TALAT
Training in Aluminium Application Technologies

TALAT Lecture 2110.02

Product Information Structure, Business Concept and Life Cycle Assessment

13 pages, 9 figures

Advanced Level

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Objectives:

- to give a brief introduction to the product information structure, a sustainable business concept and Life Cycle
- to present the product and process "Generic Code" - the chromosomes
- to generate interest about the concept of "Know Your Product", "Life Cycle Logistics", "Universal Virtues" and "Material/Component Hierarchical Structure" and their use creating a sustainable business concept.
- to impart knowledge about Life Cycle Assessment

Prerequisites:

- Be familiar with QFD (Quality Functions Deployment) principles

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Introduction

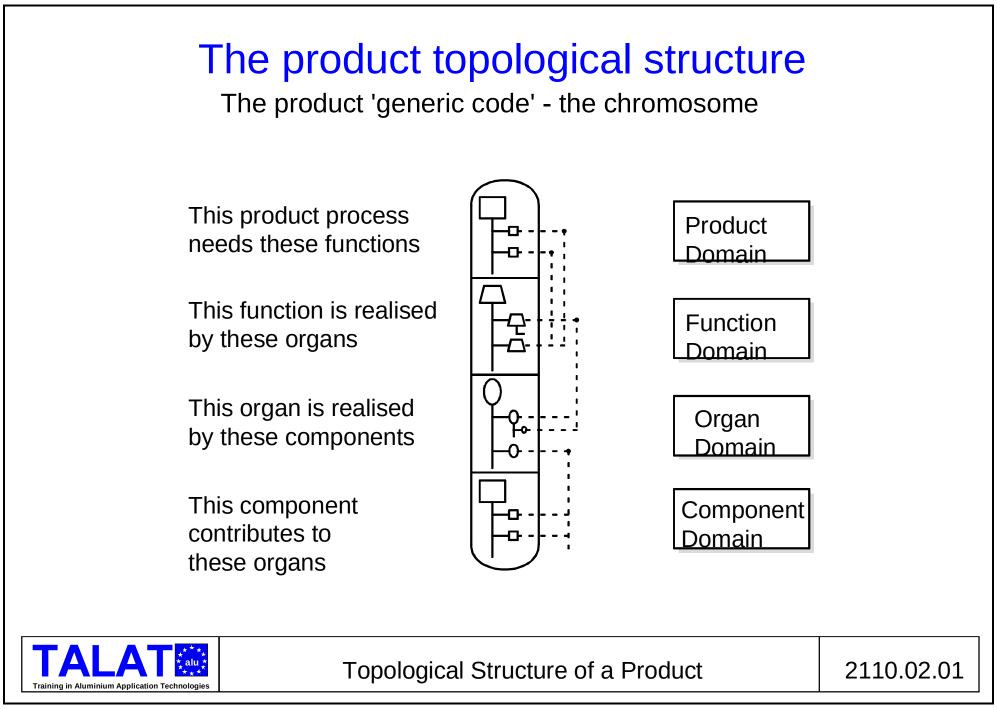
The development of competitive products demands knowledge about market demands, products and production processes. Product development is complex and existing products hold a variety of qualities that must be known to the designer and the company to attain success. The qualities that the product holds are linked to the product (consumer perceived **Q**uality - big Q) and the production (the production perceived **q**uality - small q). A thorough understanding of the product and the interdependent production processes will provide the basis for a successful business.

By use of an organised information structure grounded in the product and the production characteristics, respectively, it will be possible to get insight where and when competitiveness is located. In the following we will describe the product and process topological structures - "the chromosomes" as an introduction to a sustainable business concept.

The Product Topological Structure

During the process of product design, the "anatomy" of the product as a technical system is established. All the information about the product can be organised and connected in four levels, the theory of domains [Andreasen]. The levels are similar to the "generic code" of a biological system, and is termed a product "**chromosome**".

The domains embrace the total product process (the transformation), the supporting functions, organs and contributing components, as illustrated in **Figure 2110.02.01**.



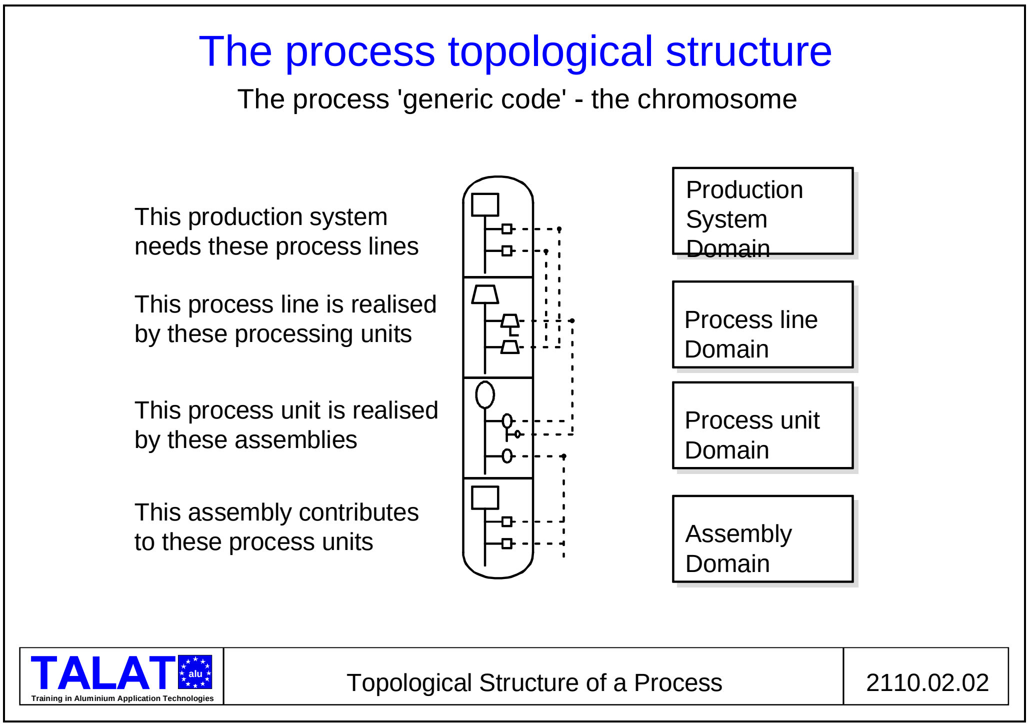
The **total product process or transformation** that the products perform is what the product is made for (e.g. moving goods or people from A to B). The total product process domain holds other sub-transformations (e.g. give controllable reduction of speed of an automobile) contributing to the total product process. Each of these sub-transformations is prescribed and solved by organising and connecting subsystems in space [Tjalve]. Each of the subsystems performs specific **functions**. They are expressed by a substantive and a verb (e.g. transfer braking power or allowing motion). The functions describe the functional properties of the product.

One or several **organs** (interactions between surfaces) realise the described functions. The organs will provide information about the interplay between the component's contribution to the realisation of the functions. Each organ may have different characteristics determining the functional properties of a subsystem. An organ may be described by its ability to create friction (e.g. the interplay between a brake rotor pad and the brake rotor). The last domain is the **component** level consisting of an organised and interrelated system of components in an assembled structure.

A complete product information organised in the chromosome, will provide necessary insight and expose key competitive parameters within each domain contributing to the total product process and indirectly the consumers' perception of the product.

The Process Topological Structure

Simultaneously to the creation of the product the related production characteristics are determined. The production system is determined at different levels/domains similar to those of the product structure. The structure of the information system, "the process chromosome", provides the total information of the processes that are needed to create the product. The process chromosome is illustrated in **Figure 2110.02.02**.



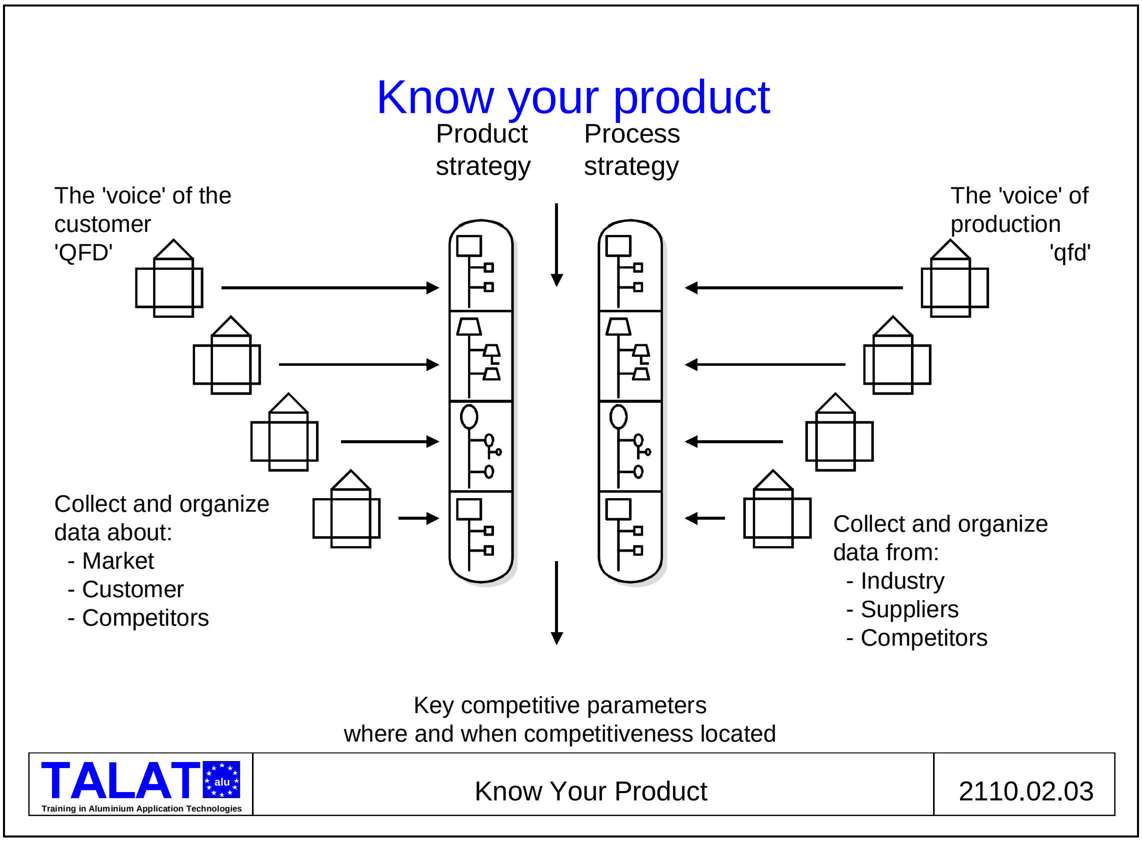
During the process of product design, the processes in the production system are established. The **production system** describes the production network and system that produce the product in production. The product organisation holds different **process lines** that produce the different subsystems to the specified system (e.g. wheel system production). The different processes that contribute to the process line are described as **process units**. The brake rotor needs to be cleaned and machined before it is assembled to the wheel system. The process units' activities prescribe the characteristics to the organs (e.g. cleaning and machining of casted components). The lowest level of the production system is the **assembly** of the interrelated system of components. The assemblies contribute to the process units.

A complete process information organised in a chromosome hierarchical structure will provide needed insight and expose key production parameters contributing to the performance of the product.

Know Your Product

The product has an operational life time and the quality of the product is the user's perception of the product, related to how well the product performs its "transformation". It may be in absolute terms, related to the users' expectations or his comparison with the competitors' products. The users of the product can be customers or company internal "employees" that meet the product respectively under its use or its production. **QFD** (**Quality Functions Deployment**) is a systematic method to investigate the customer's perception of the product. Data about the market, customers and competitors are collected and organized to get a true insight where and when the competitiveness in the product is located. The **QFD** procedures and matrixes correspond to the domains. A similar approach to systematize the productions' critical parameters as an underlying basis is the use of **qfd (quality function deployment)** collecting and organizing the small-**q** information. The small quality function deployment is the similar procedural approach as the more known big-**Q** tool revealing the productions' perceived quality. It includes collecting and organizing data from industry, suppliers and competitors to reveal the critical production parameters for the product in production

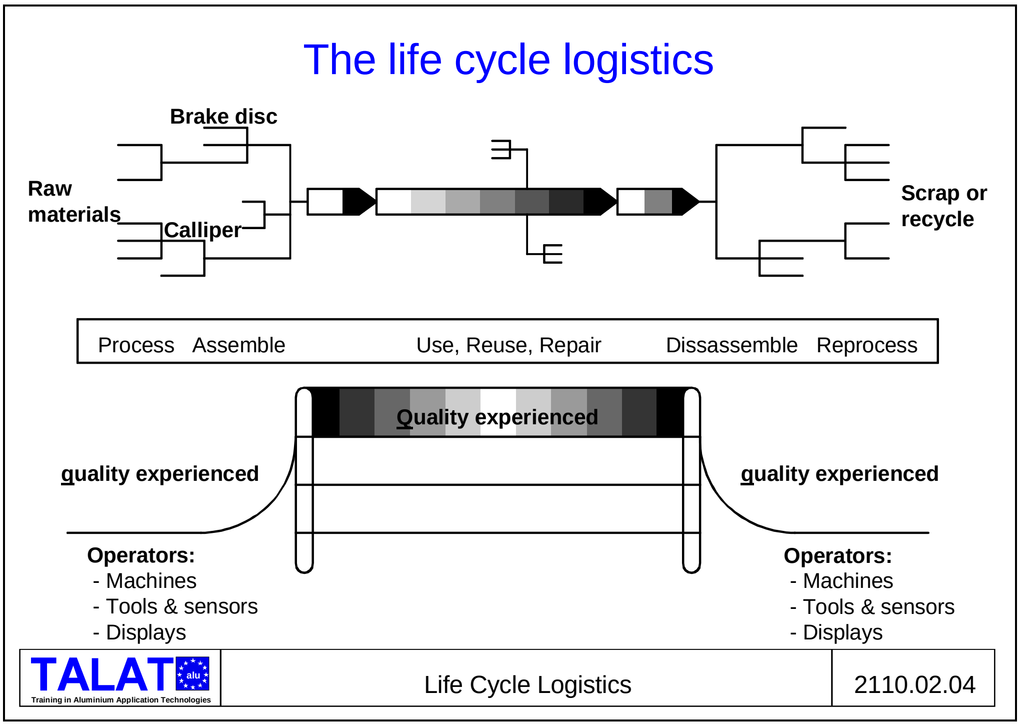
By the concept "**Know Your Product**", as illustrated in **Figure 2110.02.03**, we understand a systematic analysis of a product in production, based on the chromosomes, with the purpose to identify where the **competitiveness** of the product is located. In this way the innovative effort can be directed toward what is of real value for the society and the individual user.



The Life Cycle Logistics

In the design and product development process, from idea to production planning, the designer has to make decisions about the shape, dimensions, surface and production of each component, including material selection and the processing route. The components and the subsystems have a "life" before they are a part of the product. Also, after the functional life of the product, the individual subsystems may be discarded, reused or reprocessed. So each component has a "life" after the "death" of the product itself. By letting the "product chromosome" follow the product during its operational life, the history of the product can be monitored in a systematic way; the operational practice, the mechanical, the chemical and thermal loads, accidents etc. Likewise, any changes of the components, organs and functions, due to wear, plastic deformation, cracks, changes in material properties can be followed through the life of the product, as well as replacement and repair of components or subsystems. The "process chromosome" operates before and after use, respectively in production and after use when the product is reprocessed.

With the concept "**Life Cycle Logistics**" we understand the information about the geographical transfer and all the information related to the components at the different stages of its life from "cradle" to "grave". This is illustrated on the Figure **2110.02.04** above the "chromosome".



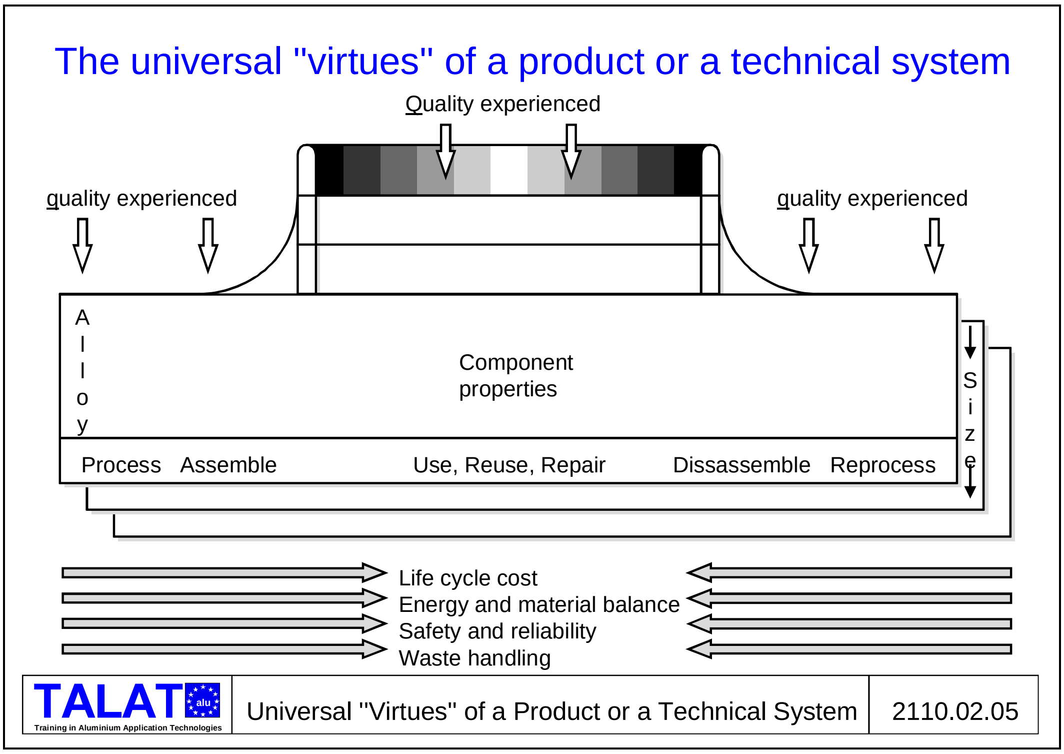
Knowledge of the life cycle of the components and the product serves as a basis together with the QFD and qfd procedures for design of products, considering the life of the product and the interdependent environmental impacts.

The Universal "Virtues" of the Product or a Technical System

Seen from a global perspective, where one estimates that the population will increase to about 12 billion in the next 100 years, and we want that every one of these persons should live a worthy life, we have to have a measure of each product to test if the one **is more sustainable than the other**. With "sustainable" is understood that the product, the materials and processes used, the production, functional and recycling practice, as well as the life style related to the product, can be used or practised forever in order to improve the quality of human life within the carrying capacity of the supporting ecosystem. The "universal virtues" are measures that can be used for a product, a subsystem or a component, in order to assess the degree of sustainability of a product or a component compared to another. It is obvious that we do not have a unique way to make such a ranking of materials, processes, product and practices. But everybody should think about it and do as best as he/she can. Improved sustainability can be "designed" into a product. We look here for measures which the designer can use to "**design for sustainability**".

Such measures are described at the lowest part of **Figure 2110.02.05**. They are:

Life cycle costs
Resource consumption: energy & material balance
Safety & reliability
Waste handling



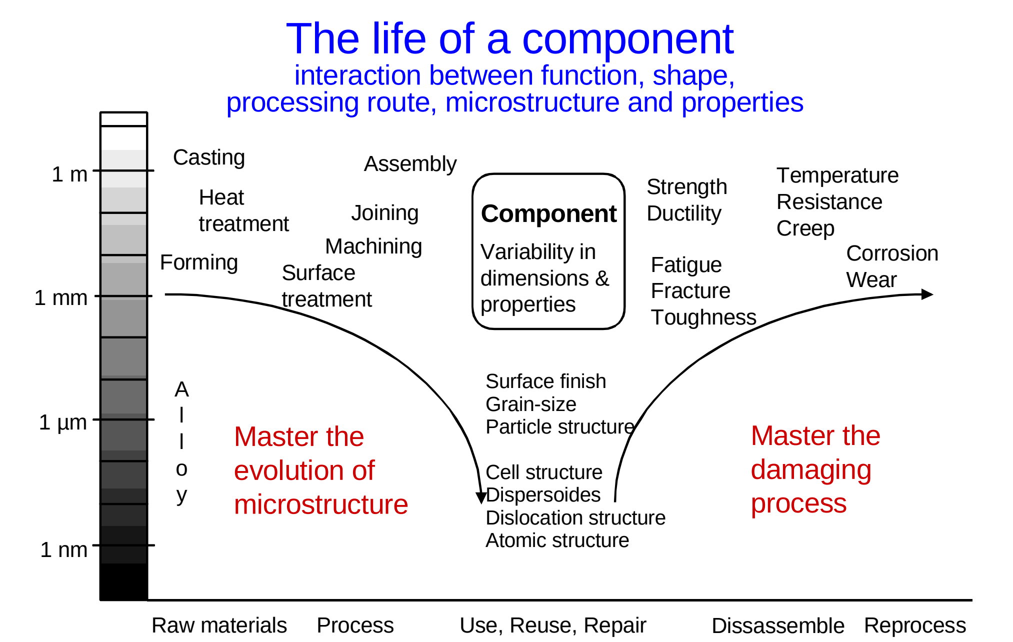
These measures have to consider time steps in the life of the component and the product, including the source of raw material and all the equipment and chemicals used to process, use and recycle the product. There is a great need for structure and quantified information as well as theories and methods for such evaluations.

The Life of a Component - Interaction between Function, Shape, Processing Route, Microstructure and Properties

In the search for improvements of critical properties of a component, it may be useful to organise the information related to this particular component as shown on **Figure 2110.02.06** [Støren].

The horizontal axis represents the life time of the component, the scale is not linear in time, it represents the main stages in the life of the component.

The vertical axis represents a logarithmic scale. The distance between the two vertical lines gives the dimension scale that the figures or the phenomena operate at that vertical position. At the bottom of the scale, we have the atomic level, dimensional scale 1nm (nanometer). At the top the scale is 1 m, representing the size of the component. At the top of **Figure 2110.02.06**, we are at a global scale, reflecting on the global need and sustainability of the component, the dimensional scale is 1 Mm.



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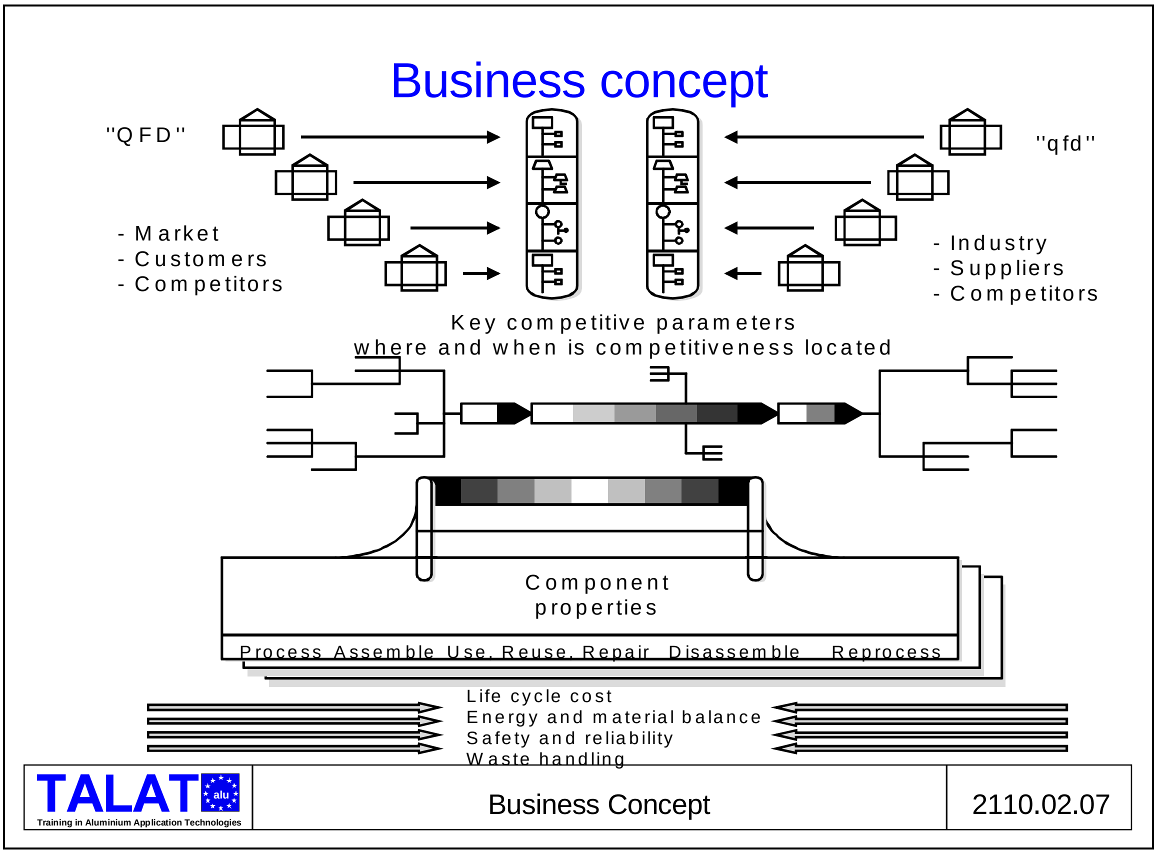
This representation is particular suited for studying and modelling the relation between alloy constituents, process parameters, microstructural evolution and the many properties of the alloy-component-system. In computer databases, often 50 or more properties of the material are given. These properties come from the same microstructure, some are very sensitive to the microstructure, other properties are not. By a representation given as above we can **focus on the critical properties for the given shape and dimensions** and identify its source at microstructural level, and then trace back to processing parameters or alloy constituents.

A Business Concept

By the "chromosomes", the "life cycle logistics", "the universal virtues" and the "material/component hierarchical structure" a complete product, process and market information are established. The combined use of the "Know Your Product" concept, the life cycle logistics and the material/component hierarchical structure constitute a **business concept**, that is well suited to expose the competitiveness of the product in production and the company's business as a whole. The concept is illustrated in **Figure 2110.02.07**.



Knowledge about critical technical, economic and ecological parameters will provide a foundation for the creation of a business concept using daily business performance indicators as input to develop **market, product and production strategies**. The output of the analysis will be knowledge about these key competitive parameters and future areas of emphasis in the **design process**.

The business concept structure demands well-organised data within all categories, a common understanding of sustainability, accessible technological, ecological and economical data besides a commitment from individuals involved. A common knowledge and information database will provide input to the different assessment tools providing data to the business concept. These assessment tools are:

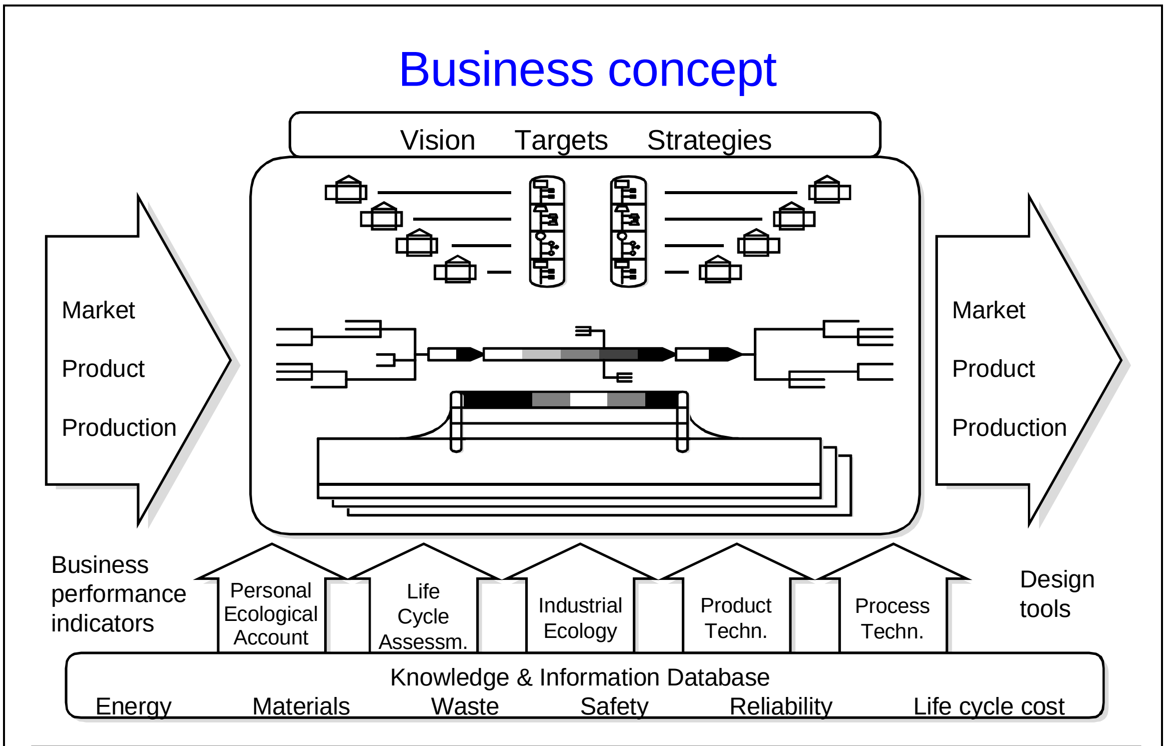
– A **Personal Environmental Accounting** system that analyses each individual's consumption of products and services. The consumption of product and services are a major source for improvements besides the importance of environmental consciousness among designers and users of products.

– The **Industrial Ecology** assesses the interactions between the industrial man-made system and the natural system evaluating flows of materials and energy between them.

– The **Product Life Cycle Assessment** includes analysis of the environmental impacts the product and belonging processes dictates in addition to improvement's analysis.

– The **Product and Process technology assessment** evaluate, respectively, the product and process technology that is necessary to satisfy the economic and ecological demands.

An overview of the business concept, the assessment tools and improvement activities is illustrated in **Figure 2110.02.08**.



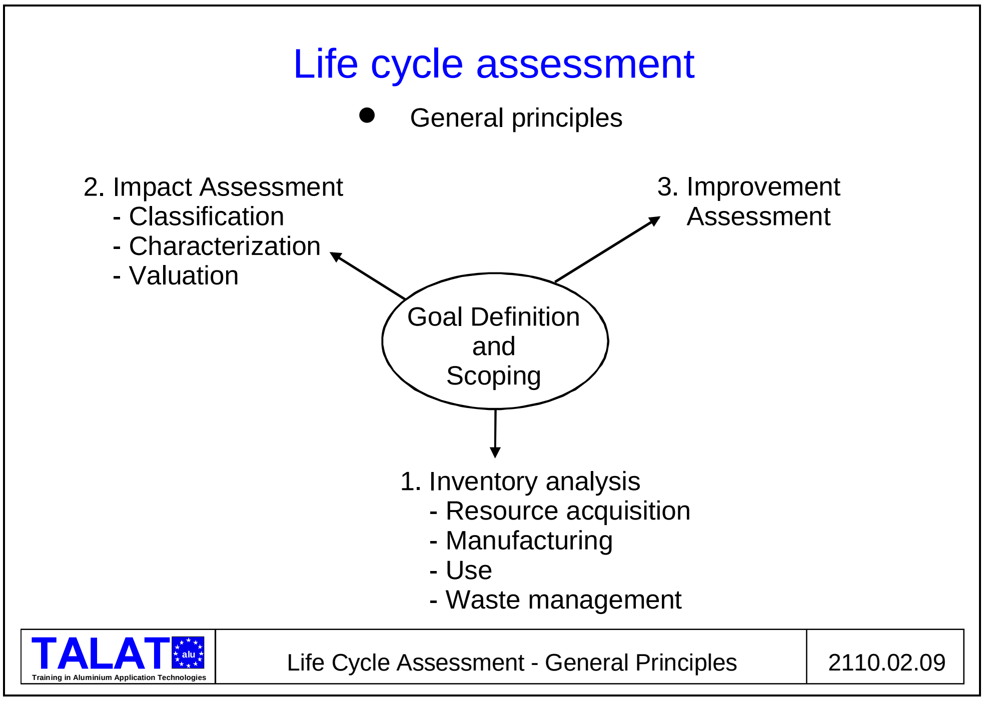
Business Concept (2) 2110.02.08

The business concept structure is well suited for computer software programming and visualisation. Within this environment, "design for sustainability" should be carried out. In the Nordic countries the first step is taken in this direction by the development of the software ALULIB/ALUBOOK based on the "chromosome" concept. (SkanAluminium project "Design with aluminium")

Life Cycle Assessment

The life cycle assessment is an objective process to evaluate the environmental burdens associated with a product, process or activity by identifying and quantifying energy and materials used and wastes released to the environment, to assess the impact of those energy and material uses and releases to the environment, and to evaluate and implement opportunities to affect environmental improvements. The assessment includes the entire life cycle of the product, process or activity, encompassing extracting and processing of raw materials, manufacturing, transportation and distribution, use, re-use, maintenance, recycling and final disposal. **LCA** is:

A scientific analysis and evaluation of potential environmental and health impacts of a product system, throughout its entire life cycle.



The LCA includes three steps which are inventory, impact and improvement assessment, see **Figure 2110.02.09.**

Life Cycle Inventory is an objective, data-based process of quantifying energy and raw materials requirement, air emissions, waterborne effluents, solid waste and other environmental releases incurred throughout the life cycle of a product, process or activity.

Life Cycle Impact Assessment is a technical, quantitative and/or qualitative process to characterise and assess the effects of the environmental loadings identified in the inventory component. The assessment should address both ecological and human health considerations, as well as other effects such as habitat modification and noise pollution.

Life Cycle Improvement Analysis is a systematic evaluation of the needs and opportunities to reduce the environmental burden associated with energy and raw materials use and waste emissions throughout the whole life cycle of a product, process or activity. This analysis may include both quantitative and qualitative measures of improvement, such as changes in product design, raw materials use, industrial processing, consumer use and waste management.

Product development or product design consists of different phases, which can be structured in a variety of ways. Market, process and product analysis serve as input to the development activities: concept, form design and detailing. In each phase different decisions are taken regarding the product and the production, selecting the best solutions. The best solution can only be determined when the designer has access to necessary data and when he/she is able to use the data as basis for trade-off's, sensitivity and error analysis. The found key competitive parameters should be focused and handled along with all acting parameters. A successful product assessment involves quantitative and qualitative aspects considering ecological, technical and economic problems in all development phases. Life Cycle Assessment serves as a basic tool to analyse the product in production or as support to environmental sound decisions in product development.

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List of Figures