production efficiency by use of automation can help a company to survive in competition. For the evaluation of automation's advantages or disadvantages it is necessary to focus on the development process and the following commercial production.

Compared to development for manual production the development for automatic production requires more analysis work to identify characteristics for the evaluation of suitable solutions. The additional work does not increase the development time. Because of the required analysis work the needed time for the early development phase is larger. The results of the analysis work save development work and time in later phases, which represent the largest part of the development process. Additionally the detailed analysis leads to a higher utilization rate in the final production. The use of automation in production results in products with better quality, less failures, and lower production cost, which are of interest for the customers.

Combine product variance and automation

Identical products, and production processes and systems would be the optimal condition for automation. No variance may be an extreme interpretation of identical products, which give the customers no opportunity to choose between variants. This is in conflict with the customers' demand for individual choice of the best suited product.

Product variance is the force that turns production from large to small series, including a reduction of production volume per variant. Small series production is conflicting with the advantages of automation. These advantages can only be retained if the elements of high volume production are transferred into flexible production systems. The demand of product variance and the advantage of automatic production can be combined if both product, and production process and system are structured for variance. The product variance can be secured by the use of interchangeable modules. They enable the generation of individual variants in a common product structure, which is identical for all products inside the same product group. A replacement of parts is possible because standardized interfaces and fixations are used. The identical product structure has a big advantage for production because an identical production process structure can be used to produce the parts. The use of standardized interfaces and fixations for variant creation (comparable to platforms and modules) enables the use of a common production process. For the variant creation the individual specialized production stations are added when needed. The identical production process enables the use of an automatic flexible, preferably agile production system, which provides high production volume with good quality, and short throughput time at low costs.

A prerequisite for the use of an identical production process is that the strategy of identical product and production process structure has been developed during the development process. This will be supported by a static product concept. But realization limits exist due to the production technology, and the production process and system. To take advantage of automation, the production process and its structure should be used as guiding principles for the product development.

2.3 Aspects of automation in production

Originally, automation in production as introduced by Whitney had the goal to ease the production work, to enhance the production and product quality, and to increase the production rate. Later a fourth aspect of reduction of costs became important. From that time on, automation was the topic of new solutions for development.

Development of automation in production has different focus areas, such as the performance of the required production operations, the part's requirements for handling, the needed automatic equipment, and the organization of production operation around the automatic equipment.

At first the required operation performance and the sequence of operations must be identified before the development of the required automatic production operations can start. In contrast to the production performance by humans, the operations for automation must be analysed in detail to identify important data for the detailed development. This includes the identification of important parameters for the needed operation performance, such as forces, pressure, friction, temperature. The operation performance itself is related to the equipment that is used. Therefore the required equipment must be specified and the market checked for needed equipment. If no equipment is available, the development of the needed equipment must be initiated. Often the required manufacturing stations for parts manufacturing are available in the market and can be configured as needed, e.g. for plastic injection or for turning lathe. Today the knowledge of automated manufacturing is good. More problems connected with the object handling before and after automated manufacturing operations are known. In automatic production not only the manufacturing of parts is of importance. Concerning the goals of reduction of production costs and quality improvement, operations such as handling, transport, and assembly of parts are important. For such operations, the replacement of humans by automatic equipment is desirable. The transport and handling of products does not enhance the product value. Often the transport and handling time is larger than the net performance time of production. The goal is the reduction of non-productive time to a minimum by use of automated equipment for the work performance.

Human fingers and hands can flexibly handle parts that can be distinguished in form, shape, geometry, and other properties. In contrast to the human's flexibility, automatic handling equipment, such as a gripper has a limited application space. A range of individual pieces of automatic equipment is required to balance this disadvantage. Individual automatic equipment is expensive. The same holds for additional storage space close to the operation place and for the time for required equipment changeovers. Therefore the handling equipment and the parts to be handled must be designed together under development to improve and ease production, and to save costs and time. It is desirable to use one unit of handling equipment to perform various operations. Even more important than the (undefined) handling of parts is the knowledge about the orientation of the part, the required production position, and the place for pick & place. Today most handling equipment exists in the form of standardized modules with a limited application range. A prerequisite for handling of different parts with one gripper is the part's design which must enable the handling. Further it is necessary that the operation can be carried out securely in the available time frame in a stable production process. Therefore the parts should be designed to comply with the specific application limits of the handling equipment. Poor ability to position and orientate products will lead to frequent stops in production and need for manual assistance for trouble shooting. A high number of automatic handling operations raise the importance for error-free operation performance in production. In assembly in particular is the organization around the production equipment important. This affects mainly the feeding of parts and their orientation. Interrupts in the production due to lack of parts or wrong orientation of parts are undesirable and must be avoided.

Fixation equipment is also important for automatic production. Fixations are used for secure positioning of objects during the operations. In the case of mass production of one product only one unit of fixation equipment is required at each station or machine. Are different parts produced on the same machinery, usually different fixations are required and often a manual set-up time is implemented before the production of a new product can start. Fixation set-up is time and labour intensive and leads to long undesired stops in production. If the set-up is performed incorrectly, all operations performed with the incorrect placed fixation lead to scrap of the parts and the output rate of 'good' objects reduces. The stop-time for changeovers lowers the utilization of automatic production systems. Hence for automatic production it is desired to increase the utilization and to reduce stops or changeover times. A possibility to avoid this is to use a form-identical basic element – a platform – for building product variants. For all the variants this platform is the standard. The same fixture can be used for all variants and no stop for changeover is necessary. With respect to the production of variants, it is necessary to ensure that all variants can use the same platform and that the part or module variants can be fed to the right place and at the right time in the production line. In cases where it is not possible to use platforms, a more flexible fixture is required, which avoids fixation changeovers for variant production. This, however, increases the complexity and cost of the fixation system but enhances the utilization rate.

Modular equipment enables the use of specialized modular elements from the market to combine them for the performance of an operation. Compared to the former available solution space of separate modules it is possible to extend the solution space. With focus on production equipment the combination of gripper and vision system enables the identification of parts and their handling without additional equipment. The combined system can save the investment in a complex, part specific feeding system. Mechanical orientation and sorting of parts is replaced by modern vision systems that can recognize parts by the help of identification software. The recognition is not only restricted to part's form. It is also possible to identify the size and to use this information for sorting and further production operations.

These examples have shown that several obstacles must be overcome for the development of automatic production processes and systems to create a good and reliable production system. A successful accomplishment is only possible if product and production development work close together. The goal is not only to have an optimal part with the fanciest design (except for expensive low volume products), the goal is to have the best part produced at the lowest production costs. This can be realized by adapting requirements to ease production into the product design without changing the product's attractiveness.

2.4 Utilization of automatic production

There is a noticeable increase in fully automated production systems in industry in high-wage countries. The advantages and abilities of automatic production enable the fabrication of products at higher volumes than by a manual, human dominated production system in the same time. Therefore higher production volumes are available. The market demand develops independent from the available production volume, which ideally should be capable to deliver the needed quantities at any time. In contrast to the increased production volume, the customer wishes have changed towards expanded product variant ranges with lower production volume per variant. Product variance relating to specialized automatic production equipment can mean low production volume and high percentage of production downtime. The high investment costs for automatic production equipment and the low utilization can make production unprofitable; in unfortunate cases the product's sales price must be increased noticeable above the targeted price. This may result in a change of the product's attractiveness for the desired customer group. A reorganization of production is then necessary to become profitable and be attractive for the target group. Still, the use of automatic equipment and its advantages of production are desired to reach the profitable area. The goal is to get a higher utilization of production, which is attainable by use of the same automatic production equipment for the fabrication of different products or product variants. Shared production equipment means less needed equipment, less investment in production equipment, and the share of costs can be distributed on a larger product quantity.

In order to increase the utilization of production equipment it is necessary to analyze various influencing factors and to adapt them:

- Sharing of production equipment with other products or variants

  The product and the needed production process must have an identical structure. Therefore a similar product structure is required with a similar basic sequence of production operations.

- Limited flexibility of the automatic production system

  Automatic production systems are built up of modules. The modules are chosen to optimally perform the special task or operation. Changeovers in the production system due to new products are limited in flexibility based on the single modules' solution space. Therefore the available flexibility range of the production system must be designed into the system under development. This includes the definition of deviations due to flexibility.

- Implementation of future improvements and changes in the production system

  The development of the production process and system is performed based on the current specifications. However, often improvements or changes are desired and required during the commercial usage, but are unknown at the time of development. Therefore obstacles for possible changes should be analysed such that later changes and improvements are realizable.

- Utilization planning for an automatic production system

  The utilization must be planned during the development process. Therefore various information should be known such as estimated production volume, estimated time for fabrication, desired order times, market behaviour and cycle. Based on this information, the sharing of production equipment can be planned and possible sharing scenarios worked out. Important is to examine the maximum available production volume which should be not exceeded. Relevant hints for expected utilization may be found in the long-term policy for product and production. Finally, based on the available and examined information the needed production system and its utilization can be defined.

- Changeover between production of several products.

  The goal is to shorten the changeover time and operations to a minimum and concurrently maintain the high potential of up-time in production. Changeovers can be performed in different ways. Manually performed changeovers are time intensive because a hardware set-up is required with the assistance of workers. Instead of hardware changeovers the application of software changeovers is of advantage because less manual work and less time is required. Not every time it is possible to reduce of changeovers to a minimum but this should be an objective during development.

High investment costs for automatic production equipment imply a good utilization concept and a careful evaluation of the planned investments. In cases where the sharing of automatic equipment enables high utilization and save of investment costs it is important to take into consideration product design and production process. Small product design changes can simplify the production process and save expensive investments. An identical production process with focus on production sharing requires an identical product structure. Therefore the products to be produced must be aligned according to a common foundation for the production system's use. A change in product structure towards more similarity under the development process is much more efficient than recurring changeovers to start a new production order. Close contacts between production development and the production department ensure a good overview of the production development team over the designed and available utilization of the production processes and systems. Based on this knowledge they can make suggestions to the product development resulting in a better adaptation of product and product structure to production.

2.5 Leadership

As shown in the discussion above, product development and production development are central disciplines in a development process and their rivalry is known. Often this rivalry has two effects: The will to win over the competitor or the impulse to be better. For the development process the first rivalry effect is not acceptable but the second is desired. Then input based on rivalry may yield new solutions. Often the identified solutions enable the realization of things that seemed to be impossible before.

Today in a concurrent development process approach a balance between the involved disciplines is desired to avoid the total dominance of one; exceptions for single cases are assumed. Balance means here that the involved disciplines have equal rights such as to formulate ideas, make suggestions for improvements, be involved in evaluation. Besides the promoting aspects of balance there are disadvantages. The development progress could be hindered because the involved disciplines are more or less occupied with monitoring their situation concerning the balance situation or level. This slows down the progress and increases the inefficiency of work. To avoid this and to secure a goal-oriented development progression, the nomination of a leadership is required.

Leadership can be seen in several contexts which are relevant for the development process. For the further discussion, leadership is split up in an administrative and a paradigmatic part. The administrative part focuses on for example availability of sufficient engineering capacity and the required development equipment, checking the milestones and gateways, meeting the budget constraints. This part has a supporting and organizing function but does not directly operate with solutions and the available solution space. The paradigmatic part focuses on e.g. the development idea, the solution space for realization, the available knowledge, the limitations and requirements, the evaluation of suggestions, the impulse motivation for changes or improvements. This allows a strong influence of paradigmatic leadership on the results of the development process. Leadership, especially paradigmatic leadership, is misunderstood if it is interpreted as a blind following of non-leaders. An important task of paradigmatic leadership is the boosting of the development process. To strengthen the development project, the leadership should be chosen with focus on the main development interests and where the most relevant knowledge for the desired solution is concentrated.

Today's comprehension of leadership tends to a strong leadership by a person. In the context of development, leadership is seen with regard to a task which is important for the development process and which is represented by a discipline. However, leadership by a leading discipline should not signify that the discipline's meanings or suggestions shall dominate the output.

In the past, the paradigmatic leadership of the product development discipline has been an unwritten rule in development. Since the upgrade or improvement development took over the majority of development projects and more and more products are based on a static product concept is it necessary to discuss the 'unchallenged' leadership of product development.

2.6 Leadership matrix

The conclusion of the previous chapter is that the leadership should be overtaken by that discipline which can contribute most based on its knowledge about the desired development goals. These goals may be quite different, and several types of approaches to attain them are conceivable. In order to find the suitable type of approach, an individual goal identification is needed.

Still it is assumed that product and production development are the main disciplines involved in the development process. Therefore at least two different approaches are possible. As demonstrated, the development process passes different stages. It is structured into four phases – need identification, concept development, detailed development, and realization. Each phase is characterized clearly with respect to the development tasks that must be performed. The development phases can be entered at various stages. Depending on the point of entering, a set of inputs and guidelines must be known and followed. The later the development process is entered, the more is defined with regard to the solution space and goal, and less possibilities for changes exist. The development phases serve as a perfect framework for a categorization of types of development approaches. This categorization can be based on the different tasks performed in the single phases.

It is important that the development process categories use a general description which is more holistic, on an abstract level and not focused on a specific situation. The four categories described below should be used for the identification of the development approach relevant for the aimed development project.

<u>New:</u>
The meaning of new is 'to start with nothing' and can be characterized as a white sheet starting position. New requirement and aim definitions for the development project are specified based on knowledge and experience, ideas, company and project strategy constraints, and other inputs. During the further development process, characterized by concept, detailed development, and realization, the product and production system are worked out. The final solution is based on combining new or existing functional principles. Never before something existed in the same configuration.
The notion of a new product means that the found configuration did not exist before, for example a new vertical take-off plane, the Hawker P.1127.

<u>Upgrade:</u>
This means a refreshment of a former or older existing object. The output of an upgrade development process differs from the starting position; it is raised to a higher grade or level. The development process is characterized by full concentration on the aims of upgrade and their implementation into the existing basis. This includes concept and detailed development, and realization. Often these upgrades base on the implementation of a more advanced technology level. An upgrade is part of the development work a company carries out to refresh the product spectrum and production facility to maintain the distance to competitors. In general the market launch of upgraded products is supported by enlarged marketing actions, e.g. advertising.
An example for upgrade is the market for digital cameras where the digital-optical technology is exchanged each time a higher level is achieved, e.g. Canon IXUS series.

<u>Improvement:</u>
This means making a change in something existent. In the case of improvement the development process is limited with regard to detailed development and realization. The change has a more obligatory character, for example to improve errors that were made under design and development. The improvement is used to defend the market position by increasing the attractiveness for the customer or by improving the economical situation.
Often the improvement is a form of part redesign and change in the production process and technology to ease manufacturing and assembly, or the replacement of labour by machines. These will help to lower the production cost and to raise the profit or to lower the product price to increase the attractiveness for the customer. In contrast to upgrades, which are often introduced by means of advertising, improvements are often not introduced this way.

<u>Current:</u>

This means to keep the status quo and to proceed with the current solution without entering real development. The current basis of the object has different operations available that can be used for the creation of product variations by adding or exchanging components or modules. The task is restricted to take available solutions, to integrate and realize them with regard to the aims in consensus with the existing basis.
This case is concrete for products which are built of platforms and modules.

The four categories can be applied individually to the development disciplines. Due to the free combination possibilities of the disciplines many different alternatives are imaginable. Focusing on the two most important disciplines product and production development, 16 alternatives are feasible which are shown in Figure 1. The dark fields in the upper left and lower right corners represent less realistic alternatives and will not be considered further. The other alternatives are named.

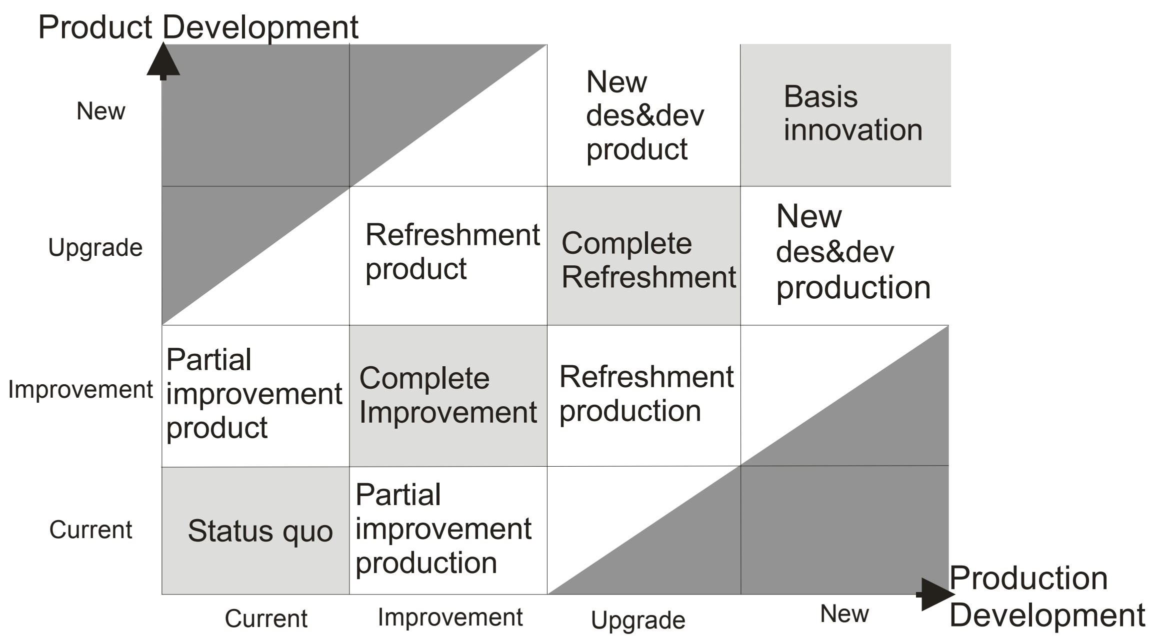

Figure1: Categorization of development approaches

Each field is an intersection of two categories of product or production development aspects. In order to find the candidate most suitable for a leadership of the development process, the priority of the involved categories must be identified. A category's priority is determined by its period of involvement in the development process, where the category New has highest priority, followed by Upgrade, Improvement, and Current. The diagonal of the matrix is a neutral belt containing intersection alternatives of similar categories and therefore with the same priority. The solution of the leadership question for these alternatives must be found in a special, separated evolution process. The alternatives besides the diagonal are intersections of categories with unequal priorities. In these cases, the disciplines have individual interests according to their goal contribution to the development project. The longer a discipline is involved in the development project the higher is its importance concerning the solution contribution. This priority can be used for an identification of the suitable leadership for the development process. As a consequence, the leadership must be taken over by the discipline with the highest prioritized category for the identified intersection in the matrix. Consider the product-production matrix with product development presented on the ordinate and production development on the abscissa as depicted in Figure 1. Here the leadership will be taken over by product development for all intersection alternatives above the diagonal. If production development takes over as leading discipline, the intersection alternatives must be located below the diagonal in the product-productions matrix, see Figure 2.

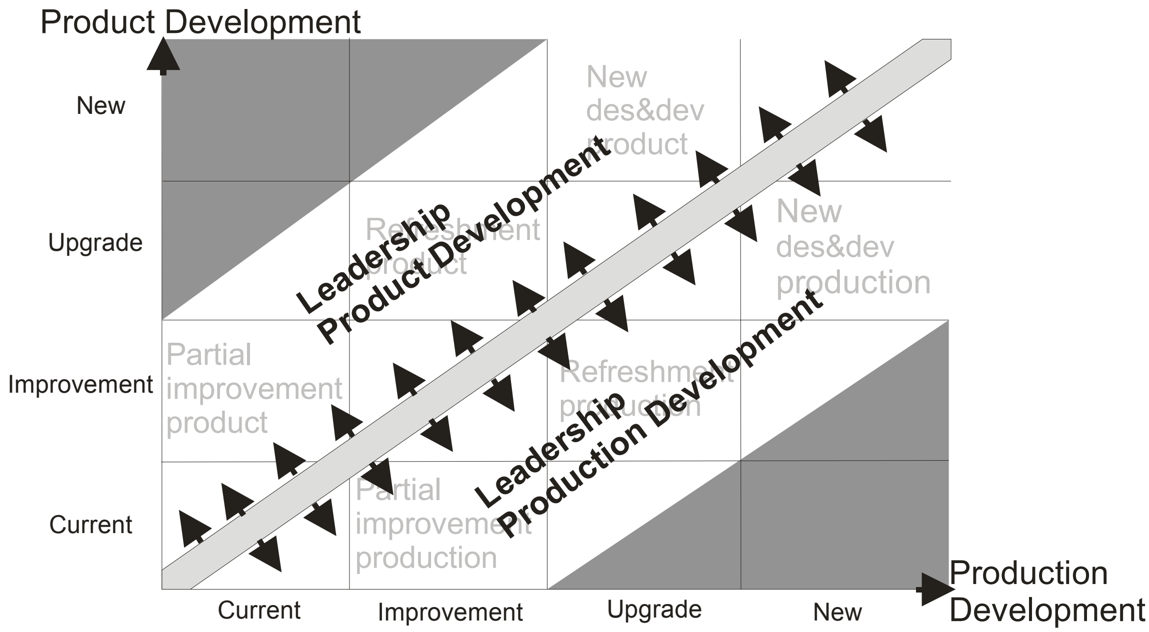

Figure 2: Leadership matrix

Typically, most of the development approaches can be classified as Improvement or Upgrade. In both situations an existing product is the starting point, which is comparable to a static product concept. Often in this type of development the decrease of the production costs is important. This can be reached by automation. However, automation represents also a limiting factor to the solution space. An unrestricted improvement of the product by enhancing its variety is not possible. Therefore it is important to take into account this limitation when identifying the most suitable leader. Due to the dominant production interest the leadership should be taken over by production development.

3 Conclusion

The authors point out that the efficiency of the development process should be improved. Besides of a product's attractiveness, quality and sales price are important in order to compete with other products. These attributes are linked to the production. Although advanced production technology is available, still limits for the fabrication of products exist. To handle such limits, a good cooperation between product and production development is required. With respect to automatic production, its advantages can be used only if product and production process and system are aligned. Ideally this should happen at early stages of the development process. Based on the importance of economical production requirements it is necessary to focus on that during the development process. This requires that the development process is led from an expert on this field. By analysing development problems concerning the use of automation, four categories of development approaches have been identified, New, Upgrade, Improvement, and Current. These categories can be used to identify the required development work for a discipline to accomplish the objectives. A direct comparison of the priorities of the category identified for each discipline helps to find the discipline which is most suitable for the leadership in the development work. In some cases, the leading discipline in the development process should be taken over by production development.

This type of approach is new and the authors showed its relevance. It is for example of interest for industries in high-wage regions in order to improve their competitiveness by use of automation rather than to move to low-wage regions. Further research is necessary in order to analyze this approach more thoroughly. The categories shall be specified in more detail, and a clear methodology has to be developed.

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