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Analysis of Product Development on Large-Scale Production with Multi-Criteria Approach

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The multi-criteria (MC) method is applied to the development of a large-scale product in the case of mid-price range washing machines using MC approach. The concept represents the method for developing a new product in the production process. The development of a large-scale product on the basis of MC analysis provides more accurate forecasting of the most important parameters in the centrefold of a multidimensional (MD) character in the way of customer demands, and important production and development restrictions are set in this MD environment with aid of MC analysis.

The production parameters are identified and through this, there is a possibility of reducing production costs. A forecasting method of production demands as possible result is powerful tool for achieving strategically and concurrent advantage.

Keywords: product development, multi-criteria analysis, forecasting, washing machines

0 INTRODUCTION

Continuous improvements produce competitive advantage, allowing a company to survive in the most turbulent environments [1].

But maintaining competitiveness appears to depend more on developing and managing a company's capacity for innovation [2] and [3].

Design and problem-solving activities [4], together with the construction of artifacts designed to satisfy various constraints [5] and [6] fall under the heading of creativity, even if not all such activities lead to radical innovations [7].

Great attention must be given to crucial manufacturing parameters. MD and MC analyses allow time-dependent parameters to be confirmed simultaneously, allowing more precise monitoring and forecasting of the future development of the product [8]. Liberatone and Stylianou [9] suggest that only 14% of innovations have significant success; the majority of new ideas never even reach the market [1]. Several authors [2] and [1] have shown that better management of innovation can increase the chances for success. Many companies wish or claim to be customer-oriented. But customer-driven product development (PD) is a demanding and difficult task. The voice of the customer should be taken into account in all the phases of PD, both in definition and design phases [10]. Therefore, customer-driven PD requires proper customer need assessment, which involves the systematic activity gathering and clarifying of customer needs, the determination of product characteristics based on these needs, and ensuring that all the important needs will be met [11].

Market-oriented innovative production systems require highly integrated information and fast adaption to market conditions. Modern computer-aided design (CAD) and computer-aided manufacturing (CAM) systems are tightly connected to ensure that CAD data can be used for optimal tool path determination and generation of CNC programs for machine tools [12].

In past decade, organisations came to believe that not all knowledge can be captured in systems. The role of knowledge workers is inwearingly recognized as crucial to organisation competitiveness. Nowhere is this more critical than in the fields of invention and innovation, which are central to the very nature of design [13].

The development of technical product to be produced in large batches must be properly targeted to meet the technical requirements of all phases of production. It is correct to claim that the more demanding a product is, the more the individual phases of the production cycle must be controlled and supervised. There are many methods for quality analysis, including ISO and DIN standards, which provide a well-developed and accurately defined framework for quality.

The washing machine is a domestic appliance that has dramatically changed the nature of home laundry. Before the invention of the

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washing machine, washing clothes was a tiresome household chore that required high physical exertion to get the clothes clean. Clothes were washed and cleaned by agitating them using a dolly, with short, stool-like legs, scrubbing them on a washboard and wringing them with a mangle. Many inventors were already looking for a means of harnessing either water or steam power to alleviate the hard work of washing clothes in the 19th century [14].

MC analysis in MD space provides product developers with a wide range of methodologies, which are well suited to the complexity of PD decision problems.

1 DEFINITION OF THE PROBLEM

Sometimes the best ideas come from outside a firm and, in particular, from end-users themselves. In care of some types of product, customers, but for other types of products can recognize and appreciate new solutions to their basic needs this is less likely. Unfortunately PD teams are often embedded in their corporate culture and view PD through the lens of their current products [14]. Table 1 reports internal data, which we are analysed in this paper and external data, which may be the subject of further research.

1. Von Hippel [16] suggests that some of the best sources of insight into user needs and potential product prototypes are 'lead users', customers to whom the product is at great importance. Lead users can have such a compelling need to solve their problems that they develop their own solutions. In some cases these users represent a very specialized market, but they may anticipate the needs of the larger market. Von Hippel also describes how to identify lead users, and how to incorporate their insights into the product design process in a five-

Urban and von Hippel [17] applied this technique to CAD systems; even through the conventional wisdom of CAD developers was that their systems were much too complicated for users to modify. In fact they found out that lead users who faced difficult problems had not only modified their systems, but had also generated significant improvements. For example, designers of complicated, integrated circuits had developed three-dimensional CAD systems that could deal with curved surfaces, multiple layers, and non-surface-mounted components. When 3D CAD software packages were developed based on these lead-users solutions, they were highly rated by the more general market.

Analysis of the functionality of CAD/CAM systems show that level of computer aided process planning in these systems is relatively low [18].

In the advanced product development MD methods are used such as software which provides assistance in comparing with the conventional two-dimensional graphs using a third parameter. In the model, that we present, the key parameter used is time, as all other parameters depend on it. These parameters form a space which has its own volume and centre of gravity, which changes over direction this time. The time-dependent character movement gives us the direction in which manufacturing of the product will progress, and shown how the variables changes in value over each time interval.

At a time of financial turmoil, it is also advantageous to take into account parameters which reflect possible changes in economic circumstances. The moment that the model used it is set of circumstances, relatively easy to find the focus, which is linear in nature and emphasizes the individual parameter. As time passes, data from the production can be integrated into the model, provided that new data are always on the same axis. Our analysis is the result of a several years spend monitoring real production data at a company which manufactures washing machines across a wide price range [18].

Developing a product using a process like a 'funnel', into which all information is poured, represents a traditional view, in which a concept is generated and developed into a number of potential products to be released. This funnel method is adopted involves the-the steps of identification of opportunity, as well as the creation of ideas to develop the concept, and the detailed choice simulated in design and engineering, testing and commissioning. Individual companies have slightly different descriptions of these steps, actuality is more or less the same.

With advanced methods, such as simultaneous engineering, it is possible to test a new concept in the early stages of product design. This saves time, which is in a competitive

situation, and yields a fast answer is to whether it is advisable to continue developing the product.

Many industries and businesses have recognized that it is much more effective to develop products that are based on platforms, which allow companies to adapt to customer demands and market needs with an MC approach [19] and [19].

The concept that includes a way of a form to capturing the data that is most important in the development of the product [21]. This data is drawn from the market and is usually in the form of requirements problem that need to be resolved [22].

Data collected from customers will not give specific answers. It merely predicts the most popular direction for PD, which is grounded on mathematical laws and statistical research. Customer data caused of small improvements and ideas, which come to the user or consumer when using the old product. The company must deploy sensible tools to recognise, collect and analyse these suggestions. This collected and analyzed data's and then entered into the model, which also contains the company strategy the limitation of the available technology, facilities, the wishes of the owners and the financial resources available. Potential new products are not just the creation of market requirements, but also depend on the ability of companies to produce them. The effect of ignorance or technological complexity on product development changes over time. MC analysis has undergone important developments during the last thirty years, as a result of the large amount of activity that it has generated and continues to generate. Regardless working on management information systems and decision support systems have recognized the important roles played by computer-based information systems in supporting managers in their semi-structured or unstructured decision making activities. Our study focuses on examining the structure of decision support systems research with a particular emphasis on assessing the contribution of MC decision making to the product development. Founders of decision support systems, such as Keen and Scott Morton [22] believe that the MC decision problem is at the core of decision support and 'a marriage' between MC decision making and decision support systems promises to be practically and intellectually prolific.

Product development is significantly easier if the problem is already partles solved by suppliers. This makes it cleaver how much is required development, and up to what point it makes sense to invest financial and other resources.

Products developed in this way are more likely to be successful in the market, since they have already satisfied needs of customers in their development stage.

Understanding the problem without using CIM is practically impossible, as there is too much information from the market, which can be hard to classify without statistical support. The computer initially facilitates the collection and analysis of data. In the next stage, the company can process the data in the context of an initial design, so as to clarify the direction in which the product should be developed. In combination with a business strategy, this can allow an interesting product to be brought to market.

Xu and You [21] observe that the planning and control of the PD process is based on early estimation of product design time, an effort at early stage. The same authors have established this fact for nonlinear systems with many uncertainties, which defy precise mathematic at analysis. There cares, a technology such as neural network or fuzzy logic are sometimes a good choice. Product characteristics are important parts of engineering factors; but product characteristics are not available before a design project begins. Do we must extract product characteristics from customer demands using quality functions and mapping methodologies.

We look at the development of a new washing machine from a design concept that contained both functional and non-functional features. Domestic objects are subject to constant evolution. Within a household the kitchen is involved in the continuing transformation socio-cultural models and is a strong candidate to reassume the central role in the house. Our present lifestyle rewards autonomic behaviour which creates a 'diffuse home', a domestic space in which specific and specialised functional sectors make no sense and are replaced by a different set of more integrated spaces and functions. A house, or 'home', is understood as an active space where people can live, work and socialise; whose components are relieved of their

rigid purposes in the search for a wider territory, and a more active part of the household functions.

2 MODEL OF MC ANALYSIS FOR ASSISTANCE IN PD

The idea of a MC analysis is presented in Fig.1 and in more detail elsewhere [21], so we only discuss the parameters which have a significant impact on of large-scale production of washing machines. We treat here variables within the concepts of CIM [1]. Time is an independent variable, on which most representative parameters of production depend.

Today's CAD technology, for example makes it relative easy to create tree – dimensional models of a part. However, simultaneously translating inarticulate customer tastes into a product concept, or a verbal product description into visual styling designs and numerical specifications remains difficult. Similarly, the timing of problem solving in consecutive stages of development, such as prototyping or tool building, and the number of iterations in the design-build-test cycle may affect the overall lead time and the productivity of development process [24].

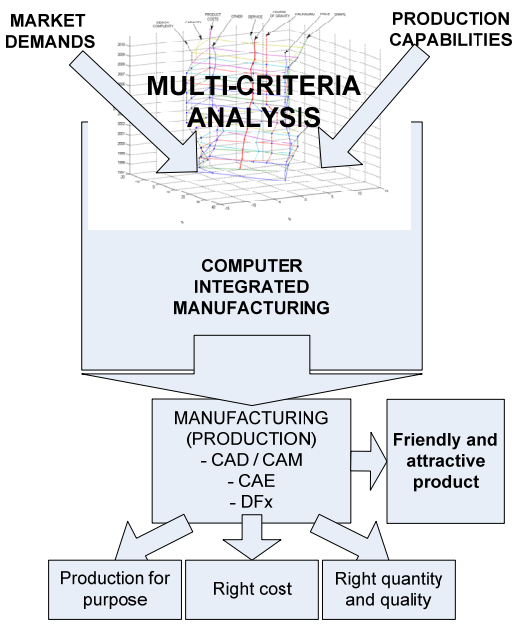

Fig. 1. *Design outline of model*

The final stage in the inward technology transfer process is the identification of a business opportunity for competitive advantage. This is the stage that allows an organisation to frap commercial benefit from the launch of a new product, an improved product, or a better manufacturing process. In science-based organisations a combination of credibility and respect, coupled with extensive informal and formal communications among individuals within the organisation, contributes to this internal knowledge accumulation process [25].

In large-scale production industries few companies are able to offer their researchers total scientific freedom, untouched by the demands of the market. Research and development programmes are must be focused on the business aspirations of the company and its future markets. These are usually set out using the most applicable technology. Inevitably there will be crisis, for instance when the competition brings out some new technology. At these times, there is usually full management commitment and money is made available to respond quickly. Here the inward technology transfer processes (as illustrated in Fig. 2) generally works well due to the commitment of all levels within an organisation.

Where technology is introduced on a more routine basis, a more measured decision has to be made about spending money on a prototype or a demonstrator.

This raises the question: what is the business need and who has the budget to address it and moreover, do they have money that can be diverted from something they are already doing to implement this new technology?

There is also an important distinction to be made here between science-based industries and other less capital-intensive industries. The vast majority of the businesses in the domestic appliance industry, for example, operate and manage manufacturing processes which are highly capital intensive and plant, when built, has a long life. But the building of a new plant depends on the future market; it sets the need for inward technology transfer and is the catalyst to bringing in that new technology. At these times, businesses tend to be very receptive to new technology, particularly during the earlier design of new plant, when there is a window of opportunity for bringing in new, but proven, technology. Internal research and development programmes are generally slightly in advance of

this and are engaged in proving the technologies which will be applied in the plant. Without this proof and qualification they would not reach the final application stage.

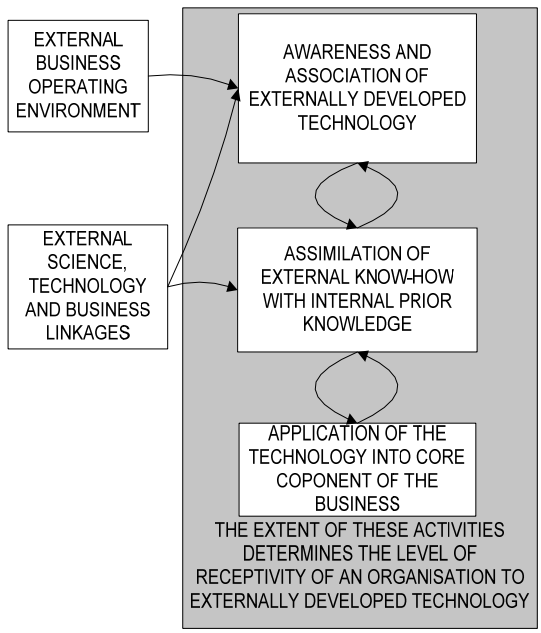

Fig. 2. *The inward technology transfer process [26]*

In addition to the internal processes illustrated in Fig. 2, there are the inescapable external issues which have been grouped together under the heading of 'external operating climate'. Presented model in this article explains how internal processes affect an organisation's ability to engage in inward technology transfer and contribute to the development of a receptive environment [26].

While each organisation conducts its activities in different ways, members of that organisation soon adopt the company's way of operating. Organisational know-how is captured in particular ways of working. The relationship between knowledge transfer between individuals and groups and the whole organisation may be expressed as two interlinked systems, as in Fig. 3.

In order for inward technology transfer to take place, members of the organisation must show an awareness of and receptivity towards knowledge acquisition. Individuals must be continually scanning the internal and external environments for relevant information that can be used to develop associations with internal knowledge.

Over time these associations, coupled with additional internal knowledge and with the aid of MC analysis, can lead to the creation of genuine business opportunities. The knowledge can then be said to be assimilated at the individual and work-group level. At this point the organisation has not accepted the change, nor has it learnt: knowledge has not been transferred, but remains within the work-group. However, the idea is implicitly accepted in its adoption by the individual and the group.

In order for the organisation to learn, the knowledge must be assimilated into core routines of the organisation. With use of CAD/CAM and CIM, a powerful MC analysis model can used to forecast the process of product development early stage of idea creation. That knowledge more accurately then becomes embedded in skills and know-how.

The separate analysis of data collected from different groups of users or production engineers in a model has been simulated within the field of domestic appliance design [27] and [30].

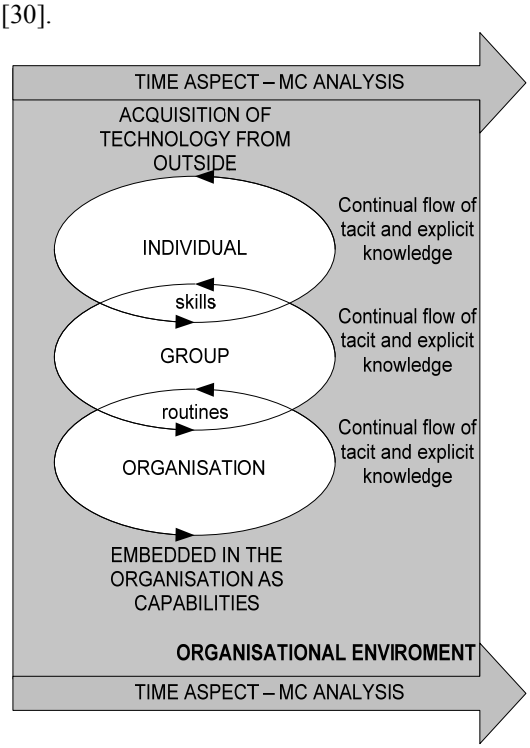

Fig. 3. *Interlinking systems of knowledge-transfer relationships with MC analysis*

3 CASE STUDY

There has not been any research on the theme of development of washing machines products with the MC method with the emphasis on production features. From the standpoint of production-engineering, field research is interesting because the product is complicated.

The sample data from which the MC analysis model for PD was prepared, included four time-dependent variables related to mid-price washing machines manufactured in Slovenia. The price-quality range was based on the opinion of experts concerned with different aspects of the production of washing machines and washing machines service [21]. The characteristics that were observed in selected washing machines were as follows: production costs, production capacity, stable production plan and product gamma complexity.

A questionnaire was used at a Slovenian manufacturer of washing machines and obtained the information contained in Table 2. The total sum of all the parameters in any particular year is completed, as only production is analysed - internal data. The observed data in 2003 represented half of the data for the total product. By the analysis of sales over the last decade can be concluded, that the product is already at a mature period of its development.

The impact of the product has been transferred from production to the consumer. Selected and observed parameters within intervals are not altered and have a constant position in the polar-coordinates position. The concept of data analysis is based on observation of the product in individual time periods. Forecasting future trends, is based on a static analysis of the approximated functions, and performed as a simulation of product development. The data that have not been empirically derived are subject to the assessment of experts in the field of washing machines. For example, in 2003, the characteristics of the product as seen by the company were as follows: the relative importance of production costs was rated as 30%, production capacity 48%, stable production plan 15% and product gamma complexity 7%. This combination of observations and the parameters covered is the focus of polygon character of observed features. Other observations require information which is harder to obtain outside the company.

In order to predict the characteristics of a product in the early stage of the PD, we prepare a systematic mapping method based on a house of quality. Customers have functional and technical demands: a house of quality is needed to map and measure the characteristics of the technical demands by means of a decomposition achieved by quality function deployment (QFD). This is an interactive process performed by a multi-functional team in the company. The pre-estimation of a product estimated by characteristics QFD are shown in Table 1.

The algorithm draws and calculates the coordinates of points in polar coordinate system for a specific period during the year n-1 and the adjacent variable, as well as during the year n+1 and the adjacent variable. The year was selected as the temporal resolution. In this sector the rate of change of products and technologies is typically relatively slow.

Table 1. *Factors in the development of a washing machine taken from case study*

Time factor set	*Factors*	*Unit*	*Expression – transformed in MC model (%)*
Internal information (production demands)	Production costs	Euro per piece	Numerical information
	Production capacity	Pieces / month	Numerical information
	Stable production plan	% of realisation / month	Numerical information
	Product gamma complexity	% of different product / all products	Numerical information
External information (market demands)	Price	Euro per piece	Numerical information
	Brand	Dimensionless	Linguistic information
	Energy efficiency	kWh	Numerical information
	Spin speed	RPM	Numerical information
	Load capacity	kg	Numerical information
	Etc...		

'Product excellence' is much broader than basic functionality or technical performance. Customers who have accumulated experience with a product become sensitive to subtle differences in many product dimensions, and demand an advantageous balance of numerous product characteristics, including basic functionality, aesthetics, semantics, reliability, and economy. The extent to which a product achieves this balance and attracts customers is a measure of product integrity [24].

Different types of products have distinct characteristics. For a specific kind of product, a list of time dependant factors with influencing weights can be determined by analysing existing production projects. In Table 1 shows a sample of most influential production parameters. External information is added to facilitate of further analysis but is not included in this case study.

Fig. 4 is a MD graph in which each parameter in Table 2 has its own dimension in polar coordinates. The movement of each parameter over time is independent of the other parameters, but they all describe a single product. For this reason, the centroid is a generic indicator of the movement of the production parameters for this product.

In the polar view of Fig. 5, the centroid moves in a particular direction to and a certain extent. Although production costs are of crucial importance, other parameters 'play' an important role and the centroid has shifted to the centre of polygon for analysed year, and balanced all parameters. This method tracks the trend and thus indicates the balance of design complexity. The design-for-method (DFx) allows a company to direct its efforts towards the designing of products.

By the simulation of various parameters using a model, a company can indicate the direction in which a product will be developed. Depending on the abilities of employees,, especially in terms of production, it can assess whether its investment in development makes sense and to what extent it will be profitable.

Table 2. *Production data's in % [8]*

Time (year)	*Production costs (%)*	*Production capacity (%)*	*Stable production plan (%)*	*Product gamma Complexity (%)*
2003	30	48	15	7
2004	33	42	16	9
2005	45	30	14	11
2006	46	26	14	14
2007	51	20	13	16

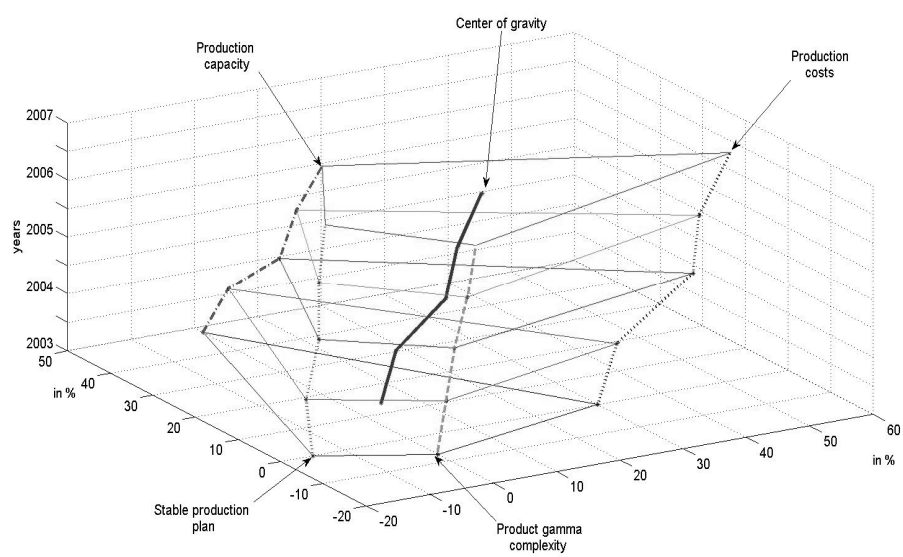

Fig. 4. *Product parameter focus for a large-scale product*

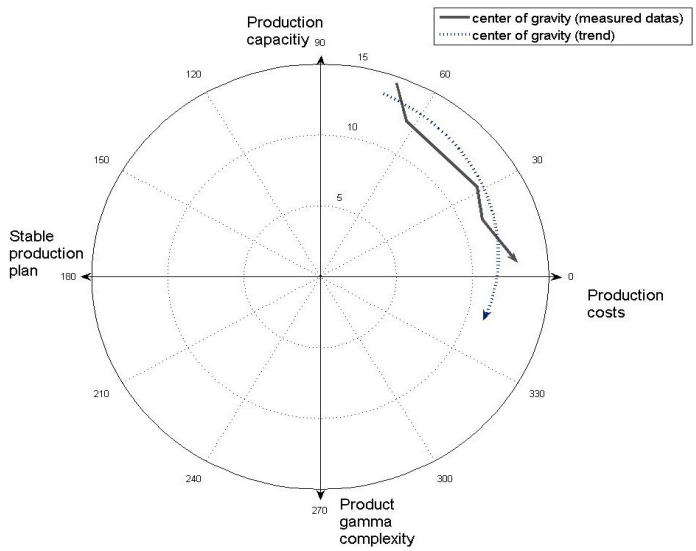

Fig. 5. *The polar centre of focus based on the observation of parameters over several years*

To directs product development appropriate makes sense to create a prototype and test it on the market. The impact of the tests can answer in detail, whether or not the prototype is appropriate for further development and potential production. An analysis of similar parameters elsewhere [1] also suggested that the market trend is towards product design. The key parameter is therefore the complexity of the design model, which emphasizes the use of 'different' external shapes, which be tested on the market. There might, for instance, be a commercial advantage in chancing a whole appearance of washing machines.

With the help of CAD/CAM, the DFx method can be the key to find new product ideas. The trend, which gives the answer in case of washing machines, is linear approximated. The movement of the centroid is spiral and extrapolating of this spiral would give a more detailed response to stress specific parameters at the time of analysis.

5 CONCLUSION

Future products developments can be predicted independent of current production capabilities. This gives much more flexibility. Reliable trends for the most important product parameters can be evidential that a route of product development can be established.

The life cycles of technologies, products and processes are becoming shorter, so it is very important to predict technology in planning [18]. An alternative form of product development can be based on the simple idea that a product at a given time is of various parameters an instance [1].

This concept can be applied to the development mid-range washing machines, which according to mathematical results and in accordance with time change, move from the direction of unexplored elements to the direction of product design [21].

In the presented model, the fulfilment of requirements within a company is not viable or technologically possible, capacities are not achieved or it is not in the strategy of the company. A graphic display makes it easier to show the direction of movement of the most important parameters within the company through visualization of the problem.

Using inputs from the process of generating ideas, analysis by lead users and MC concept selection, the PD team creates smaller set of high-potential product concepts. Following there concept gives the PD team result with great potential. This means linking engineering solutions to customers needs and vice versa not only on the analytical base but also on base of mathematical analysis of future trend. In this

paper we suggest further integration of the possibility of directly introducing CIM methods into the development of new products, and by forecasting the trends based on years of experience. This model of the developing products by multi-criteria analysis is useful for almost all involving products.

The gamma complexities of a product is the direction of linear trend, as shown in Figure 5, and suggest the diversity on and development of different products. The domestic appliance industry is based on product platforms. In the future trend it should be in building different product platforms with additional emphasis on reduction of production costs. In this direction the firms should invest in tools which are easily reassembled or outsource production.

Ultimately, MC product development translates production and customer priorities, as captured by a prioritized list of most important list of needs, into design engineering.

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