Paradigmatic Options for Future Production

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1 BASICS OF APPEARING PARADIGMS

The evolution during the last years in the fields of production sciences and production company practice has brought major changes /28/. It became painfully felt in many places that formerly successful actions, methods and strategies have no longer been suitable to produce good results. These action models can be outlined as follows:

- technologically orientated basic strategies,
- premise of the decreasing return on the product investments (life-cycle thinking),
- labor division organization principles and structures, orientated towards repetitive task fulfillment with mechanistic processes.

Rethinking processes and restructuring activities began in many places caused by unsatisfactory or even existence threatening results. After a phase of incremental improvements the sum of the single solutions developed to a coherent outline which showed as a common feature an integrated viewpoint of the relations in production and market. Connected with that are the enlargement of view by non technical dimensions (in particular the social dimension) and the concentration on analysis and design of processes.
As a consequence better approaches of producing originated which overcame the classical technical view. One basic thinking model is replaced by another which partially overthrows rules and regularity or even leads to contradictions. The point is a basic paradigm change. That means that the thinking model which is the background of the rationality of producing is changing fundamentally. Such paradigm changes occurred often in history of science (mechanics ? quantum mechanics, geocentric ? heliocentric world view etc.). They bring so strong modifications to the affected sciences that the term "scientific revolution" is widely accepted in general discourse. It is often to observe that the validity of the former predominant rationality is redefined or appears as an enlargement of the new viewpoint (classical mechanics is only valid for not macro- and not microscopic fields or fields of low speed).
This paper attempts to describe such a ("revolutionized") superstructure for the production sciences in its fundamentals, that means to find new principles and platforms.

1.1 Problems with the prevailing paradigm

In order to collect some key issues of the prevailing rationality in production sciences first single facts will be discussed which are typical for present thinking.
First the phenomenon of technology constantly being added to the products should be mentioned. This is partially not even wished by the market and complicates the use of the products /25/. The intention was to increase the prices due to the wider range of functions. The basic view that leads to this effect is a result of the extrapolation of formerly successful actions on the basis of standard strategies /26/ ,/33/, /40/.
So far, recognized and asked by the customer were new technical products and functional performance. In the past every producer could be sure that an additional technical complement or innovation for known and proven products would increase the demand. Where this mechanism was not only practiced intuitively but systematically, concepts for model politics of "proportioned technology increase" were developed in order to decrease demand for lower developed products (cannibalism effect) not to early.
Technology-orientated standard strategies which are to be encountered especially in Germany represent only one of many kinds to deal with the "law of the decreasing profit of products". The background is the assumption of products constantly loosing value from the day of their first sale. This asset value shrinkage has to be compensated by the utilization of effects of the learning curve and therefore by rationalization. If competitors appear on the market, the market will be saturated relatively fast, further loss of value of the

product is sped up. The conceptual background of this point of view can be visualized by the model of the life-cycle, which is based on the implicit assumption of constantly reducing benefit and value of the single product /2/. Nowadays it is getting clear that life-cycle thinking has its limits.

All structural decisions were made against the fact of this rationalization commandment which is derived from the law of decreasing profit. All efforts were made with regard to the description, determination and documentation of functions. The usage of more flexible functions which are available within shorter times, together with the request for speed and flexibility of the turbulent task environment, became a basic request. But this basic request which seems to be easy to realize was not possible to fulfil without radical structural changes in many production companies. Numerous tools and concepts for structuring and reengineering were generated which were - although sometimes very comprehensively – without an organizational framework /1/, /8/, /30/.

Immediately the demand for optimization and knowledge increase got clear in order to ensure the adaptability of the processes as well as the further developments and improvements of the products.

Especially the production technologies which are still indispensable for the evolution of the human society were influenced within the last decades:

?? by the introduction of numeric and computer-controlled tooling machines and machining centers at the beginning of the 70’s which pushed productivity and quality

?? by the strategic concept of a continuously computer-integrated factory (CIM) in the 80’s which included the integration of the computer in all fields of the product development-, -planning and -generation process and within the material flow to and from manufacturing cells and systems

The flexibility and the automation of production was to be pushed forward in this way in marvelous visionary dimensions.

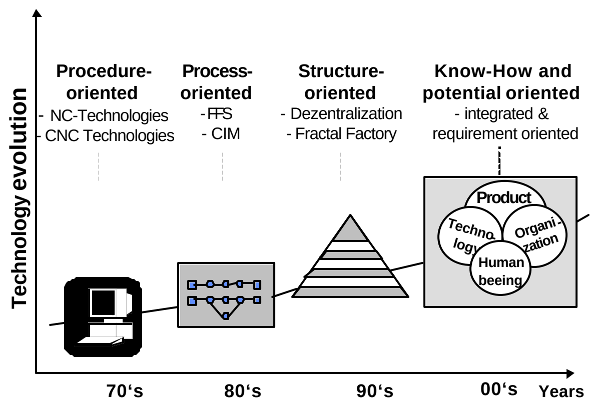


Fig. 1: History of the technology development

Past experience has proven that these concepts were only put in action partly because of the impossibility to handle the demanded level of complexity and automation by man. Also the predominant hierarchical organizational structures were only insufficiently able to support the concept /20/.

That is why a structure-oriented approach started in the 90’th. The guiding idea was a "leaning" enterprise by clear and decentralized structures. /5/. Its emphasis was set on the renewal of companies culture, organization and management. The main result was that human creativity and innovation was given high decision competence /4/. Efforts for computer integration and production automation were newly adapted to the abilities of humans. These efforts did not contradict this structure-oriented concept. However, the rationalization potentials were mainly determined by the organization. Today, these potentials are exhausted giving reasons to think about paradigms of the production of the 21st Century.

The new approach can be characterized as knowledge- and potential-oriented. Central Point is the product which meets customers demands. Fast development, generation and return into the circuit ensure the compatibility of human being, organization and technology /23/.

1.2 Paradigm change

As shown in the introduction, there is a series of phenomena in production sciences which cannot be classified into proven and known explanation models. Production sciences therefore are confronted with wide spread enlargement of their effected field. Simultaneously the validity domain of the known systems is shrinking. Considerable reorientation as well as re-definition of basics seem to be necessary. The so far well proven theories have to be understood as special cases with only limited validity. The way science in crisis takes, as shown by Kuhn /15/, appears most promising. The point of this approach is that in the case that results of experiments cannot be explained with theory any more, it causes a state of crisis. This crisis is not solvable with instruments of the paradigm. The conventional platform becomes attacked by the following critical driver factors (see figure 2).

These driver factors can be very different, but all of them have the common feature that certain phenomena are no longer in line with theory. These are set ups which indicate an extended frame. Expected result of these implementation propositions is the ability to explain the phenomena currently outside of the ability of the old paradigms theory using this new frame. However, the new approach will encounter resistances due to the fact that it is not easy to let one frame of reference go for another.

2. solution quantities as well as solution potentials for existing (or arising) so far unsolved problems are included,

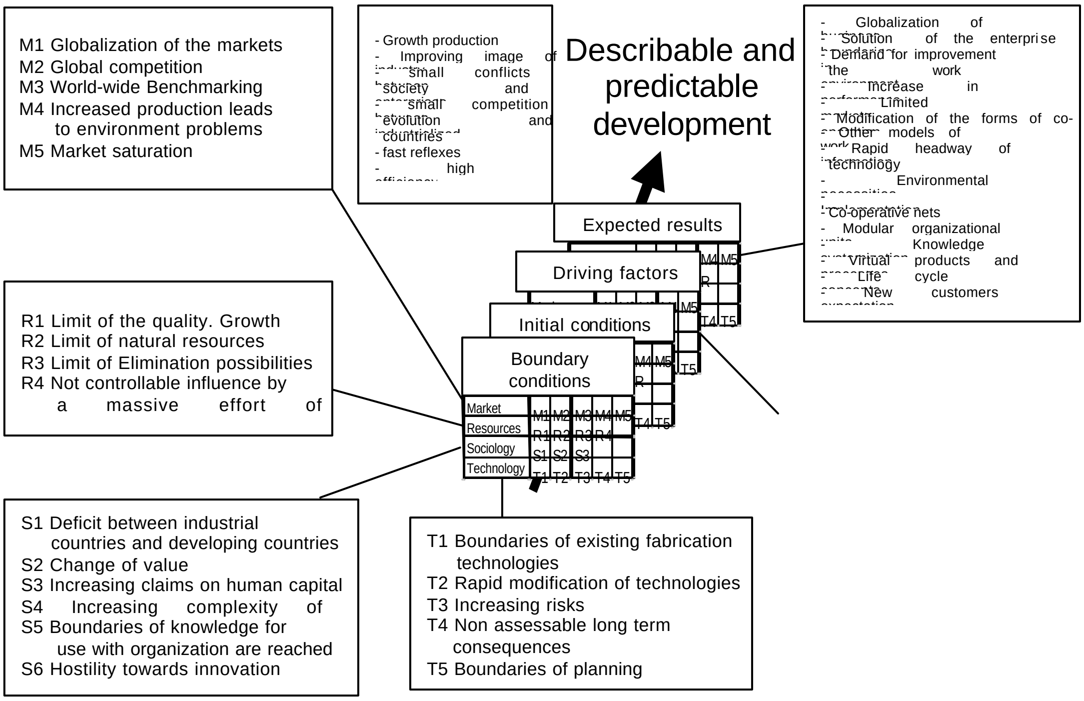


Fig. 2: Combination of initial and boundary conditions to critical

1.3 Basics of new paradigms

Apart from the fulfillment of the expectations described in the previous paragraph, which are to be understood as short and medium-termed, wider dimensions are to be covered. A "set of rules" which is to concrete is inadequate for being the pole for such a basic attitude. At longer term descriptions must cover wide projections and suggestions of outlines on abstract fields.

Principles for the formulation of new thinking models and super ordinate visions and aims should be linking as well as differentiating.

Each paradigm regards the world as from different constituents assembled. (Questions about the planet masses were fundamentally for Newton and heretical for Aristotle / Some events, which can be described in the context of quantum physics, presuppose uncertainty (Heisenberg) for which Newton had no place.) In each case the basic requirement for an appearing new scientific paradigm is an increasing number of scientists and practical men of the "Scientific community" who follow these basic aspects. This is to be expected if

1. all important driving factors are categorized and the appropriate driving forces work strongly evolutionarily (not contradiction-evoking) and foster development,

3. no explanation difficulties for the new (inexplicable) phenomena exist in the new paradigm.

Following this principle first leads to irrefutable postulates of the integration which are influenced by the requirements:

?? integration of different thinking approaches and

principles for the organization of the production

?? integration in the meaning of the removal of alleged contradictions:

- Inflexible Organizations
- Conventional production systems
- New technical solutions are available
- Maturity of the population exceeds requirements of work
- Bad productivity

?? production vs. service

?? physical vs. mental work

?? acting vs. Thinking

?? economy vs. Ecology

?? we vs. the others

The inclusion of multiple aspects, not only of the object itself, but also its multiple-layered reference framework with the most important interactions is required. This assumes an open view concerning the framework as well as variable, dynamic structure principles. Less specifications and rules but rather improvisation, creativity and communication as well as the shaping forces. The development of potentials and re-configurability move into the focus of success yardsticks due to the development of own forces for the connection with markets, partners, social forces and the continuous new finding of suitable organizational solutions for the structure /21/, /22/.

For the creation of thinking models - in particular also for the derivation of organizational suggestions and practical solutions - it is often appropriate to mark out a reference framework which was only a shadowy projection before and to enrich it by specification of some basic ideas. In particular this is valid also for the attempt to outline a future production paradigm (anticipative or projective).

It is impossible to keep prepared the requirements of information, communication and knowledge requirements for all possible situations and constellations. It must be left to the employees in which ways they procure which information, how they analyze and edit these for decisions. Information technology and state of training of the workers are more than sufficient to handle this conception of the pull-principle for information /31/.

Personal responsibilities of teams, combined with the immense efficiency of the information technology, enable new management ways with the goal of efficient products/processes. In particular the availability of topical, near-to-time process information makes classical reports and statements unnecessary. An optimal function is ensured, if all substantial information are requirement-referred accessible by each worker and can be individually analyzed, edited and developed further to specific knowledge.

2 PREFERED OPTIONS TO PURSUE - GUIDELINES FOR A NEW PARADIGM

2.1 The re-configurable production system

At the end of the 80's and at the beginning of the 90's German products passed through a partly dramatic degradation of sales abroad. One main reason for that is the internal cost-structure of many German enterprises, which effect the prices for the products on the international markets.

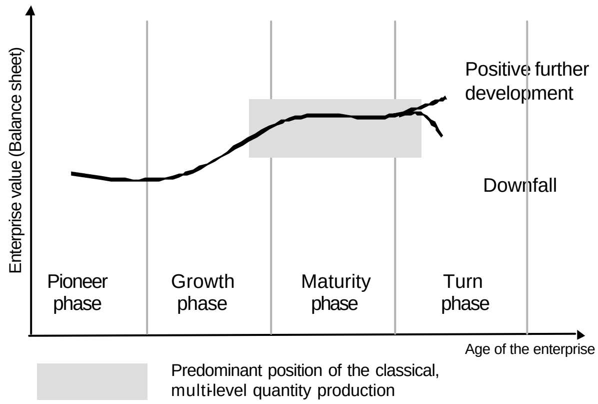


Fig. 3: Evolution alternatives of production systems

If unexpected recessions in sales occur, then the management of the production system is in demand to initiate preventive actions for the enterprise. The success of these actions determines the further development of the production system (figure 3).

In the context of the sketched requirements, which are also called a "turbulent enterprise environment", the institute does its work about re-configurable production systems.

Re-configurability contains the fast detecting and using of new market tendencies and of the chances which result from them. Material flow, production methods and systems, organization as well as the information and knowledge systems of the enterprise have to adapt as soon as possible to these new tendencies. Management of decentralized structures thus not only means the unique planning of products and processes for long periods and the attempt to react by optimal operation of the existing production system to the changes in market and technology but rather active and constant change /17/, /19/, /22/.

If change is to be enabled, the requirement of an equal coexistence of chaos and order exists. In case of order being dominant the system becomes rigid, which implies an inability of adaptation to modifications. Here a total loss must be expected in the predictable future in case that the environmental conditions turn worse. In case of a dominant chaos, anarchy or disorder without either structure nor regulations grow. The more pronouncedly the requirement for change becomes, the more necessary becomes constructive handling of the component causing the modification - the chaos. Modern systems are subject to a constant adaptability requirement, whereby those systems are successful that are characterized by the ability to transform chaos impulses into risk calculations. In this way the chaos becomes rationally accessible and usable in a positive way for the system.

For a scientific analysis of the chaos a paradigm change in the natural sciences is necessary. The reorientation

leads away from the preferred research direction of classical physics for linear and reversible correlation. Dividing systems into its elementary constituents for the purpose of exact calculation and forecast of the system development can no longer be assumed as a scientific research ideal (compare with the abandoning of the ideal of "factory without human beings"). They are replaced by the approaches of chaos research basing on non-linearity and irreversibility /7/, /36/.
In the context of these considerations it is remarkable that descriptiveness of production systems does not have to be pursued in highest detail by the items contained in them. Rather the pursued targets and the resulting variables determine the level of detail of the description. In practice it is noticeable that especially the large regulation within the freedom of work (or activities) is diametrically opposed to self-control effects.

2.2 The virtual factory, the virtual factory network

Almost all products that are presently offered to the consumer at the market, presuppose the fact that their production process already exists physically and is established. This binds substantial resources in the design-phase of production systems (in the simplest case it concerns a creation of a value chain with only a few process steps) without a guarantee for the acceptance of the developed products by the customer. So the sales have to cover costs of the development of products and production. Beyond that today single enterprises develop products at own risk. Not all enterprises - in particular not small and medium size enterprises - are in a position which allows to balance out delayed returns of sales of a product line with returns of other divisions (e.g. the Daimler Chrysler company with the lines SMART and A-Class).
Alternative to these methodologies is the concept of the virtual factory network. This is used by single enterprises as an inter-enterprise instrument for additional flexibility in order to secure existing business and to enable a low-risk entrance into new application fields. Market chances with a small "strategic window " can be opened by efficient and fast bundling of core competencies of independent enterprises. The independence of the individual enterprise remains protected /13/, /14/, /38/.
Experiences with co-operation show that a successful flexible co-operation between enterprises requires a long-term preparation /9/, /10/, /27/. Similar to internal hybrid organizations the basic concept of the virtual factory covers therefore a stable (longer term) and a dynamic (short term) component. The stable component is called “co-operation network” (this corresponds to the relations potential), the dynamic component is called “activated network” (or order-specific virtual factory). The system virtual factory acts in form of a dynamic network /41/.
Legally or economically independent enterprises or divisions unite to a stable "co-operation network", in order to create the prerequisites for fast and efficient co-operation. Here co-operation rules, roles and functions, instruments and above all the mutual confidence as basis of success are built up /29/.
On the basis of these prerequisites highly flexible co-operations between prepared partner enterprises can be entered: a dynamic element develops, the "activated network" or order-specific virtual factory. If the performance fields of the associated members are described in a sufficient way and the status of available capacities of these performance fields is known then the performance required by the market can be generated within shortest time. Obligations in advance which bind capital and know-how are less than for a single company /11/, /39/.
Approaches for the transfer of the fundamental ideas of virtual enterprises into practice - the producing industry speaks of virtual factories – are so far only in the beginning. Both the enterprises and science are opening the field of the virtual factory as a new model for inter-enterprise co-operation /34/, /23/, /37/. The organizational implementation of the virtual factory occurs in the tension field between work sharing and co-ordination of the value chains. The total removal of this tension field is impossible. Inside the virtual factory different performances (within a multiple-level value chain) of independent enterprises (high work division) are connected to generate an individual customer use (the co-ordination/integration requirement essentially depends on the product).
From these boundary conditions three requirements for the arrangement of the blocks of a virtual factory can be derived:

?? First of all it must be guaranteed that all enterprises bring excellent competencies into the co-operation network
?? Secondly the ability of all enterprises to co-operate must be secured in order to be able to connect these competencies fast and efficiently to a co-operation
?? Thirdly the partner enterprises must have the willingness to co-operate to be able to activate virtual factories by purposeful actions /38/.

In a virtual factory enterprises are united, which are specialized in different fields of the value chain. Within its field an enterprise must have excellent competencies, it has to be better than comparable competitors. The success of an activated network depends on the possibility to link specialists synergistically in the meaning of "best of everything". Therefore the

competencies of each enterprise are to be developed continuously /3/.
In order to make the required "Ad-hoc"-co-operations possible the ability to co-operate between all enterprises of the virtual factory must be ensured. This ability is to be structured and improved constantly on the level of the co-operation network and within the partner enterprises.

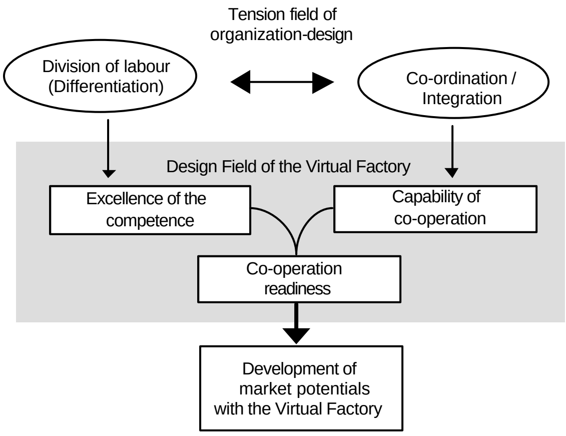


Fig. 4: Mode of operation of virtual factories

Three substantial steps for the common access to the market are necessary:

- ?? Orientation of the co-operation potential on attractive potentials. Existing or latent market chances "at the edge of way" can promptly be identified; the strategic flexibility of the individual partner enterprise is extended.
- ?? Bundling of selected competencies to a performance and their positioning in the market
- ?? Additional proactive development of business chances. Particularly the success of this step depends on the will of all partners to arrange and to act. This requires the power of the acting persons and a new pioneer spirit in order to overcome initial difficulties.

This means for the production science to concentrate consequently on the arrangement of virtual factories (figure 4), on the care and active organization of co-operation processes. The meanwhile success-promising approach of virtual production is to be added to the so far rather linear view of the enterprise. The number of pre-works for this is sufficient /6/.

2.3 Eco design

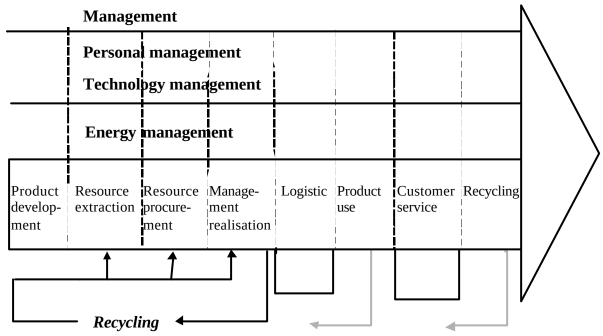


Fig. 5: The integration of re-processes into the factory of the future

Companies' ecological goals concern the use of resources during the production process, the avoidance of waste and the application of pollution free technologies. Emissions, water pollution and waste depend on technologies. Because of this a positive influence on ecological targets can be attained primarily by the advancement of production technologies. This contains also the finding of organizational structures which support the production processes in a way that leads to a guarantee for the environmental compatibility of production. From the viewpoint of the production science this means to arrange the value chains (which are the basis of structures and organizations) within the planning of factories in such a way that allows the re-integration for example of recycling processes (figure 5).
Another question is about the conception of supply logistics under the aspect of re-integration from presently externally running process steps. With this view production science steps over the borderline "sale and use of the product" and researches the phase of the product recycling processing and the further use of component parts. This opens an inter-disciplinary research field which gets substantial impulses from the co-operation of technologies of construction, manufacturing and production. However, condition for the creation of production systems which are ready for re-integration is an extended planning horizon of all partners and the removal of the up to now valid borderline "product distribution".

2.3.1 Renewable raw materials

Ten per cent of the organic raw materials used annually by the German chemical industry are renewable raw materials. In addition almost 2 million tons of renewable raw materials are processed annually. These facts prove that the use of renewable raw materials is not insignificant. Apart from the for years constantly increasing share of these materials an increasing public sensitizing for the topic can be noticed /18/. First

applications for the use of renewable raw materials already showed up in the 70's. At that time the technical product parameters for the use dominated the selection of the raw material. An example for this is the linoleum production (e.g. for floor covering).
Today the production of plastics and packing materials, from materials which are categorized to be "made of renewable raw materials", has a renaissance. Reasons for that are a high number of positive material research results which result last but not least from a number of public promoted material developments and use analysis. By the example of the rapidly progressing developments of product/materials from renewable raw materials (figure 6) it can be clarified that in a foreseeable time horizon completely new materials and technologies can be expected. This brings naturally also new requirements for workability and becomes a challenge for the knowledge management in construction and production /24/.
An indicator for such new challenges for the production science are e.g. the process chains in the production of microchips or fiber-optic cables which take place under clean room conditions and thus define new requirements for all elements of the production process. So e.g. new materials in connection with new innovative technologies cause revolutionary modifications when they enter existing production systems. This will for example take place when the “cold burn" with gas cells will come into automotive engineering and into decentralized energy production of house building.

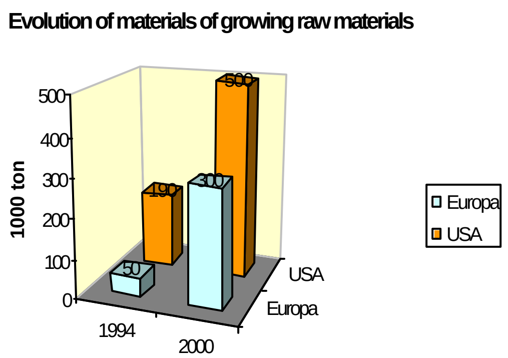


Fig. 6: Evolution of materials of growing raw materials

These are positive contributions not only for the solution of environmental problems. Rather they result in new challenges for the production science: To deal with new materials as well as with the technical and personnel production conditions in such a way that a fast transfer of the research advance into the practice and thus into the series can be realized by intelligent production systems.

Because of the fact that a wide application of renewable raw materials will take place only if their prices are comparable with those of synthetic products the present developments in this field direct at making these products competitive (apart from the further improvement of their principle material properties). But at the moment pioneer enterprises that deal with the processing of renewable raw materials still have to overcome high market entrance barriers in Germany.

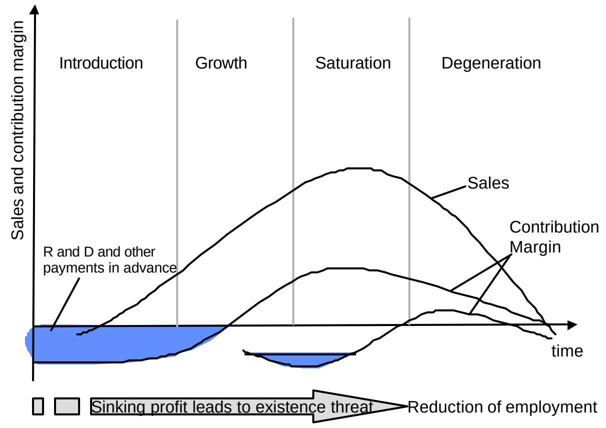
2.3.2 Cycle economics

The inclusion of environmental and recycling-orientated targets which played so far a rather subordinated role flows more and more into the process of the factory operation. In future this trend will continue. For this there are various reasons like the risen environmental awareness, the increasing resources scarceness, and last but not least the constantly aggravating legal editions. Due to this enterprises are forced to consider the factor environment more.
In particular the concrete requirements which result from the legal conditions show the need for action in industrial enterprises. The cycle economic and waste law forces the industrial enterprises to act by the aggravation of the product responsibility and the obligation to create waste concepts and waste balances.
The participation of commercial enterprises in the common system for environmental management and environmental audit as well as the introduction of environmental management systems are regulated by German and European regulations and still are voluntary. But perceptively they will develop to a competition factor similar to the quality certification according to DIN ISO 9000. Large-scale enterprises already react noticeably to these requirements which leads directly to consequences for all potential suppliers /32/.

2.4 Modified life cycle

The industrial production process and the design of production structures usually follow products or product spectra, which are to be created by the production systems. But the constantly shortening product life cycles in combination with an almost inflationary integration of technologies into products lead to higher expenses for research and development. In case of smallest deviations in the planned output, the financial return from product lines then falls below the break-even point.
Decreasing contribution margins (see figure 7) are only one of the possible consequences that can lead finally to existence threats for the enterprise. The possibility to create new products in an advanced phase of the product life cycle of individual products (by additional functions or changed usability) so that the developing

costs are substantially reduced is one possibility to use already acquired knowledge in the best way.



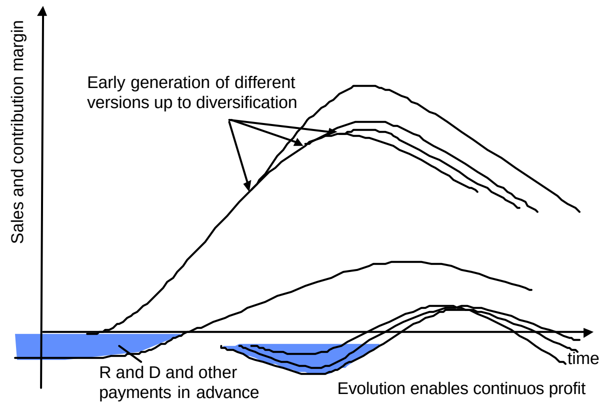


Fig. 7: Modified Product Life cycle

This kind of multiple use of basic knowledge by standardized product platforms with different facilities or customer-specification is demonstrated presently by the German automobile industry /16/. The "platform" of the Golf IV is basis for four very different automobile types. The offering reaches from a sports car to a family-friendly station wagon. Figure 8 clarifies that a once acquired amount of knowledge has to be testable regarding its expandability into "new products" in order to re-use all potentials of already done pre-work.

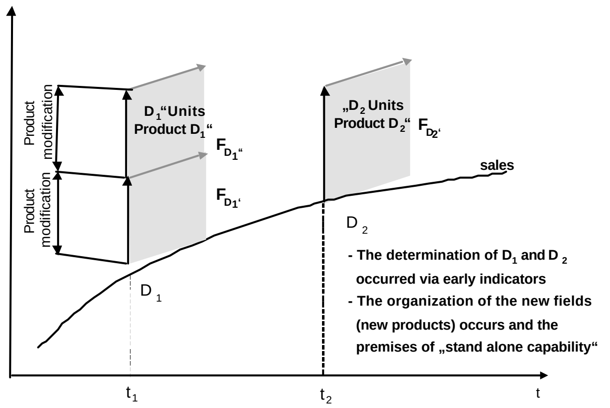


Fig. 8: Early generation of new products based research an development - modified product life cycle

2.4.1 Results and perspectives

Beside the described guidelines all these models are based on additional notions which are linked with extended knowledge about material cycles, competencies and their developments and chances, faster configurability of resources and further possibilities of diversification /12/.

Among the great challenges that are identified for production of the year 2002 in the context of a Delphi-study are fields of substantial problems:

- ?? parallel production,
- ?? Degradation of humans and resources (for the increase of satisfaction and efficiency),
- ?? transformation of information into knowledge,
- ?? increase of environmental compatibility,
- ?? re-configurable enterprises,
- ?? innovative processes.

There is nobody who would not use knowledge in the fields of:

- ?? technology management,
- ?? use of modeling methods,
- ?? organization design,
- ?? configuration of competencies,

for the accomplishment of the questions which are on the agenda and would not request its fast and requirement-orientated development.

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