Improvement of planning quality by the early use of "Quality Design" in the product development process

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Abstract

Purpose – "Failure-prevention Teams" and "Kaizen-Teams" are used after the "Start of production" in order to improve deficits in quality and to reduce costs and production times in the automotive industry. This paper shows the connection between "classical failures removal" and "waste avoidance" and why this should be done already during the product development process.

Methodology/approach – The abstract definition "failure" is extended. Building on that a combined application of the methods "3P" (Production Preparation Process) and "Failure Mode and Effect Analysis" (FMEA) is developed and verified. Besides, an approach to measure the benefits of combining the 3P and FMEA method is given.

Findings – The results imply that 3P and FMEA are complementary approaches and once they are combined, their capabilities to avoid failures are enhanced. The capability and maturity level of the organisation determines the success of using this method.

Originality/value – This paper redefines the abstract definition "failure". It shows that a great optimisation potential is available in the product development process and how it could made useful.

Keywords – automotive industry, product development process, Kaizen, 3P, FMEA

Paper Type – Research Paper

1 Introduction

The challenge of a turbulent market is drawn by globalisation trends, altered preferences on the buyer's market and a reduced product development process time (Weißgerber, 2001). Furthermore the saturation of traditional markets and an ascending diversification of products lead to a fierce competition. The customer demands high quality requirements to the product and the service involved. Apart from this the customer demands a quick delivery with an adequate price. Because of the ascending diversifications the customer is not bound to a special manufacturer and moving to a new manufacturer is simplified. In consideration of quality, price and availability the customers will make their purchase decision. The competitive capability of the manufacturer is based on productivity and quality. Only those manufacturers, who are capable to serve the *triad of success* which is quality, deliverance and costs for the customer, will overcome the challenge (Womack/Jones, 1996).

Especially European and American automotive manufacturers are struggling with problems as poor quality, high manufacturing costs and time schedules (Harbour, 2007), although an increase of productivity (Figure 1) can be stated (Rauber, 2007).

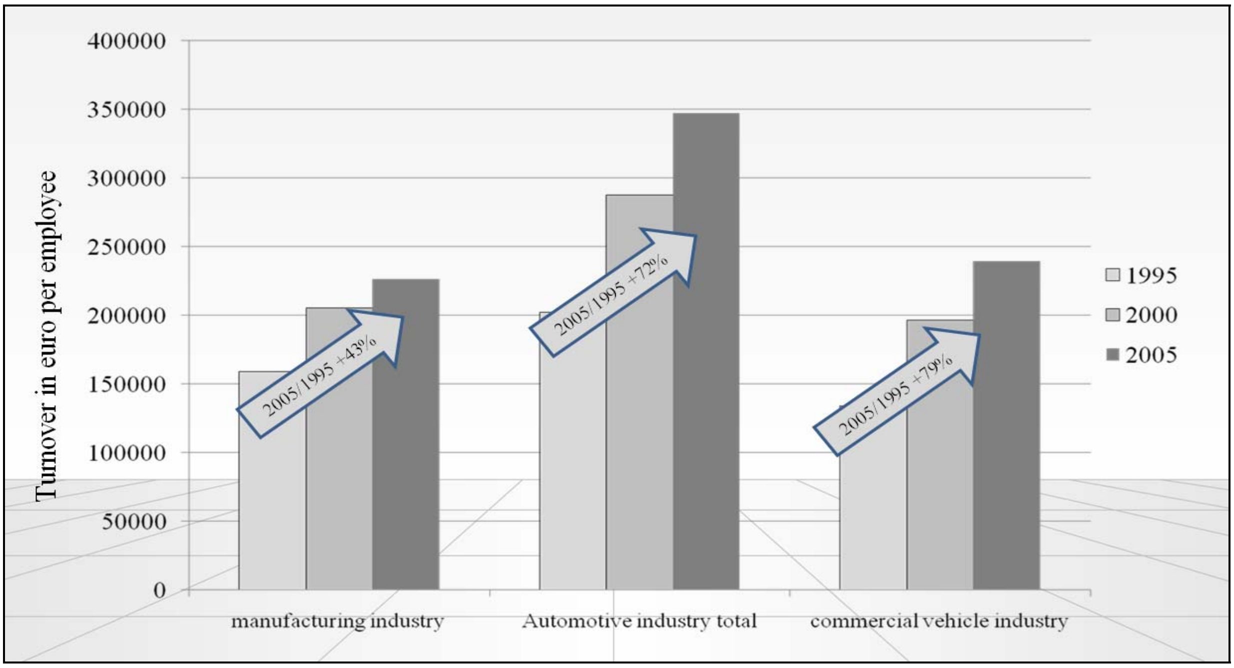

Figure 1: *Productivity – Turnover in euro per employee (Germany) (Rauber 2007)*

The production time of the European and American automotive manufacturers is much higer than the production time of the Japanese competitors - although the "Hours per vehicle" (HPV) are continuously decreasing. Besides production time, quality deficits and subsequently the low degree of customer satisfaction increase the economic pressure on the European manufacturers. Studies of the market research institute J.D. Power and Associates suggests hat the Japanese Manufacturers Toyota, Honda, Mazda and Subaru are leading the customer satisfaction statistics (JD-Power, 2006).

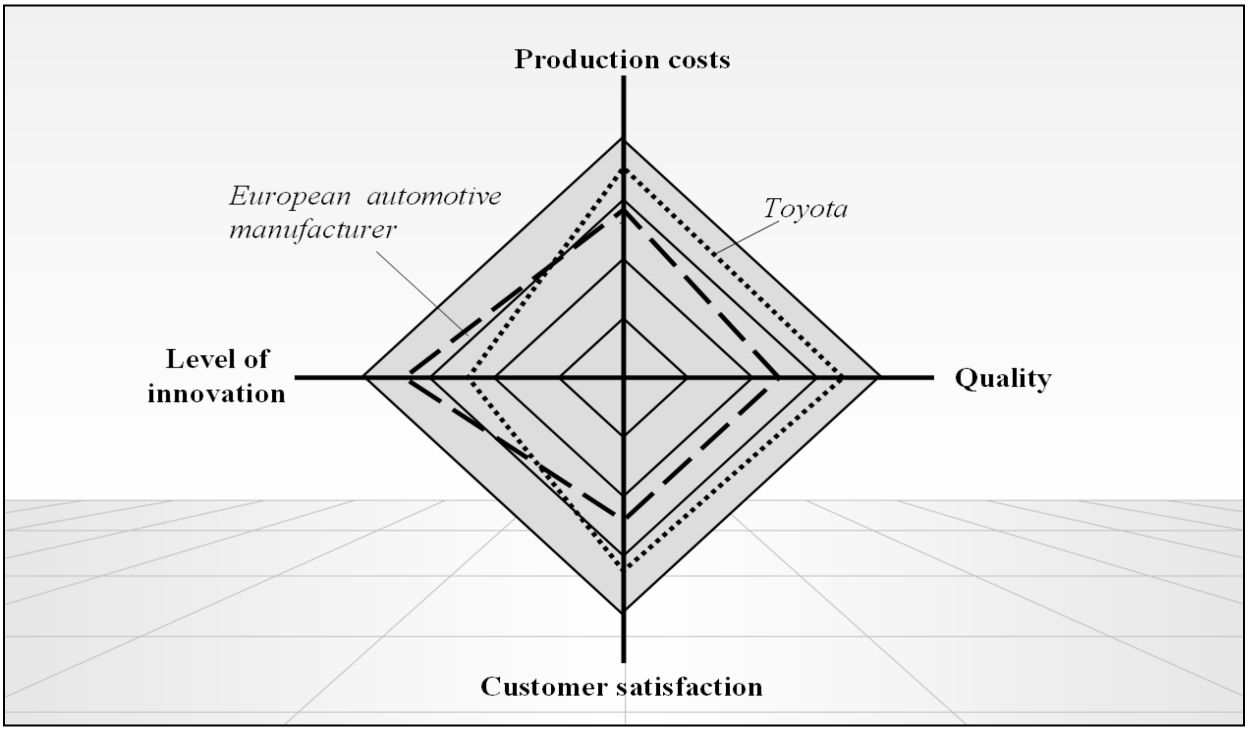

Figure 2: *Challenge of Manufacturers*

Besides the high manufacturing cost, deficits in quality entail enormous follow-up costs which could sum up to 5% of the annual turnover of the manufacturers. In simple terms the expenditure for warranty expenses and accommodation costs is as high as the expenditures in the Product Development Process. Moreover the effective date and volume of occurrence is not predictable (Dörr/Feldmann, 2006). The actual costs caused by negative effects on customer satisfaction and dwindling brand loyalty are incalculable. Provided that only 5% of the unsatisfied customer will complain, 95% of the customers drift away silently (Albright/Roth, 1992). In addition to that they could damage the reputation of the manufacturer based on negative mouth-to-mouth propaganda due to the fact that they keep prospective buyers from purchasing (Biallo, 1993). In order to keep their competitive ability against the "Japanese Competitors" European and American automotive manufacturers have to cut down their costs and increase their quality simultaneously. The Japanese automotive manufacturer Toyota is not only highly profitable (152 billion € turnover, 9.9 billion € asset) but also the highest sales volume manufacturer (Götz/Rumpelt, 2006). For that it could be seen as benchmark. In order to lower the expenditure for warranty expenses and accommodation costs, and to renew the customer satisfaction, European and American automotive manufacturer try to reduce the quality deficits in product and process by using a reactive and resources intense "quality offensive" (Jones, 2006). It seems that these quality offensives are considered as "random-button-pushing". Supply difficulties are solved by additional shifts, poor quality by additional surveys and rework (Sharma/Moody, 2001). It becomes clearly recognisable that merely the symptoms during the production process after the Start of Production (SOP) are improved but not the ultimate/real cause. This leads to the conclusion that product and process quality and therefore the productivity could only be improved by changing the symptoms and connected failures.

The product development process and an innovative quality management

First of all the challenge of an innovative quality management is to ensure or increase the economical performance. Essential profit maximisation is possible in two different approaches. The off-site approach is characterised by a high consumer satisfaction. In contrast to the off-site approach the in-house approach is directed at a decrease of costs. In order to improve the productivity the product and production process have to be optimised. As a consequence of these approaches the quality level has to be increased sustainable (Bruhn/Georgi, 1999).

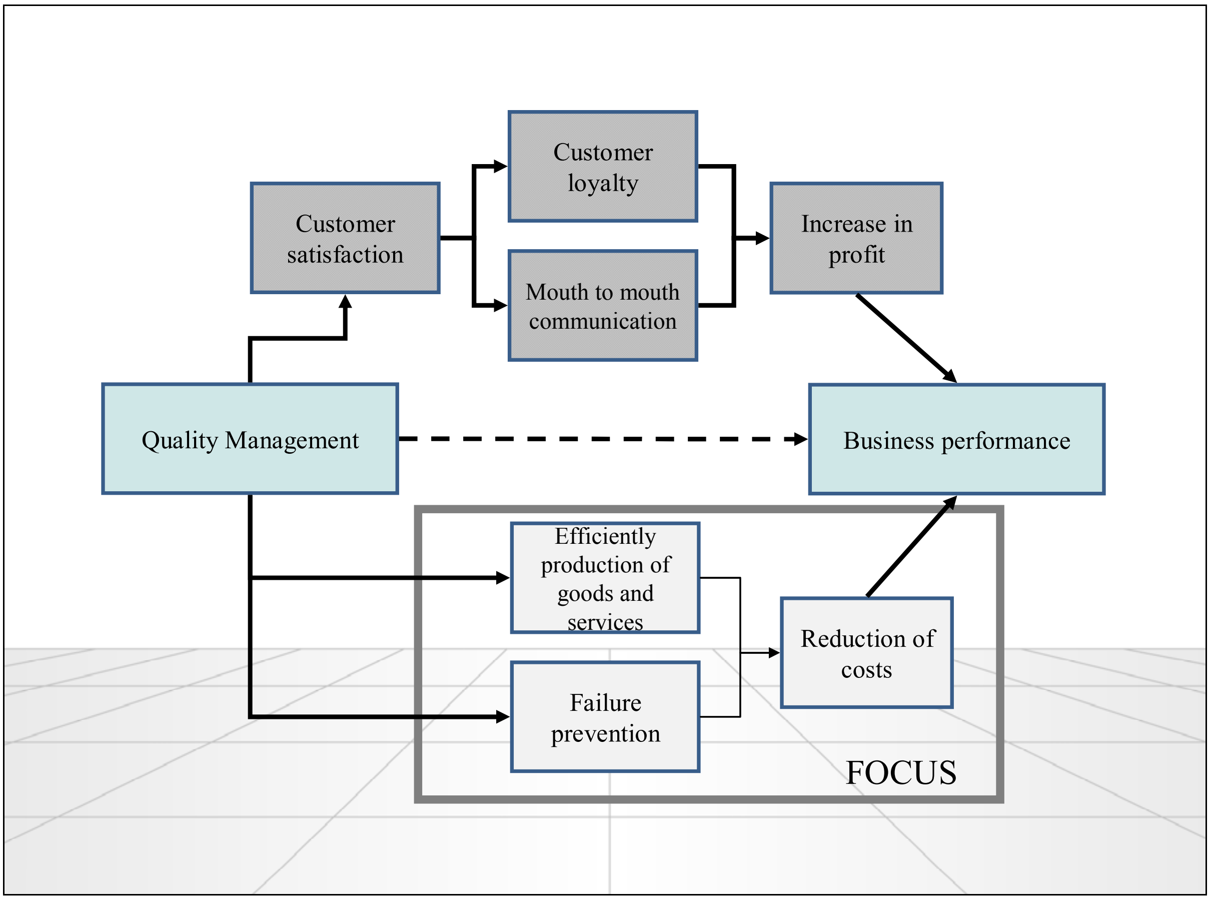

Figure 3: *QM off-site and in house (Bruhn/Georgi, 1999)*

The formula of success of the global automotive market leader (Toyota) depends on a homogenous production flow which is based on high quality level. In addition to that the advance labour productivity contributes to lower production costs continuously. Based on the Toyota Production System (TPS) (figure 4) cost-cutting are implement by an advanced labour productivity associated with a high customer satisfaction. The goal of the TPS is specified as maximum quality, lowest production costs and shortest through-put time. This correlates with the triad of success.

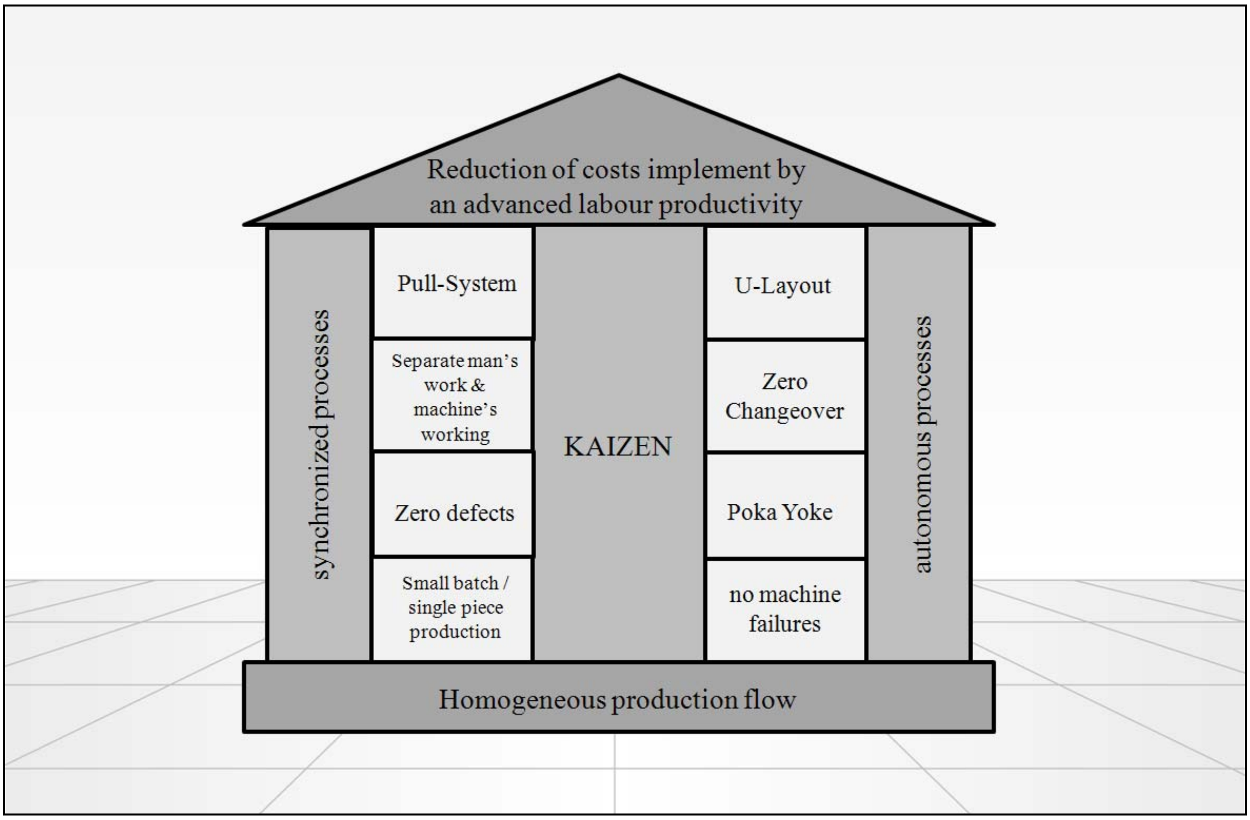

Figure 4: *Toyota Production System (Ohno, T., 1991)*

Currently the European and American automotive manufactures adopt well grounded the main principles of the TPS under the designation "lean production" because of the MIT Study "the machine that changed the world", which verifies the advantage of the TPS in contrast to the "western" production plans (Womack/Jones, 1991).

The basis for the following serial mass production is set during the product-development-process (PDP). In this time frame the "product development and –verification" as well as the "Planning and verification of the production process" are projected (Figure 5). The productivity is influenced by the product as well as the intended production process. For this reason the first level of influence is located at the PDP. The aim of this approach is to increase the process reliability in the following serial mass production characterised by the aspects of cycle time reduction, ergonomics, safety and quality.

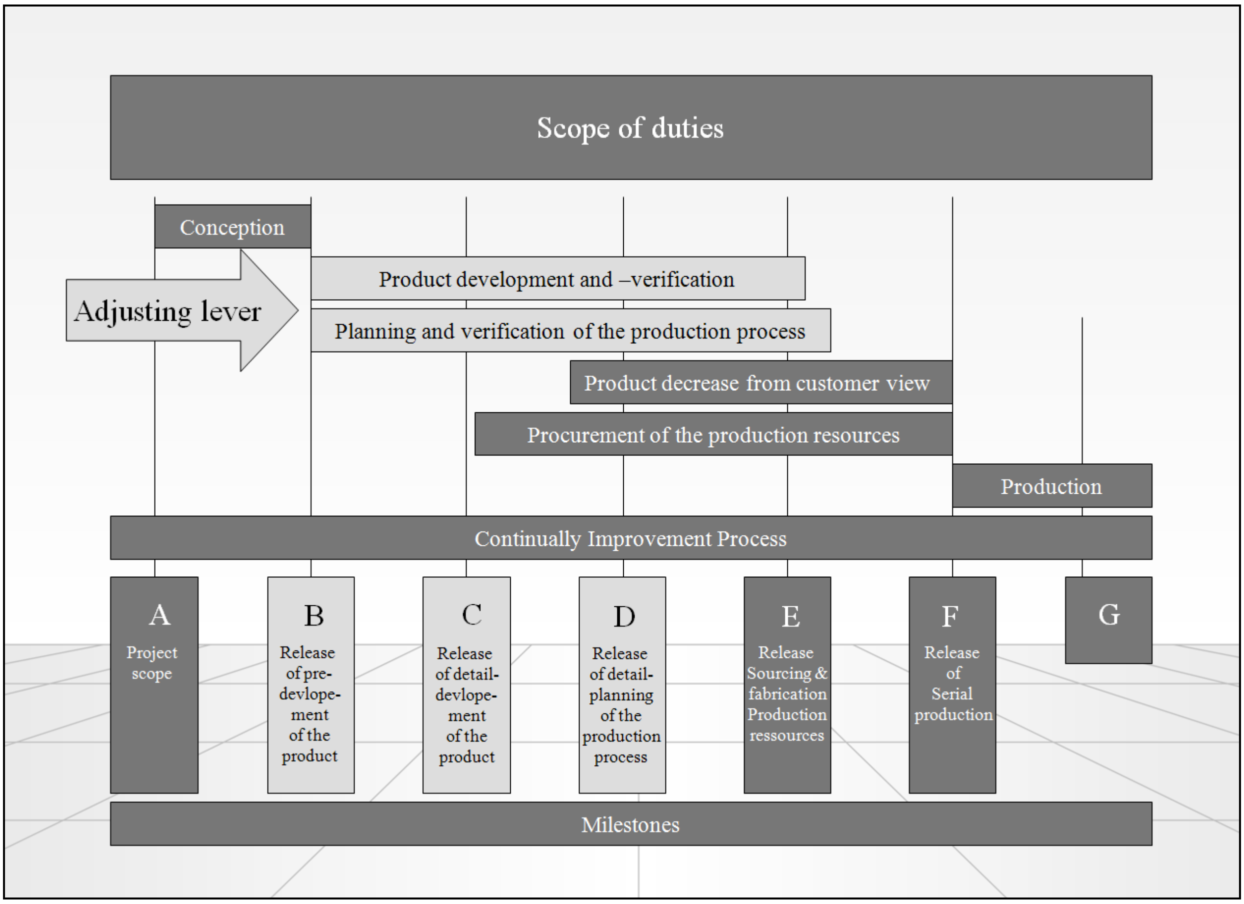

Figure 5: *VDA-PDP* (VDA, 1998)

Essentially four of five levers are available during the PDP to increase productivity on the “product-side”. The first lever is called the ”engineered hours per vehicle” (EHPV) or construction-conditioned production time. In this case it describes the initial situation that the worker is in range of the vehicle equipped with the needed tool (for example impact screwdriver) and the device which should be assembled.

The second lever is called “Failure prevention”. The device should be designed accordingly so that potential failures (for example wrong sheeting) could be excluded.

Moreover the third lever is called “Time spreading” and describes the time-based delimitation between the sheeting of a maximum and a minimum model. It goes without saying that a huge “Time spreading” could easily lead to a fitment which is only possible above several cycle.

Furthermore the fourth lever “Standardisation” refers to a minimal number of variant-parts. This could be achieved by standardisation of components (for example a modular upgrade of a generic building block) or standardisation of single devices (for example bolts screws etc). The goal of standardisation is the large scale use of equal devices.

Finally the last lever is called “First pass yield”. It may be defined as the quote of finished vehicles without ex post treatment. On one hand the “First pass yield” must be used with some reservations because of the small influence during the PDP on the other hand it has a great significance for the later production process. Additional levers to increase the productivity “process-sided” are investment costs, human-resource allocation as well as the required floor space which are influenced during “Planning and verification of the production process” (figure 6).

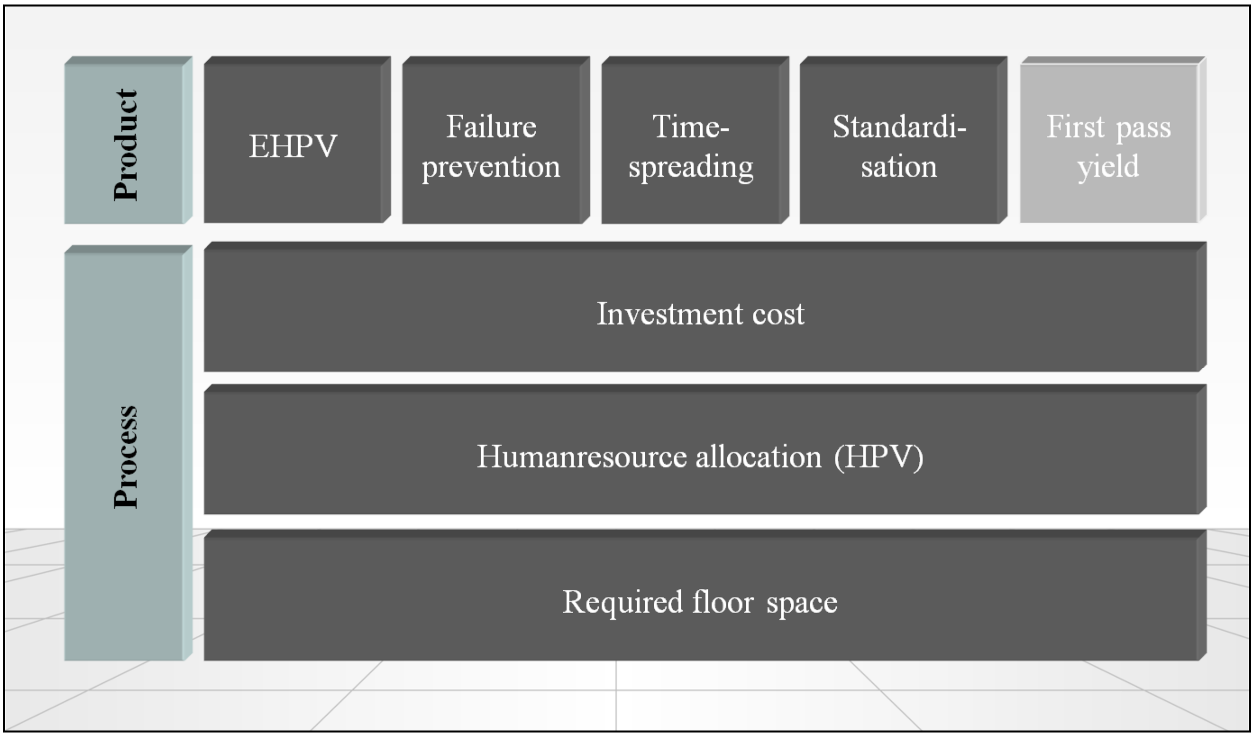

Figure 6: *levers productivity*

Productivity is the quotient of output to the use of resources. In order to increase productivity available resources must be better utilised. Levers could be found in the product as well as the process. First of all the resources must be used optimal and free of waste. On this account the abstract definition “failure” must be extended. A failure is not only the non-compliance of an operation or standard but also a non efficient performance (waste) with regard to the product preparation.

In summary, nine issues of waste can be stated (Liker, 2004):

1. Overproduction: This includes every unit which is produced without sales order result in a non interest-bearing accumulation of capital.
2. Idle time: Essentially a result of starving or blocking because of machine bottle necks, die change etc.)
3. Dispensable transport: Basically multiple transport of raw material without processing
4. Inventory: In essence, stock of materials and buffers between individual process steps since these buffers are often not emptied “first in first out” old material remains frequently and could only be disposed later.
5. Movement: Basically long and non value-adding movement
6. Reoperation: Deficient devices must be reworked costly or are directly scraped. The disprofit is increasing the later the failure is detected during the value added chain
7. Insufficient communication: Imprecise information which causes requests and if the worst case comes to worst, leads to failures and reoperation.
8. Unergonomic operation technique: Essentially “Zwangshaltungen“ (stoop working position) but also inaccessibility especially during assembly
9. Needless processes: Basically unpacking or repacking of materials, idle running but also “retorque“, die change and conforming of work content as well

Regarding to the nine issues of waste, only 10 % of an employee work is direct value adding for the customers (Sekine, 1995).

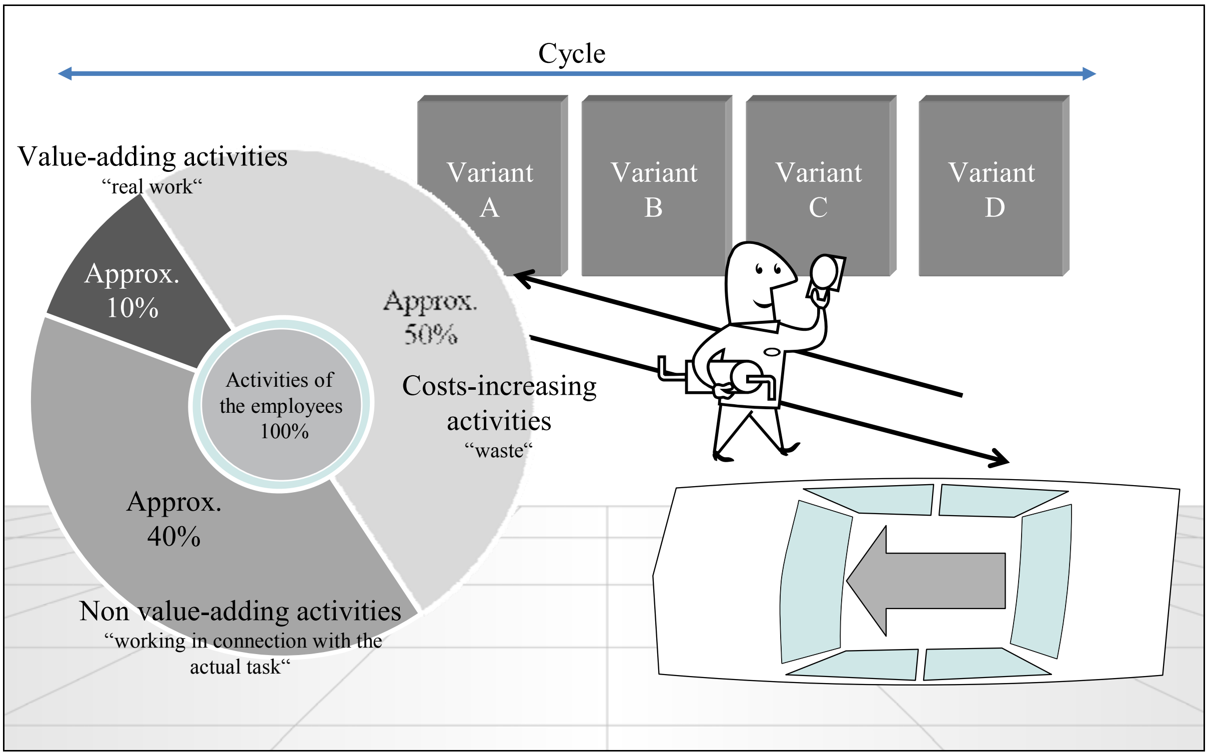

Figure 7: *Value-adding activities on the basis of Sekine*

This provides an interesting example for the different point of “problem viewing” between the European automotive manufacturer and Toyota. This is considered to be an important factor in appliance the Lean-thought. Toyota identifies correctly that the non value-adding time of the employee must be reduced in order to increase productivity. Lean means free of waste. The European and American automotive manufacturer on the other hand increase their productivity by slimming down the numbers of employees.

”Lean is not mean“ (Daniel T. Jones)

The assignment of an innovative Quality Management is to avoid failures (including waste) and accordingly the poor quality which originates from the developing and planning of new products and processes.

2 Reason for waste – unilateral focussing on product innovation as well as the general planning process

Principally it is not possible to split the planning in “normal activities” and failure prevention activities. One does simply not develop something and add on a certain amount of quality (Masing, 1993). In simple terms the grade of quality, which is considered in the Product developing and Product planning, is strongly influenced by problem perception of the Product developer and Product planner. Essentially the problem perception of the Japanese automotive manufacturers - especially Toyota - is focused onto standardisation of processes, to products, to operating equipment, to infrastructure and to organisation according to the TPS. These standards are improved continuously. “Innovation jumps” as in the European automotive industry simply do not occur. Product developers and planners do their business through the guidelines of the TPS. Because of that they know which problems need attention. (Liker, 2006).

So the reason for waste lays in the unilateral focussing on product innovation, which could be particular observed by the European automotive manufacturers. New products with more and more technological innovations and conjunction to shorter lifecycles put highest requirements to the development and the associate planning. It is not surprisingly that the planning on its part transfers the increasing technological demands (product) by the use of more and more technical innovations in the production process (new manufacturing-process, new equipment etc.). The problem perception indicates that the technology must be increasingly more precise in order to meet the demands of the product innovation. In this context employees are frequently seen as pure expense factor which has to be minimised. The preventive verification of the product and processes is done by the use of different quality methods (for example FMEA, etc)

On grounds of the superior Japanese automotive manufacturers, European and American automotive manufacturers adopt several parts according to the TPS:

- KAIZEN
- TPM
- JIT
- One Piece Flow and
- Pull-Systems etc

are only some examples. Nevertheless the parts of the TPS are converting inconsequently in the Product development and Product planning because of the unilateral focussing on innovation during the PDP. It can be easily demonstrated by the example Pull-System. Although the Pull-System (one piece flow) is accepted to be trend set, it is not adapted consistently by the European and American automotive manufacturers. Still inappropriately big buffers and safety stocks are planned. Not surprisingly that this is caused by suboptimal production processes. As a result a „Fake-Flow"(Figure 8) is created which suggests a Pull-System although it contains waste in form of inventory and therefore "hidden failures" (Sharma/Moody, 2001).

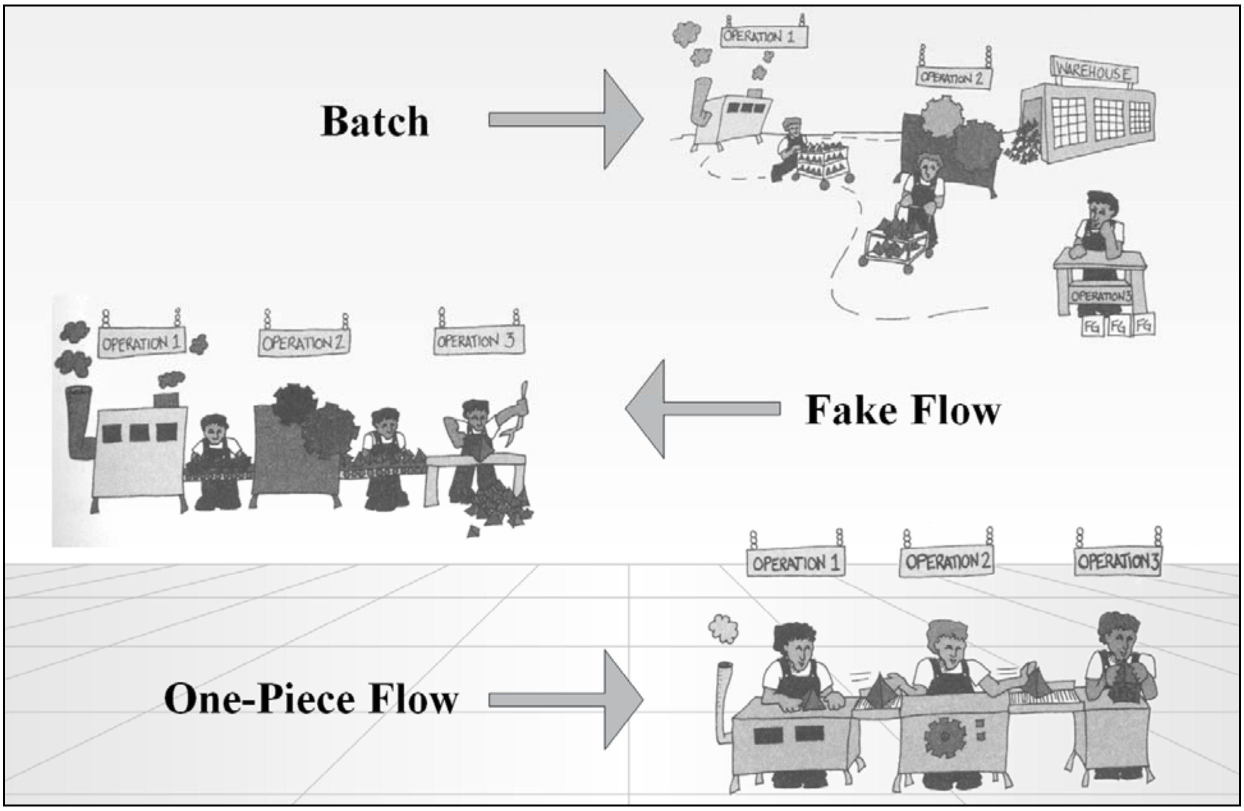

Figure 8: *Fake Flow*

Considering the whole, it must be determined that failures in the classical sense are prevented by the use of quality methods (for example failure mode effects analyse - FMEA) but failures in form of waste are not consequently cut off during the planning process.

Several reasons could be observed. On one hand new product innovations lead to special specifications which have to be adhered bindingly. The waste which is designed into a component (variants, different torques, screw types, working position etc.) is frequently not confessed in the development. On the other hand the planner is not aware of the different types of waste, because they did not appear in his problem perception. Accumulating for many years, several paradigms have been cultivated and are regarded as fix (requirement of large stocks in order to prevent downtime and loss of production if a previous process is broken down). Machines that show a large number of features are purchased although a lot of features are not needed to the performance of the task ("over engineering"). In addition to that too little practical relevance is put in the process planning. In this context it is interesting to note that this is intensified by the tools of the Digital Factory since they suggest that ideal processes can be generated by "plug & plan". This is made clear by assistant solutions that are supposed to help the workers (for example manipulators) but for various reasons (for example time duration, complicated handling) are not used by them. The most beautiful plan does not use anything if the person responsible does not stick to that! The Digital Factory could not ascertainable the reality in a ration of one to one. It does not provide any feeling for movements, weights etc. This raises special problems, processes which seems to be easy digitally emerge as non process-secure in reality.

In order to change the problem perception, the participants in the product development process must be supported. A key function is attributed to the planner for that reason, since he is the connecting link between development and production. To sum up, the planner must bear in mind the requirements of the development but also the production needs. The plan must be tested preventively on failures.

3 CIP at the Product development process

Production lines are optimised by continuous improvements (CIP) after the Start of production. This is necessary and important in order to increase the productivity of the local existing production lines. But it also demonstrates which great potential was left behind in the development process. At this stage the method 3P (Production Preparation Process) is brought to application. First of all the set goals of the 3P-Workshops are maximum quality at consistent prevention of waste (optimal workload of the employee etc). Moreover a minimisation of used resources in regard to production time, technology (investment) production area as well as logistics expenditure as a goal. Naturally the reduction depends on the preliminary planning status.

Fundamentally the ambition of the 3P-Workshops is characterised to gain perfection during the production process. In order to reach these, the product and planning state is checked for so called method building blocks, similar to the TPS. Essentially the avoidance of waste, but also the simple failure recognition (visualisation) is set as goals in the production process.

Basically the use of teamwork creates a large number of various ideas how the production process can be optimised according to the prerequisite of the KAIZEN-Method:

- Increase the value of the product continuously during the process
- One piece flow
- Pull Systems
- Use ideas, no money (reuse of available things)
- “Trystorming” (instead of discussion try out at a 1:1 model)
- Quality, Quantity, Timing (do not think of costs)
- Sacrifice „holy cows“ (creative thinking – out of the box)
- Low cost automation instead of high tech solution (only features which are absolutely needed)
- Employee stands in the centre of interests (ergonomics)
- Elaborated measures must be transformed

The group of participants, a “crossfunctional team” consists of planning, industrial engineering, development, logistics, quality assurance, workers as well as the management which has to bear the results of the workshop.

As a rule 3P could be described as a searching for simplification. Every team member has his own viewpoints onto the different problems. Especially colleagues from a different subject/profession have their own domain knowledge and do not have any thinking-boundaries (paradigms) and are therefore important “new idea senders”. This does not mean that the developer product-sided and the planner process-sided have planned poorly. The result of their good work is strongly influenced through existing paradigms.

The course of the 3P-Workshop occurs in three steps. First of all the so called Virtual Product-/Process conversation serves as an upbeat. It contents affirmation of the general reducibility by the use of Digital Mock Up (DMU). This is necessary against the backdrop. If the product is not producible in theory it must be changed. Following to this Virtual Product-/Process conversation the 3P-Workshops takes place.

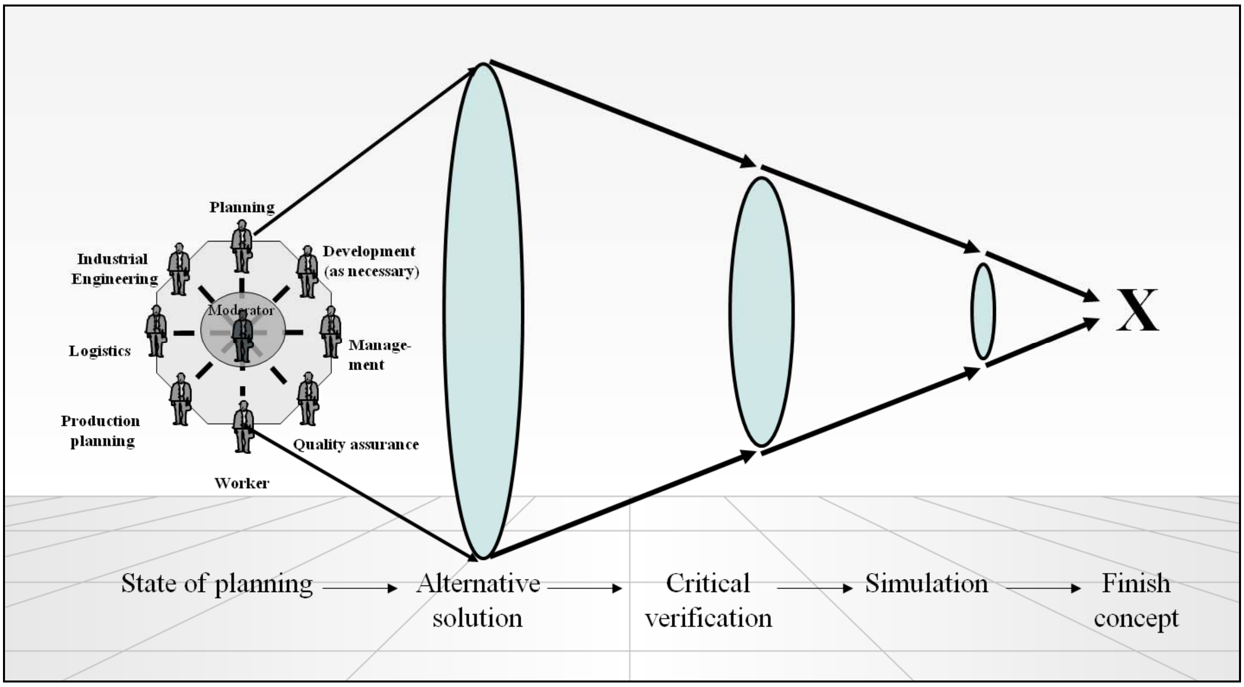

Figure 9: *Participants and their focal points*

3P-Productworkshop

During the 3P-Product workshop the existent development status is analysed through potentials for savings (EHPV, standardisation, etc). The Design states are examined with regard to feasibility, tolerances and variants (Time spreading). In this case the focus is set onto the premises of the planning meaning the adjustment of product concept and the design of the process and operating equipment. The goal is to minimise the EHPV for the device (Figure 10).

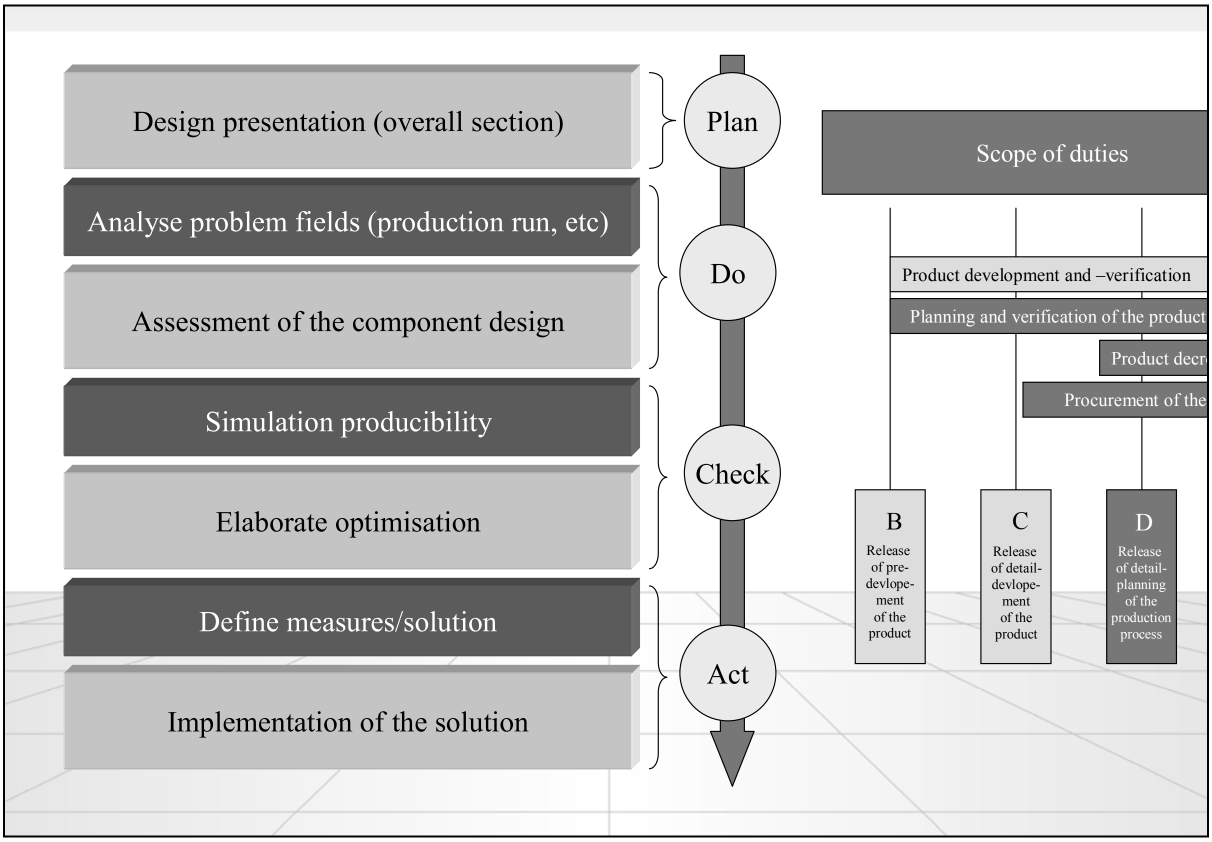

Figure 10: *3P-Product workshop*

Subsequent to the 3P-Product workshop the 3P-Process workshops occur.

3P-Process workshop

Adapted from the basic concepts of the value adding and synchronic production the focus of the 3P- Process workshop concentrates on the inspection and optimisation of the planning based design. Therefore the manufacturing process, the production equipment, the appliance, fixtures and the configuration and the layout of the production line are defined. Moreover the logistic conception and cycle time is defined (Figure 11).

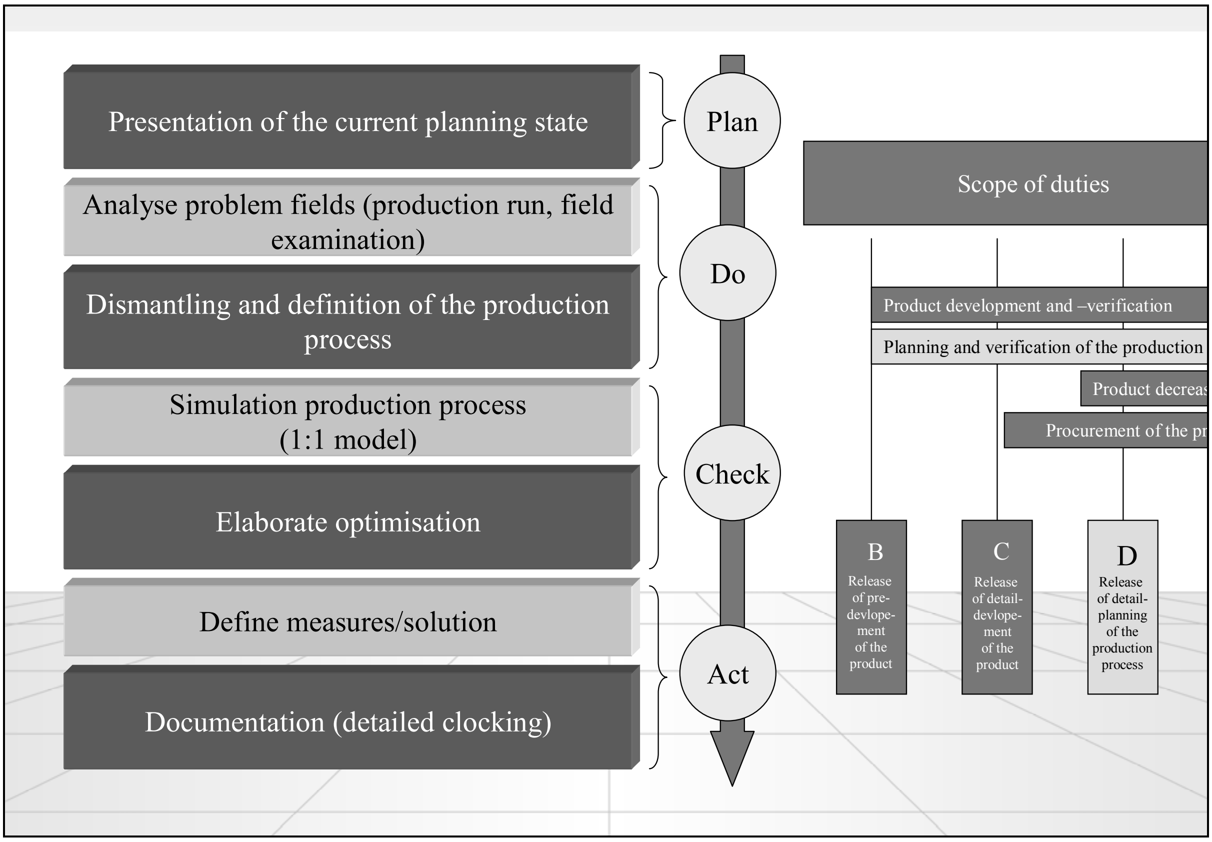

Figure 11: *3P-Process workshop*

For that reason several “main method components” must be considered:

- 9 types of waste
- “Eintakter” (signifies that within one cycle the complete work content is sheeted)
- Ergonomics (optimal labour conditions for the worker)
- One touch one motion (install components the way they are caught in one motion by the worker)
- Poka Yoke
- Container designs (no large standard stillage)
- Cycle time & value adding (minimise ”Time spreading“, focus on value adding)

Essentially the method components are used for breaking existing paradigms open and to give new/fresh impetus to the planning. In conclusion, it should be pointed out that the HPV is decreasing and therefore the internal costs can be lowered. The condition precedent is an optimisation of the EHPV and the reduction of the production time. However it is very difficult to define the saving potentials in form of a hard figure, because the quality of the preliminary planning status can vary. In general the difference between investments, production area and HPV could be compared.

External costs, especially in form of a case of damage occur in addition to the internal costs. In this context the question is how these external costs could be lowered (Figure 12). Roughly speaking these costs are most simply made as “an amount X that is set to every car” in order to pay cases of damage in the field (warranty and guarantee).

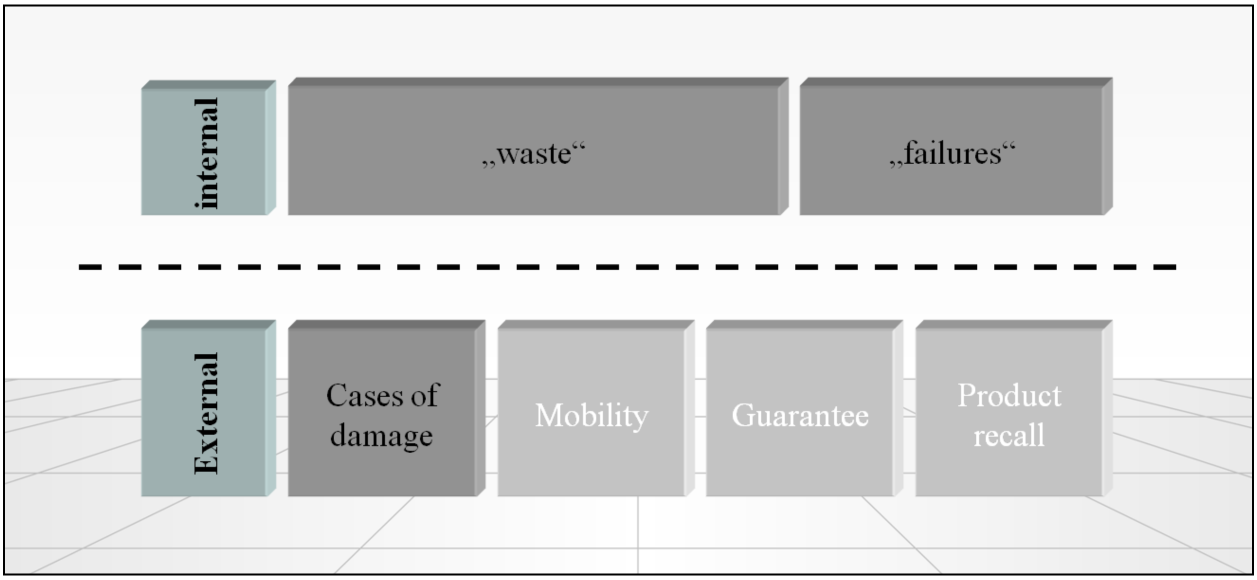

Figure 12: *internal and external costs*

4 External costs – waste through defect cases

Until now only the internal waste was considered. As pointed out in the introduction, the costs for pay cases of damage (SF) in the field are near up to 5% of the turnover. Annualised, a sum of approx. 3.0 – 9.6 billion € is spent by the western automotive manufacturers.

The classical error avoidance and failure prevention is requisite in order to minimise these costs. The quality method FMEA is proved to be effective if it is used correctly. Since a lot of external failures have their origin on internal failures, a connection between these two cost drivers must be established.

3P-Workshops are helping to reduce failures before SOP (internal failures in form of waste). But the costs for pay causes of damages in the field evolve after the SOP. That is why the pay cases of damage must be estimated and respectively predicted. For this purpose experience of the predecessor models, actual analyses of available defect cases (also of other products), “Reifegradspiegel inquires”, quality method check, production planning as well as the technological design-description are considered. The definition of the accrual heights is purpose of these efforts. The amount is the sum of the different mathematical products (Figure 13).

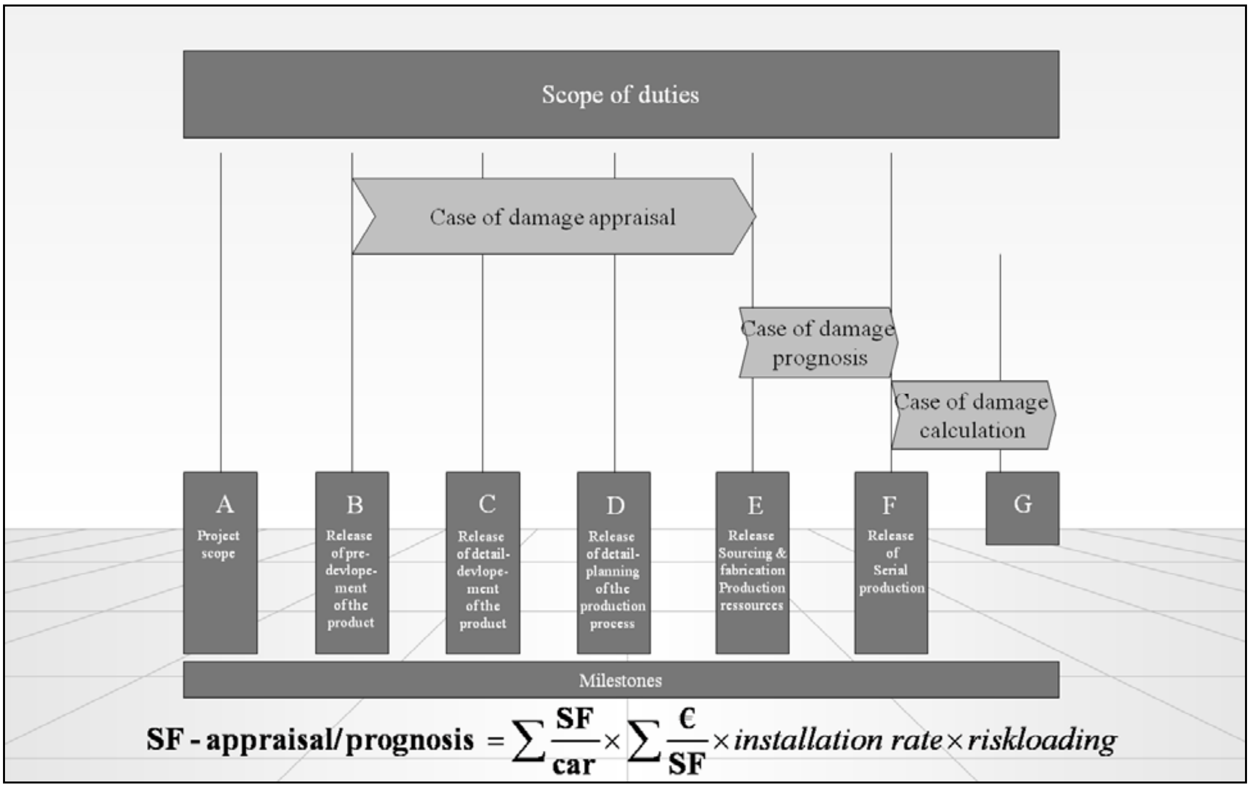

Figure 13: *Case of damage appraisal/prognosis*

With assistance of the 3P-Workshops the production of goods and services can proceed more efficiently. A large section of failures emerging after SOP can be prevented.

Nevertheless the focus is set on the process improvement and not on the classical failure prevention. At this stage the quality method FMEA can support the 3P- Workshops. To a large degree the participants (specialists, experts) of the 3P- Workshop and the FMEA are the same. Because of the visualisation during the 3P-Workshops the Data base which can be used in the FMEA is very large. The product as well as the process could be verified preventive. For that it makes sense to check the elaborated improvements according to the 3P-Workshops at the end of the creative phase and to make necessary adjustments.

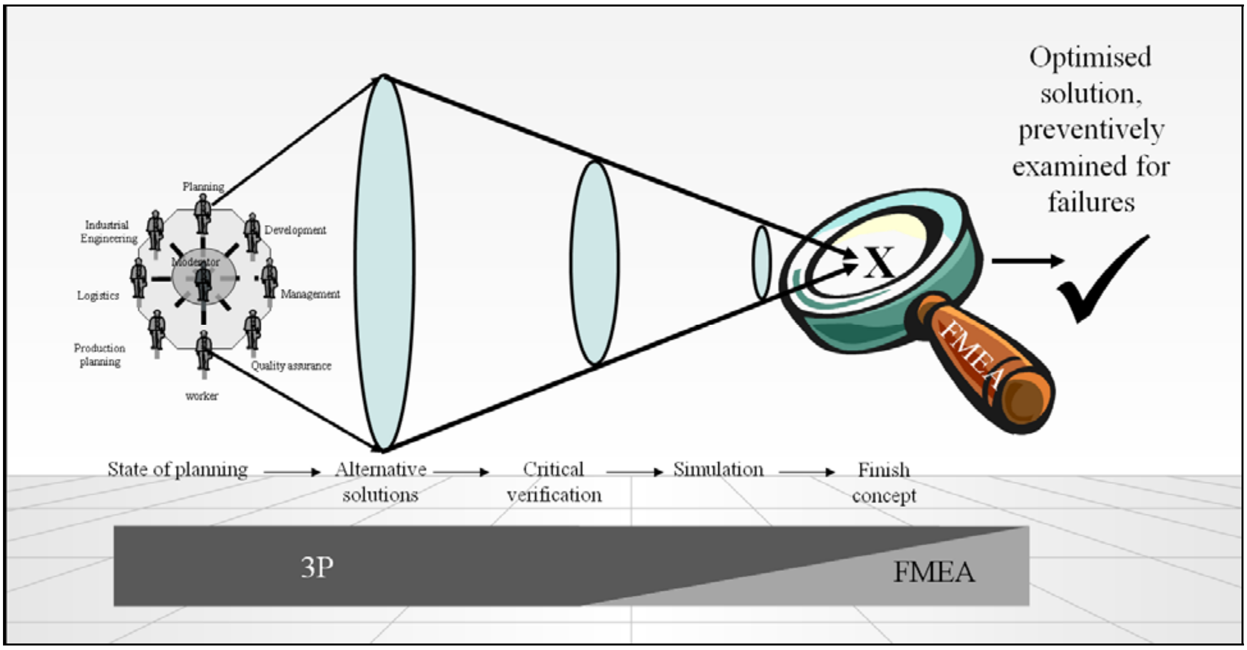

Figure 14: *Combination 3P & FMEA*

The products and processes are improved inside the 3P-Workshops appropriate to the special request of the planning. On this account changes which are resolved in the 3P- Workshops within vital components and critical processes must be checked preventively. For this purpose as already mentioned the quality method FMEA has been established.

It can easily be demonstrated at the example of the Process-FMEA (P-FMEA). The purpose of the P-FMEA is to check which failures could arise inside the production process (false sheeting, interchanges, damages, non capable process etc.) and how these failures could be prevented. These remedial actions could be verified during the 3P Process and the process accordingly changed. To simplify, according to the creative phase the inspection occurs.

It is necessary to evaluate the performance of the 3P-Workshops combined with FMEA because of the prognoses/approximation of the costs by pay cases which is directly linked with the performance of the workshop. This applies to both the actual process and the transformation inside the organisation.

5 Measuring Capability- and Maturity Level of the processes and organisation

“Today’s problems come from yesterday solutions…” (Senge‘s law)

Defect cases can only occur after the SOP and therefore be measured. In order to reduce the pay cases of damage one has to attest that every possible failure during the production process is regarded and eliminated. On this account no accrued liabilities for pay cases of damage must be formed. It may be noted here that this is not possible in reality because pay cases of damage have their origin in a multiplicity of reasons which cannot be respected during the product development process (vendor parts, suppliers etc.). Failures which could lead to pay cases of damage could be avoided by the use of quality methods. These pay cases could be subtracted of the sum of the accrued liabilities and the accordingly damage case prognoses. Due to the great chronological offset between the realisation of the quality methods and the result of the same ones it is necessary to have a gauge which approves an inference for the defect case prognosis.

It is arguable whether the result of the method is realistic. The probability that the result of the quality method will be stated in the production process enhanced so much the better the quality method has been accomplished before the SOP. For that reason the defect case prognosis could be lowered.

The Capability Maturity Model Integration (CMMI) is used in the software industry as a gauge for the development progress and therefore as an inference on productivity and quality (Kneuper, 2003)

For this purpose the realisation of the several methods (process layer) is analysed as well as the maturity level of the organisation (Figure: 15).

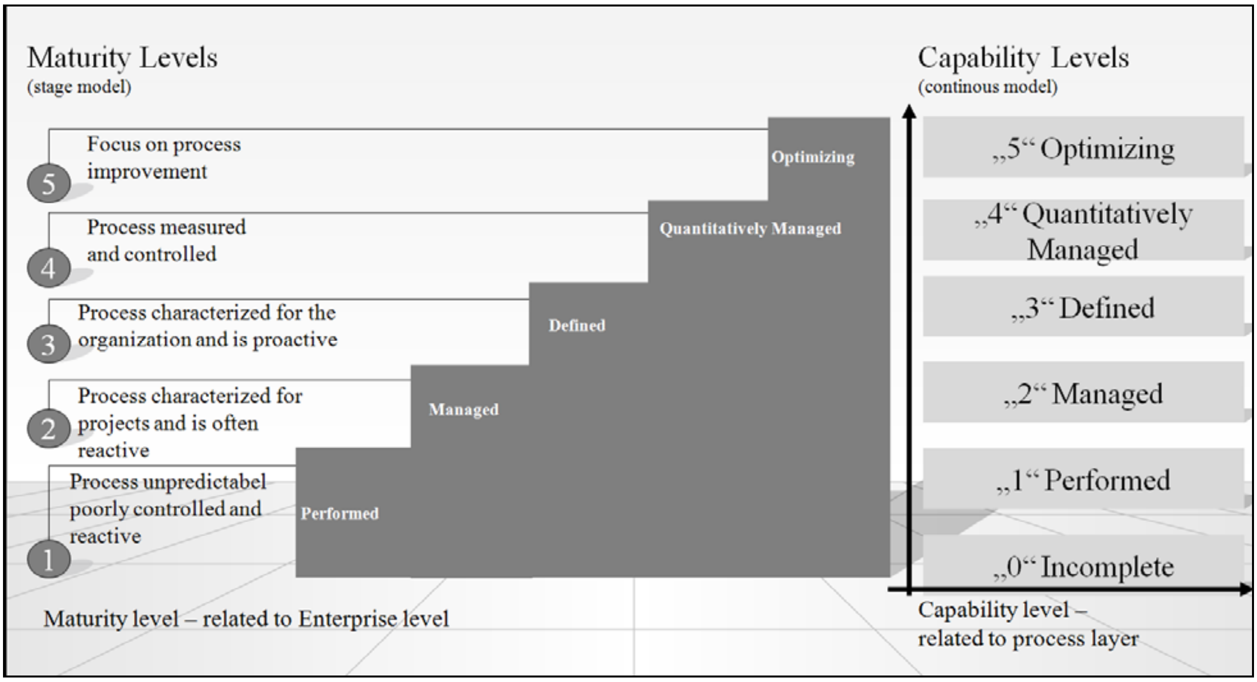

Figure 15: *CMMI-Model*

Within the framework of the capability measurement it is checked how the individual method was carried out at itself (topic, preparation, participant, procedure, documentation, measure interrogation etc.). The stage of maturity is not only measured by the grade how the processes are embedded in the product development process, in this case the quality methods, but also how they are put into practice in the different projects. The higher the capability respectively maturity level the stronger the defect cases could be lowered.

6 Conclusion

The global automotive industry struggles with sinking margins and an increasing overcapacity about 20% (Schubert, 2006). This competition will still intensify by the time the Chinese automotive manufacturers press forward on the global market. Only those manufacturers will overcome the challenge who are capable to serve the triad of success - quality, deliverance and costs for the customer. Not surprisingly, that the automotive manufacturers must improve continually. This approach is widespread after the SOP (CIP, valuestreammapping). Since the problem focus lays on the actual production process an optimisation of the product development process itself was not strong enough considered. Moreover it became clear, that a great optimisation potential is available in the product development process, in particular in the product development and verification as well as the planning and verification of the production process. Not surprisingly, the success of Toyota is based on the procedure within the product development process. The avoidance of waste and therefore the concentration on value adding processes for the customer has a high priority. These are the components of the TPS which is put into practice continuously. In doing so the creative potential of their employees has been fully taken up in the production development process as well as after the SOP. A great relevance is set on the so-called “try-storming”. New approaches result through testing (1:1 Simulation), ideas could be easier proved concerning to their feasibility. The European and American automotive manufacturers are still detaining to their pattern of thought (Push-systems). The effect is noticeable; the western automotive manufacturers still search solutions for the wrong problems (Morgan/Liker, 2006).

The basic approach to use CIP before SOP (→3P) proves to be a complete success. The basic prerequisite is to break up the old paradigm (with the knowledge that complexity forces failures (Nakao, 2007) the simple, capable solution must be found). For that the creativity potential of the employees must be used more efficiently. The employee who has to built the devices faultless and free of waste has to be in the centre of the planning. For this reason, a special role comes up to planning as interface between development and manufacturing, since it must fulfil both the requirements of the development and those of the manufacturing. With the help of the 3P-method it is possible to use the creative potential of the team members better. Problems and/or improvement suggestions can be examined by the common exchange faster on their feasibility. Furthermore, by combining 3P with the method of the FMEA, one can extend the preventive use of 3P, since both the wasting and the potential failures are prevented in this way. Failures become questions, questions becomes changes (Lotter, 2007). This leads to the fact that the case of damage prognosis can be decreased, and thus the costs noticeably reduced. Depending upon the automotive manufacturers savings up to one billion € can be realised by a 10% drop off.

To sum up, the way of employing the methods is important in order to lower the case of damage prognosis accordingly. It goes without saying that pretending the methods will not be leading to the desired results. Essentially the capability and maturity level of the organization must be measured. This is important, as these determine the success of the methods, and thus the case of damage prognosis affect. The digital factory can support but not replace the methods (e.g. Augmented Reality).

The key to success is to understand both, the problem and the solution, perfectly (Spear, 2004). For that reason the journey is the reward.

7 List of references

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