THE TOYOTA PRODUCTION SYSTEM TPS vs. VALUE ORIENTED DESIGN SYSTEM VDS

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ABSTRACT

This contribution shows the development of **T**oyota **P**roduction **S**ystem **TPS** and the new development of the **V**alue Oriented **D**esign **S**ystem **VDS** – its benefits, present state and some successful results of automotive applications: less parts, less complexity, less costs, less weight, less CO_2 emission, better quality. VDS is a synthesis of design, purchasing and supplier network.

1. INTRODUCTION

In today's global economy, the competition has become much tougher. The market situation requires higher flexibility towards the sales market, more control of the distribution operations, lower stocks but improved customer service and a demand–orientated manufacturing process. A number of major manufacturers have coped with the above-mentioned development by the implementation of the Just-in-Time production system or derivatives of Toyota Production System TPS.

There is a more demanding aim than just reducing costs. The new philosophy requires the design, purchasing and the supplier network to develop into a strategic function that is becoming recognised as a key tool for greater competitiveness and profitability in an increasingly global and exacting business economy. To meet these challenges, the need for new ways of increasing productivity and quality is obvious, and includes the new development of the Value Oriented Design System VDS.

The costs and quality of manufactured products are largely determined at the design stage. The development from a Just-in-Time production system to a value oriented design means that it is possible to cut life cycle costs including logistics costs, improve quality at an early stage, reduce time to market and enhance customer satisfaction. Value oriented design aims to reduce the complexity and number of parts within a component/module design through parts synthesis. Complexity reduction is very important for the automotive industry, which has to cope with an enormous increase in the number of models and variants (Fig. 1).

No end to the diversity of **VARIANTs** ?			
SUBASSEMBLY			SHARP RISE: Factor
Door Inner Panelling - front, left	608	18 816	30,9
Door Inner Panelling - rear	76	1 764	23,2
Door Inner Panelling - front, right	608	4 704	7,7
Glove Box	20	152	7,6
Tray, Driver's Side	10	54	5,4
Fuel Tank	13	45	3.5
Cover, Door Handle	132	432	3,3
SEAT	3 696	10 880	2,9
Support Exterior Rear View Mirror	38	76	2,0
			Source AUDI

Fig. 1: Enormous increase in the number of models and variants

2. THE TOYOTA PRODUCTION SYSTEM TPS

The design and development of this system in Japan was characterised by extreme lack of space and post-war shortage. In 1969, the set-up time for a 1000-ton press was four hours at Toyota, while VW required two hours for the same job. Within six months, Shingo [1] and his staff succeeded in reducing set-up time to one and a half hours.

As a result of this excessive set-up time, large batch sizes were manufactured and, as a consequence, large stocks piled up. In order to implement just-in-time production, it was essential to drastically reduce set-up time still further; a decrease in time to a maximum of three minutes for a 1000-ton press was demanded by Taichi Ohno, managing director of Toyota. Shingo and his staff attained this goal within three months, thanks to the SMED principle (Single Minute Exchange of Die), which was a new method developed for replacing internal tool exchange by external change-over [1]. The material requirement card 'KANBAN' is an integral part of the information system and serves as an effective means of monitoring the production process. Total Productive Maintenance is a progressive approach to enhance productivity and quality through equipment improvement and reliability, reduce set-up time and lot size and increase the employee qualification, Nakajima [2].

Waste reduction is an effective way to increase profitability. The following *Seven Wastes* were identified by Toyota's Chief Engineer, Taiichi Ohno as key part of the TPS:

- Defects
- Overproduction
- Transportation
- Waiting
- Inventory
- Motion
- Overprocessing

The Toyota Production System TPS is well described in many publications including the 14 principles of the Toyota way (Table 1).

Table 1: The 14 principles of the Toyota way, Liker [3]

1.	Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals
2.	Create continuous process flow to bring problems to the surface
3.	Use "pull" systems to avoid overproduction
4.	Level out the workload
5.	Build a culture of stopping production to fix problems, to get quality right the first time
6.	Standardized tasks are the foundation for continuous improvement and employee empowerment
7.	Use visual control so no problems are hidden
8.	Use only reliable and thoroughly tested technology that serves both your people and processes
9.	Grow leaders who thoroughly understand the work, live the philosophy and teach it to others
10.	Develop exceptional people & teams who follow your company's philosophy
11.	Respect your extended network of partners and suppliers by challenging them and helping them improve
12.	Go and see for yourself in order to thoroughly understand the situation
13.	Make decisions slowly by consensus, thoroughly consider all options; implement decisions rapidly
14.	Become a learning organization through relentless reflection and continuous improvement

Toyota represents an interesting combination of corporate strategy, corporate governance and corporate culture. Although it appears that everything is already known about Toyota, the corporate culture and its effects have, so far, been omitted by the majority of OEMs all over the world or they have been unintentionally ignored, Schmidt [4].

German companies started their lean implementation at a higher level of efficiency because they were already using a higher level of state-of-the-art, high-tech, CNC-operated machinery and comprehensive enterprise resource planning (ERP) software. Therefore they did not exhibit the same levels of improvement in quality, cost, productivity, and delivery. It was, in fact, the higher education and skill level of German employees that facilitated German companies to achieve higher levels of manufacturing efficiency and to allow the extensive utilization of high-tech machinery prior to lean implementation. The German companies also modified a higher number of the typical lean principles to suit their own special needs.

The potential for improvement is far from being exhausted in the German industry. Costs for processes could be lowered substantially. A number of car manufacturers produce according to lean principles relatively successfully, but they lag behind the performance of Toyota. The current competition in the automotive industry requires higher productivity and, at present, it is mostly cost saving programs and concepts that are being installed as a corrective. Thus, whilst they are focused on getting their process under control, they do not give enough time to process improvement by redesign, Schmidt [4].

3. VALUE ORIENTED DESIGN SYSTEM VDS

The costs, functionality and quality of manufactured products are largely determined at the design stage. It is important to consider manufacturability early in the design. A lot of the design tasks are executed by suppliers. In manufacturing industries such as, for example, the German automobile industry, the in-house production of parts has been drastically reduced over the last decades: The costs of materials and parts in percent of revenues has been increased from 50.3 to 75.1 percent from 1979 to 2006 (Table 2). To cope with the development of complex products, the design, procurement and supply have to shape up to a mutual strategic network, Schmidt [5].

Suppliers not only deliver just in time, but they will also collaborate from the early stages of design onwards. Value oriented design closes the gap between design and procurement as well as with the suppliers, Herrmann [6]. Therefore the tools for the design for the complete life cycle are very profitable – these are described with results in the following, Schmidt [7].

Table 2: The costs of materials and personnel in per cent of revenues, Schmidt [5]

Year	Cost of materials In per cent of revenues	Personnel costs In per cent of revenues
1979	50.3	25
1984	53.6	23
1989	60.4	21
1994	63	20.0
1997	64.0	17.4
1998	66.4	17.7
1999	66.2	17.1
2000	68.7	15.8
2001	71.2	15.3
2002	70.4	13.5
2003	71.0	14.6
2004	72.7	14.5
2005	74.2	14.7
2006	75.1	13.0

3.1 Design for the Complete Life Cycle

Many major corporations have been seeking to improve their 'product profitability' by increasing manufacturing and assembly efficiency. In order to achieve this, Concurrent Costing®/Design for manufacture and assembly (CC/DFMA®) has been widely applied in the U.S.A. and now in Europe. CC/DFMA aims to reduce the complexity and number of parts within a component/ module design through parts synthesis. CC/DFMA is a method for the value oriented design process and its implementation has already commenced in most German automobile manufacturers. The benefits are, Schmidt [7]:

- Team building in early stages and improved team work
- Enhanced quality and secured functionality
- Simplification of product design, leading to reduction in costs / assembly time
- Integration of parts, resulting in decreased number of parts
- Reduction of weight
- Realisation of ecological requirements
- Reduced development time and shorter time to market

The CC/DFMA-software tools lead the team of experts methodically step by step through the analysis and optimisation process thereby supporting each of the procedures. The team consists, for example, of project leader, designer, production planer, technology expert, service, controlling, quality, procurement and supplier. The cost influence of design decisions and recognition of future manufacturing problems will be quantified by the system. This gives the team a direct feedback about the cost of their ideas and plans. The teamwork is speeded up and, by having this direct feedback of improvement or deterioration, the time expended on product and process development is drastically reduced. In order to be able to cut complete life cycle costs at an early stage, the following teamwork-tools have been developed:

- DFM® Design for Manufacture
- DFA® Design for Assembly
- DFS® Design for Service
- DFE® Design for Environment (® of BDI and amc)

Over 70 per cent of costs, quality and environmental impacts are influenced during the early stages of design. With the above mentioned-tools, it is not only made possible to optimise proactively one single aspect such as cost reduction for manufacturing, but it also enables an overall optimised process over the whole live cycle of the new product, including the collaboration of the suppliers network. It begins with the complexity reduction and cost optimisation of the first step in manufacture and reaches right up to the optimisation of toxicity, energy and costs of the last step in recycling and disposal. This renders CC/DFMA a powerful management tool for both value oriented design, including the concurrent control of costs, and a strategic launch of new products, Schmidt [4,5].

3.2 Successful Concurrent Costing / DFMA Applications

The CC/DFMA procedure as a preventive optimisation process, is profitable when a new product has to be designed and marketed or an existing one improved under new targets of costs and functions. Results of some applications are shown in the following, Schmidt [7]:

- Automotive industry: CC/DFMA is integrated into the product development process. Benefits are the reduction of part number, assembly time, investments and the cost of production by a margin of 3 to 34 per cent. Goal for the new model is the reduction of standard parts by 86%, tools by 60% and torque by 94%, Pfammatter [8].
- Automotive industry: Reductions of the number of parts and operations per glove box by 42 percent, and of the assembly time and costs by 52 percent, Naujocks [9].
- Electrical industry: Improvements of DFA index, reduction of assembly time/production costs by 80 percent and a part count reduction by 60 percent.

- White goods industry: A project has been performed and implemented within a time span of only nine weeks. The results show significant product improvements, complexity reduction and savings of several million Euros.
- Designer products: This winner of nine design awards in one and a half years reduced the costs by 15.4 per cent and the number of parts by 23 percent which is equivalent to a saving of 15 millions Euros, Iglseder [10].
- Design For Environment DFE: The recycling company MIREC uses DFE in many consulting projects. As an example, the redesign of a converter results in reduced part count, disassembly time and costs, assembly time and costs, total weight and **MET** points (environmental impact **M**aterials, **E**nergy, and **T**oxicity). The costs are calculated for the whole life cycle of the products, Grieger [11].
- A redesign of the front end of an automobile saved more than 30 kg in weight. This reduction of the vehicle's dead weight will save 400 to 800 litres of petrol over its entire life-span, which represents a reduction of one to two tons of carbon dioxide emission and 30 kg of material less to recycle, Schmidt [5].

3.3 Reduction of Administrative Costs

An electronics company implemented CC/DFMA in a TQM environment and integrated CC/DFMA in the product development process. The reduction in parts achieved through the DFA analysis leads to reductions in the administrative expenses associated with maintaining, updating and creating a part number. Such expenses include, Becker [12]: Parts master, billing, quality effort/expenditure, bill of material, calculation, original inspection, technical drawing, planning, inventory, process sheet, test planning, incoming goods, procurement and spare parts.

Participants in DFMA seminars/workshops, estimate the annual costs for maintaining a part number in the master data to range from a minimum of 1,500 Euro up to several thousands Euros per year, Becker [12].

4. CONCLUSIONS

The benefits of the **V**alue Oriented **D**esign **S**ystem with the use of the CC/DFMA tools are: team building and teamwork, a reduction of product costs, assembly time, number of parts, weight, development time and time to market as well as enhanced quality, a standardisation of parts, complete documentation and a realisation of ecological requirements. The results of a automotive project shows, Schmidt [5]:

Less parts, less complexity, less costs, less weight, less logistics, less CO_2, better quality!

Its special benefit is the optimisation of the product development process and the creation of new innovative solutions. An analysis requires only a few days instead of many weeks or months of product development time. This renders value oriented design a powerful management- and teamwork-tool for the launch of new products and it closes the gap between design and procurement as well as integrating the suppliers into a strategic network.

5. REFERENCES

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