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APPLICATION OF AXIOMATIC DESIGN IN OPERATIONAL DEVELOPMENT

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ABSTRACT

Prioritizing plays a complex role in workprocesses, forming the vision, goals and strategies for the future. Axiomatic Design offers principles which can improve prioritizing. Therefore, Axiomatic Design was applied when creating an operational development model at one department of semiconductor manufacturing at Ericsson Microelectronics. This particular model includes all fellow-workers in the forming of vision, goals and strategies.

The procedure for carrying out an operational development at Ericsson Microelectronics is presented in this paper. One of the most significant results of this procedure was a clear strategy for the future, providing convincing arguments for financial sponsors.

Keywords: Operational Development, Axiomatic Design, Vision, Goal, Strategy and Competence Development

1 INTRODUCTION

New technologies are considered as offering significant opportunity for enhancing productivity. New technology is, however, solely one of a number of necessary prerequisites for such progress. More attention has been attracted by such factors as new methods of working, altered forms of organization, and competence development.

A common problem in design of organizations and operational development processes is lack of awareness and experience of systematic approaches. The result is that existing systematic approaches seldom are adopted. This far, studies from technological and organizational alterations have shown that technological changes tend to have higher sustainability than the organizational ones [Gest et al., 1996]. The sustainability of an organizational change tends to be dependent on a few characters in leading positions at the company. Thus, organizations are inclined to change as managers are replaced.

To reduce the strong influence of managers, Axiomatic Design and its principles for design can be implemented. Drawing up plans with Axiomatic Design principles is one way to facilitate strictly performing of the strategies. This, Nordlund [1996] showed in a study at Saab Military Aircraft in Sweden. Furthermore, bottom-up and top-down strategies become communicative by working according to described procedures. The present paper extends previous knowledge regarding the application of Axiomatic Design within the operational development and organizational field.

2 BACKGROUND

Microelectronics is a key technology for Ericsson. The products of Ericsson Microelectronics are widely used in Ericsson's own products and systems and those of other telecom manufacturers.

Competence is to acquire, use, develop and share knowledge, skills and experiences. This is the competence definition of Ericsson [Telefonaktiebolaget LM Ericsson]. Opportunities for competence development and learning can be provided in operational development. In a world rapidly changing knowledge, skills, and experiences have to be shared in a competitive organization. Working with systematic approaches is a way for Ericsson to ensure competitiveness.

2.1 ERICSSON MICROELECTRONICS SUBMICRON FACTORY

The Submicron plant at Ericsson Microelectronics, or 'fab' as it is known, produces integrated circuits for radio frequency applications. In order to stay competitive, such a 'fab' works with new technology like decreasing line-widths and features and increasing sizes of silicon wafers.

This particular Submicron 'fab' has been working with a non-traditional organization with just one manager and a new type of organizational chart, see Figure 1. The fabrication of integrated circuits is organized around six areas: diffusion, lithography, etching, thin-film, clean-up and defects. Integration, test, planning and logistics are competence functions supporting the fabrication.

The Submicron factory both produces integrated circuits and develops new processes (process of a silicon wafer from start to finished product). This affects the entire organization. It is always a challenge to prioritize between production of ready to sell products and development of new processes for new products. However, by working with systematic approaches prioritizing can be facilitated.

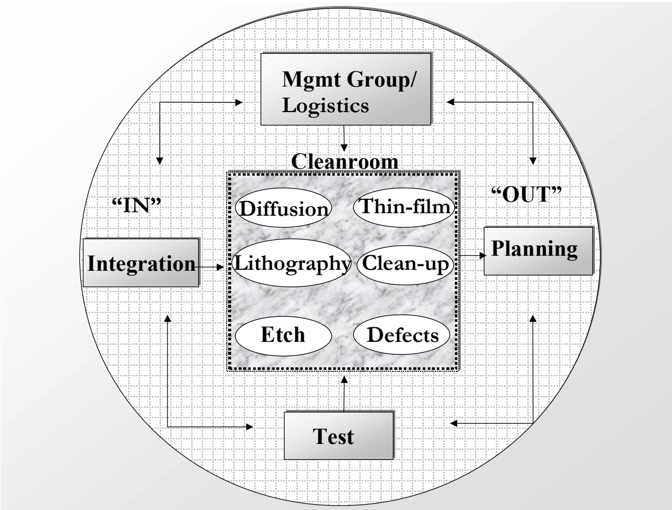

Figure 1. The organizational chart of Ericsson Microelectronics Submicron fabrication department [Adman, 1999].

2.2 PROCESS MANAGEMENT

According to Rentzhog [1998] process management is a continuous managing and improving of processes. The resemblance between managing of processes and quality management is stressed by Juran Institute, AT&T and Pall [Rentzhog, 1998]. Many quality tools and methods are today used in engineering. Some of these tools and methods can advantageously be adopted for use in process management, as can knowledge and experience originating from the field of quality.

Working with process management often requires a new focus. Therefore, dealing with why-, what-, how- and who questions has to be amended. According to Bergman and Klefsjö [1994] process management consists of the following steps:

Table 1. The Process management procedure according to Bergman and Klefsjö [1994].

Step	1 Action
1.	Organize for improvement. Define ownership and a process improvement team.
2.	Understand the process. Define the boundaries, investigate who are the customers and suppliers. Document the flow of work.
3.	Control the process. Establish control points and implement measurements.
4.	Improve the process continuously. Use the feedback from the measurement and control system to improve process.

Instead of continuous processes many companies, however, conduct projects when working with development tasks. Moreover, far too often logical solutions fail in comparison to 'political' solutions. In other words, the 'who says what' is more important than the contents of what is actually said. One method to overcome the political level is benchmarking, by which facts are compared on a neutral basis. Benchmarking as a method is, however, a rather time consuming process. Sustainable improvements should be supported by principles able to track answers and facilitate rapid and correct decision-making. Such principles allow logical improvement decisions.

2.3 SUSTAINABILITY FAILURES

There have never been so many sophisticated technical software programs as today to help us predict the future. However, the future is still not easy to forecast. Production systems are extremely complex involving changes in human attitudes and values. Many companies have failed to design sustainable changes, since they have taken selective measures instead of continuous developing the process as a whole. Senge et al [1999] write: "without better maps, it is extremely unlikely that organizational change efforts will ever sustain themselves. Each new adventure will be the first." The 'maps' for changes within organizations can be improved by using knowledge and skills from different disciplines and thereby provide insight into the entire system.

Excellent performance of process management requires implementation of all four steps in table 1, all of which demand continuous activities. These activities can be seen as parameters in a design case, for operational development. Step 4 can be translated into Senge's [1990] recommendation that one must remember to act like a gardener, when working with progress, allowing reinforcing growth and cutting back.

2.4 AXIOMATIC DESIGN: A MAP FOR DESIGN OF A LEARNING ORGANIZATION

Axiomatic Design provides principles for designing that make that process more effective. Efficiency in the design process can be assured by creating the proper prerequisites. This means 'getting it right' from the beginning instead of discovering the design problems when using the completed product, software or service. Following Suh's [1990] Axiomatic Design principles also allows us to track the answers to why something is created the way it is. It also enables us to learn from others' design processes.

Axiomatic Design has been shown to be applicable to problems outside the traditional field of engineering [Nordlund, 1996 and Moestam Ahlström, 1997]. For example, it is one map to use when approaching a learning organization. As Senge [1990] defines it, the learning organization consists of five disciplines: Systems Thinking, Building Shared Visions, Personal Mastery, Mental Models and Team Learning:

- Systems Thinking: The ability to discover and analyze connections as well as underlying structures in complex systems.
- Building Shared Visions: Developing and working with a shared vision.
- Personal Mastery: Developing of personal learning and maturity.
- Mental Models: Discovering and understanding of your own and other's mental models.
- Team Learning: Learning and communication to learn as a group.

Personal and organizational learning is facilitated by the application of the content of these five disciplines, according to Senge. However, acquiring a comprehensive view of a complex situation is problematic. In fact, most human beings can only handle a few parameters at a time. The principles of Axiomatic Design give opportunities for humans and computers to overcome more complex situations and consequently reach the right conclusions.

When analyzing changing procedures, Axiomatic Design principles can be used to include the complete system and its effects on the operations. Moreover, Axiomatic Design can be applied when predicting implementation. Axiomatic Design [Suh, 1990] provides principles simplifying decision-making based on actual facts, facts with data related to many parameters. To make decisions quickly and successfully requires both a good grasp of the overall picture and knowledge of procedure details.

2.5 PURPOSE OF THE RESEARCH

Assessment models, mainly emerging from the Total Quality Management movement, have been rendered into Quality Awards. The quality award models stress the importance of systematic and integrated development. Therefore, analysing the process of progress work is included when examining companies applying for the award. Zink [1999] presents how several award models measure employee oriented activity approaches.

Previous studies have underestimated the request for practical support methods for operational development. Consequently, managers on the front line are still battling to succeed with both key[1] processes and support processes. Thus, the gap between theories and practical implementation is evident. Practical guidance covering implementation of sustainable and systematic improvement work is requested. Here, researchers can play an important role.

Lewin, considered as the founder of action research, concludes: "Rational social management proceeds in a spiral of steps each of which is composed of a circle of planning, action and fact-finding about the result of action" [Westlander, 1999]. The model presented in this paper includes planning, action and fact-finding as well as structured participation of all fellow-workers.

Each fellow-worker should be faced with operational development daily one way or the other. Operational development is a concern for all fellow-workers, not solely for managers. Managers fighting against time schedules can gain time by applying process management. Thereby, managers can concentrate on future improvements. Sustainable improvements for the future are dependent on comprehensiveness of entire systems and correct prioritizing.

Despite complex systems and sustainable operational development methods being in their infancy, there are ways to improve progress work. This paper suggests application of the principles of Axiomatic Design when breaking down vision, goals and strategies. Thus, this paper extends previous knowledge available for overcoming the gap between theory and practice in this field.

[1] Key processes at Ericsson are for example the Time To Market-, Time To Order, and Time To Customer processes. Support processes are for example the Competence Management - and Management Planning processes.

3 OPERATIONAL DEVELOPMENT

In 1998, improvement potentials for the operations at the Ericsson Submicron factory were defined. To professionally approach these potentials for improvements, a model for the operational development work was created and applied.

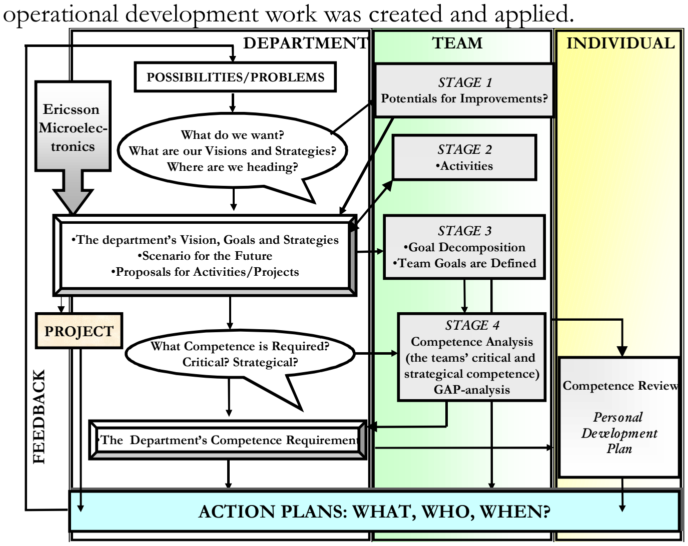

Figure 2. The model for Operational Development at the Submicron factory department at Ericsson Microelectronics [Adman, 1999]

The model for the operational development visualizes the parts played by the department, the different areas, and the individuals. Approaching a learning organization [Senge, 1990] requires that individual learning takes place. The individual, the areas and the entity of the department in its context must be part of the changes if they are required to last.

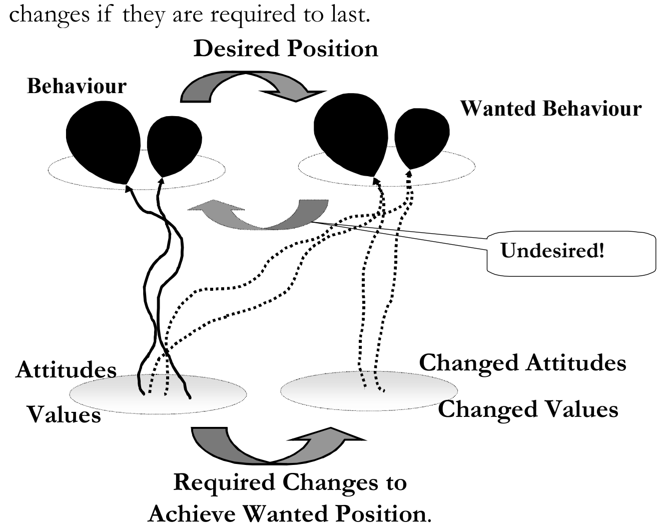

Figure 3. Lasting amendment work is depending on the fellow-worker's and organization's willingness to apply changed values and attitudes. Progress work means occasions for learning. Learning requires willingness, knowledge and opportunity [Werneman, 1999].

3.1 AXIOMATIC DESIGN AS USED IN THE CASE STUDY

Ideally, it is vital to know what technology to continue working with and what to abandon. -Still, one does not know.

However, by using the competence of all fellow-workers together with engineering methods, tools and models for organizational learning an organization can come closer to the right answer.

Jernberg and Tholin [1999] presents parameters of success in a study on future requirements conducted by the Swedish Institute of Quality. Parameters of success are: strategic work, value creating, organization, competence, handling of information, power of innovation, customer focus and culture. Customer focus is taken for granted by companies of world class, according to the study made by Jernberg and Tholin. It is so very evident that world leading companies do not bother to mention its importance. The requirements for reaching the top are: clear values, strict performing of strategies, perfect processes, carefully prepared co-operation, higher pace, attractive employer, creating value for owners, efficient technology for interactivity. These requirements can be divided into four customer categories as follows:

Table 2. The customers of an organization and the customer needs. [Based on Eklund, 1998]

The Customers of an Organization:	The Customer Needs:
The owners of the company/ The management of the company	Competitiveness
Business Customers	Quality
Fellow-workers	Attractive competence/ employability/ good working environment
Society	Sustainability

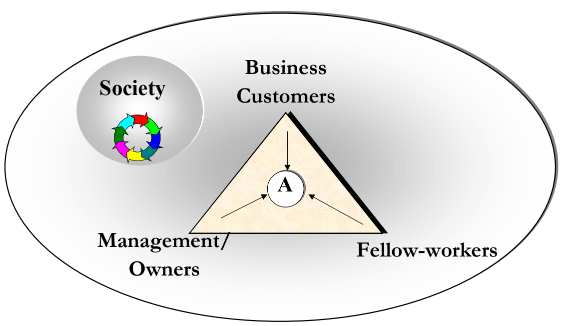

Figure 4. The customers of an organization are shown in the figure. Point A might be the point where the total quality losses are the lowest according to Taguchi's [Phadke, 1989] quality loss function curve. [Figure modified from Eklund, 1998]

Drawing conclusions based on the study of future demands [Jernberg and Tholin, 1999] should leave the customer more clear-sighted than ever. The customer is the management together with the owners, the fellow-workers and the business customers [Eklund, 1998]. Owners and management are interested in efficient organizations, the fellow-workers appreciate good work environment and the business customer values quality [Axelsson and Bergman, 1999]. Furthermore, society wants successful sustainable systems. The mentioned four categories of customers should be referenced when creating win-win situations. Creating win-win situations is one way of finding the point where the total quality losses are the lowest. The quality loss function curve applied by Taguchi [Phadke, 1989] enables target setting. The total quality loss function curve is proposed to be applied when the customer requirements, the functional-, and the design parameters, and the process variables are decided, according to Axiomatic Design.

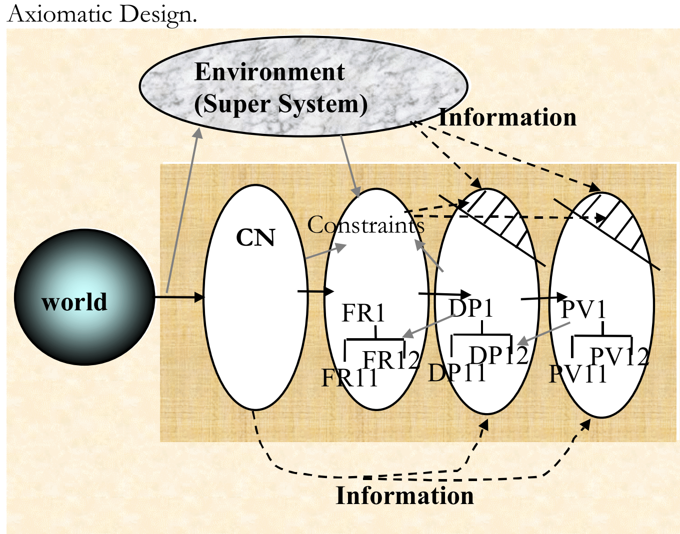

Figure 5. The Information Framework [Nordlund, 1996] (CN: Customer Needs, FR: Functional Requirement, DP: Design Parameter, PV: Process Variable)

Axiomatic Design principles are shown to be applicable to overcome the limitations of practical guidance on how to accomplish operational development systematically in daily work. Nordlund [1996] presented case studies where Axiomatic Design theories where applied in practice. Nordlund's The Information Framework clarifies the links between the different domains of Axiomatic Design, see Figure 5.

3.2 Vision, Goals and Strategies

Very few people in an organization are familiar with the total system of the company. Executive management teams need an 'upwards' stream – or rather communication – of input to be capable of setting the overall targets. In addition, the executive management team needs to convey the overall mission. Breaking down and refining of the vision, goals and strategies should take place in all levels of the organization.

The vision, goals and strategies constitute a significant part in change work. So do leaders. Replacements of leaders often cause discontinuous progress work. Therefore, clear vision, goals and strategies owned by the entire organization are important as well as Systems Thinking, Team Learning, Personal Mastery and Mental Models as suggested by Senge [1990]. Including the entire organization in designing, breaking down and refining of vision, goals and strategies provides learning opportunities. The leaders should furnish these occasions for learning. In return, leaders will get information that is more useful and an organization striving together for successful results.

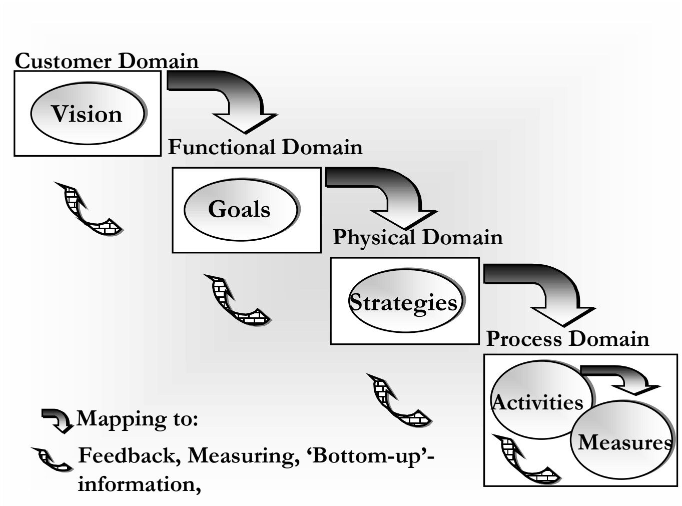

Figure 6. Mapping of vision, goals and strategies and the 'bottom-up' feedback presented in Axiomatic Design Domains [Modified from Adman, 1999]

Figure 6 presents an example of how Axiomatic Design principles were used in practice when working with vision, goals and strategies in a department. The zigzagging between domains is essential for the working procedure (see Figures 5 and 7). When using Axiomatic Design in the product design case, the design process is split into four domains. By asking the questions "WHAT should it be done?" and "HOW to perform?" one moves between the domains. When asking "WHAT?" the answer is found in the domain to the left and when asking "HOW?" the answer is found in the domain to the right. These two questions enable us to follow the designer's creation process.

It is crucial that the designer is well aware of the needs and demands of the potential users of the product or the system. Thus, firstly the customer demands must be known. The next stage is to translate the sometimes indistinct customer demands into specific functional requirements on the design. In the organizational approach, this is equal to the establishing of goals based on the vision.

When the functional requirements (goals) have been specified, the design solutions (strategies) should be dealt with. The last step in the design process is to establish production methods (activities), enabling the implementation of the chosen design solutions. Figure 6 presents a part of the overall work presented in Figure 2.

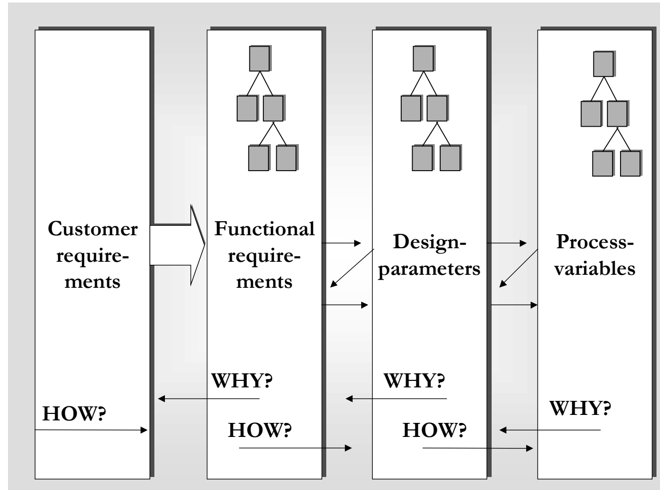

Figure 7. Questions asked in the different domains when mapping of vision, goals and strategies. In the zigzagging process, the question 'What' is asked to the domain on the left [Adman, 1999].

3.3 Overall Procedure

The overall procedure describes the work according to the model in Figure 2.

1. Potential improvements and problems are defined. A group is defined to co-ordinate the organization of the procedure.
2. The management group of the department communicates the coming procedure with the fellow-workers of the department.
3. The management considers vision, goals and strategies for the department. Groups[2] at the department propose future improvements and strategies.
4. Common vision, goals and strategies are decided. These are affected by the vision, goals and strategies of the company and by fellow-workers' proposals for improvement. A future scenario is communicated, discussed and refined. Improvements recognized as possible to deal with instantly become activities. Progress projects begin.
5. The teams break down the vision, goals and strategies of the department. Action plans are drawn up. Measurements and control points are defined.
6. Definition of required critical[3] and strategical competence.
7. Competence Analysis for the department and the teams. Action plans are drawn up.
8. Competence review for individuals. Action plans are drawn up.
9. Feedback
10. Back to 1.

[2] The fellow-workers were working in different groups during the procedure.

[3] Critical competence is the competence required for ensuring competitiveness today and in the nearest future, while strategical competence is the competence required for future competitiveness.

3.4 STRATEGIES FOR THE FUTURE

The process of working according the model in Figures 2, 4, 5, 6 and 7 resulted in vision, goals and strategies of the department, areas and teams, see Figure 8.

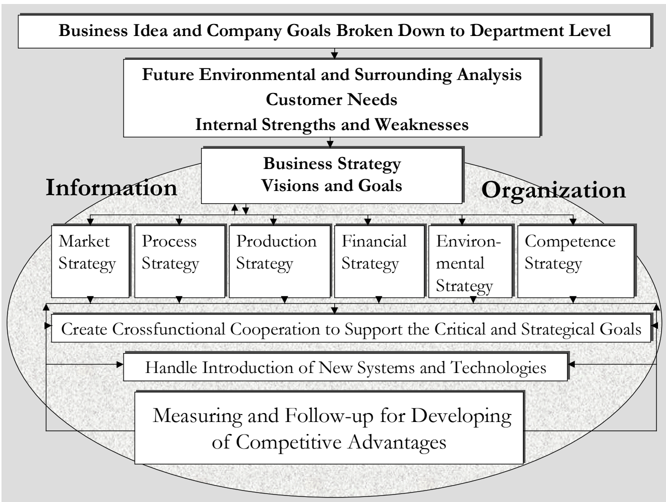

Figure 8. A 'map' of the vision, goals and strategies at the Submicron Fabrication department. [Source Michael Thulin, Ericsson. Modified by Kjellberg and Werneman 1998]

In the ideal case, each goal is supported by one strategy. Further, the strategy is supported by an activity. In reality though, operational goals often affect more than one strategy just as one strategy often affects more than one goal. According to the theory of Axiomatic Design, this is defined as a coupling, and considered negative to the design of the product or system.

An example of a coupling is when a production goal interferes with a goal of the prototype manufacturing. The prototype manufacturing requires valuable production time in the workshop. This conflict between production and prototype manufacturing is a *negative* coupling. If one strategy is changed, it affects the others if they are coupled. In the long run, however, prototype manufacturing, as being a part of product development, is essential for the competitiveness. When working according to the model in Figure 2, the model in Figure 8 and further detail information provide an understanding for the entity. Working according to Axiomatic Design principles can thus be a way of avoiding conflicts in daily work. Furthermore, the entity of the system provides a basis for a development of the system and work organization. The awareness of couplings should thus lead to better design of planning.

The above working procedure resulted in clear strategies for a complete department, providing all fellow-workers with arguments to realize the vision of the department. The strategies in Figure 8 are related to the customers of the organization and their demands. Consequently, there are arguments for convincing the different customers. An entire department with strong arguments for investing in their operational development is hard to neglect. Fellow-workers in a department with substantial arguments are also more likely to convince the upper management faster than a department without well-founded arguments.

In response to a survey, the majority (90%) of the employees at the Submicron Fabrication department expressed the need for clear goals in their daily work [Adman, 1999]. However, to appreciate clear goals, one must be able to influence the defining of these goals. This requires leaders' willingness to create an opportunity for this. It also requires knowledge of people's reactions to such a process. Having the opportunity to influence is not equal to 'having it my way'. However, by communicating and maintaining a dialog to reach continuous improvements increases the chances of sustainable changes. When starting such progress work it is of great importance to have the participation of all fellow-workers. Furthermore, it is vital to create real occasions for influence.

Firstly, the model of the Submicron fabrication department did not have an exactly defined task to fulfil when initiating the operational development. Secondly, the methodology was kept open and finally the expected result was not defined in advance. Such pre-conditions permits reflective learning to occur in daily work [Kjellberg and Kvarnström, 1996].

3.5 COMPETENCE DEVELOPMENT PROCESS

As can be seen in Figure 8, the department expressed a *Competence strategy,* based on the needs of the customers of the organization. The operational development model, shown in Figure 2, presents how the task of competence development is a part of the operational development.

There has been a growing interest in competence during the last decade. Competence once meant specific formal skills and practical experience connected to a certain work assignment. Today, many definitions of competence are applied. Nevertheless, a lowest common denominator for today's definition of competence is possible to detect. Firstly, competence is now defined as consisting of more than skills in a specific task. Secondly, social skills are an important component. Thirdly, the relationships between the different components have become a valuable aspect of competence. Fourthly, systematic work and learning are incorporated in the definition.

Competence as Kjellberg and Kvarnström [1996] define it is "Knowledge plus the ability to be ready to act just-in-time, and to undertake the proper actions." A central issue in competence is the different parameters affecting the competence. A competence complex model, designed according the SADT principle [Kjellberg and Kvarnström, 1996], indicates the variety of parameters influencing competence (see Figure 9).

The output of the process illustrated in Figure 9 can also be expressed as Nordstrand [1993] separates the outcome of a construction process into three components: A Final Product, A Financial Outcome and Knowledge. Thus, the outcome of Competence Management could be expressed as:

- final product: *competence*; abilities to act just-in-time with proper actions,
- the financial outcome: *competitiveness* (increased value of shares) and
- knowledge

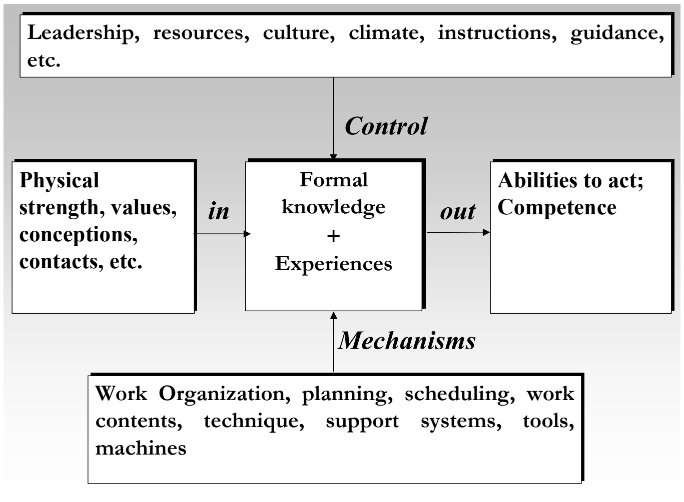

Figure 9. The Competence Complex], an illustration of parameters affecting competence [Kjellberg and Kvarnström, 1996.

To succeed in the planning of critical and strategical competence requirements also calls for a systematic approach. To realize the process in practice, the following order of achievements is suggested. Firstly, vision, goals and strategies should be defined. Secondly, team roles should be analyzed and defined. Then, competence analysis and planning can be successfully accomplished.

This order of performance gives a triangular coupling of the parameters affecting the result. The vision, goals and strategies must first be defined as they affect the team set up and the competence requirements. The team constellation can be changed without changing the vision, goals and strategies but a change affects the competence of the team.

3.6 THE PRODUCT REALIZATION PROCESS AND THE MODEL OF THE SUBMICRON FABRICATION PLANT

Organizational changes are often conducted as single projects. However, thinking of organizational change as a process is gaining ground. This requires regarding organizations as designed products.

An 'organization realization process' resembles the 'product realization process' as Sohlenius defines it, see Figure 10. There are obvious similarities between the product realization process in Figure 10 and the operational development model presented in Figure 2. Furthermore, the models can be used together when working in design processes.

The Submicron plant model is an example of how to ensure involvement and participation. Moreover, planning, action, and fact-finding are included. The model can be implemented both in the development of the product and production, in the creation of the process plan and when producing the product, see figure 10.

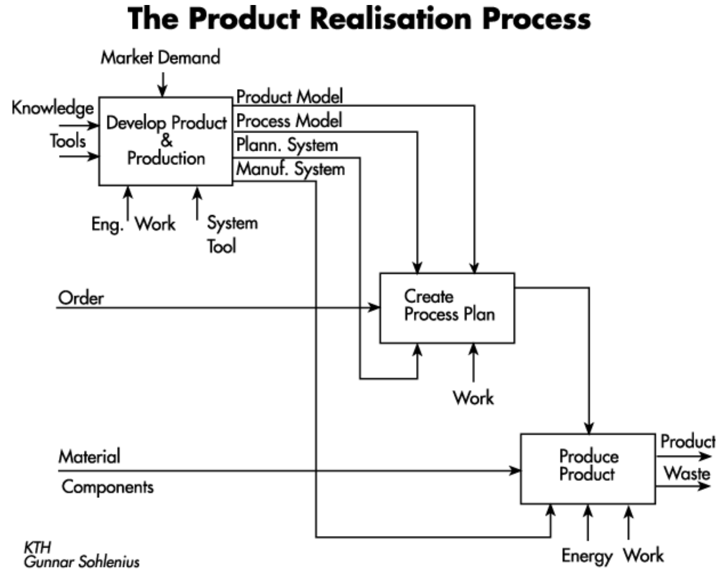

Figure 10. The Product Realization Process according to Sohlenius [1997, 1999]. An operational development work, such as the work at Ericsson Microelectronics, undergoes the same procedure as a physical product.

4 CONCLUSIONS

The procedure described resulted in arguments for fast decisions concerning changes for the future. This work allowed forming of vision, goals and strategies. The department formulated good arguments for investments in necessary actions to achieve competitiveness, competence development and attractive quality products. By using the competence of fellow-workers involved in the procedure, the arguments for what to prioritize became strengthened.

The principles of Axiomatic Design and process management have shown to be applicable when forming working procedures. Therefore, when creating sustainable solutions, the systematic approach of Axiomatic Design and process working should be applied to provide logical solutions. This enables the designing of operational development that is less dependent on single individuals. Thus, the accomplishment of sustainable changes is facilitated. Although, attempting to become a learning organization takes time.

The model in Figure 2 presents a procedure designed according to Axiomatic Design principles. The model involves all fellow-workers at the department and provides opportunities for building shared vision, discovering one's own and other's mental models, personal mastery, team learning and systems thinking. This enables the application of Ericsson's competence definition where *competence is to acquire, use, develop and share knowledge, skills and experiences*.

The strategies of the Submicron fabrication department in Figure 8 are products of the 'breaking down' process shown in figure 6. The strategies of the Submicron fabrication department fulfil many, if not all, of the success parameters found by Jernberg and Tholin [1999].

Applying the models in the figures and tables presented in this paper give advantageous prerequisites for practice and simultaneously providing opportunities for learning and influence on the working situation. Parameters for success are described in chapter 3.1 and practising the procedures described in this paper provides requirements for reaching the top.

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