Managing Product Development

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ABSTRACT

Any economy is based on the production and consumption of material or immaterial goods. Development is the process that creates a concise concept of a product. To develop good products within a given frame of time and resources is one of the most challenging and most important tasks within an economy. We state the common features within development project management for several different kinds of products. Most general issues are the model transformation and decision making process at phase transitions.

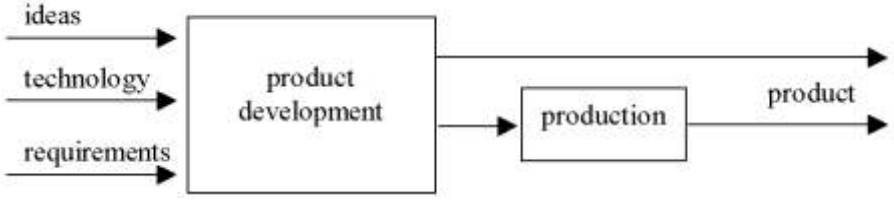
Key words: Management / development / product development

1. Development

Innovation is a vital ingredient of business success (see De Beer 2002). Product development is the core of innovation. Development of something usually means that this object is evolving. When we talk about product development, we consider the product to be created by this process, but the description of the products evolves from an idea to a concise description.

1.1 Development process

Development creates the exact and unambiguous description of a product. This product may be final and given to a customer or it may be a blueprint to multiply or produce several (up to millions of) identical products. In any case, development is the crucial factor for the products success.



The development process creates a description or product

Within development we subsume all the phases that comprise the way from ideas and requirements to the decided product description, leading to an implementation phase that may comprise production activities for physical products.
Engineering and handcrafting are two metaphors that describe the approach to product development. While engineering focuses more on the systematic and scientific part of the task, handcrafting focuses on experience and transmitted knowledge [software handcrafting].

1.2 Product and customer

ISO 9001 defines the term “product” by a list of four cases:
Product classes of ISO 9001

product case (ISO 9001)	characterisation	
service	intangible, immaterial (although with a material carrier or component)	interaction with the customer
software		program/ information
hardware	tangible, material, physical properties are characteristic and important	countable, identifiable
processed materials		continuous (weight, volume)

Product is any good that has been created (developed and manufactured) for somebody's use. The product comprises anything that is needed to use it: documentation, supporting tools and spare parts. The supporting infrastructure is an important factor for the success of the product.
An individual product is produced in one item, typically for an individual customer that is known a priori. Mass products are produced in several items for an unknown customer.

	individual product	mass product
service	personal service, consulting	transportation, event
software	customer individual software	standardsoftware, browser
hardware	plant, machine	screws, food products
processed materials	special chemical products	gasoline, drinks

Individual and mass product

Also systems (organisation, logistics, production, servicing) should be considered as products as long as their development is a planned one. Products may also comprise of a combination of HW/SW and supporting system or infrastructure.

physical component	sevice componente	additional benefit
computer hardware	software, installation	use for games or videos
slides	lecture	social contacts with students
scissors	haircut	movie, social contacts

Product combinations

Customer

When dealing with the concept of a "customer" we have to consider his various roles:

- consumer, user: This is the one, who has immediate contact with the product.
- buyer, purchaser: This is the one, who has to pay directly (payment, cash flow) or indirectly (cost responsibility, cost centre manager).
- decision maker: This is the one, who makes the decision whether to purchase a product, selects which product should be bought and prepares the purchase order.
- stakeholders: These are all people, who benefit from the product and initiate the purchase but also all people that are influenced by the product in a positive (secondary benefit, indirect use) or negative (environmental impacts, competition) way. A lot of stakeholders influence the success of the product.

Benefit

The customer's benefit from a product can be separated into primary and secondary benefit. Secondary benefit is any factor that customer will esteem but which is not the primary purpose of the product. Typical secondary benefits are image, cultural identification, environmentally friendliness. Also an alternative use of a good may lead to a secondary benefit. Brands combine an identification function with a promise for quality and a lot of secondary benefits.

In Economics, the corresponding term is "goods" which comprises raw unprocessed resources as well as products. In an evolving economy, unprocessed goods from the primary industrial sector are becoming more seldom and less important. Most times, value is generated not from taking these raw materials (mineral and organic) from nature but from processing them or adding value via services or other benefits.

Even classical goods are becoming product by adding value. This will be a chance for the primary sector. In Germany, direct marketing is becoming an important source of income for farmers, but it will work only, when supported by added customer benefits such as brands (eco-label) and events.

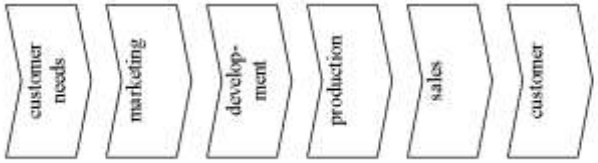
Area	basic goods	products	added value/ benefit
farming	grain/cereals	cereals, meal	processing, information, wellness
animal farming	meat	meat, meal	hunting, direct marketing, brai
tourism	landscape, nature	touristic site or trip	information, activity, event
mining	ore/ metal	any metal product	fit for purpose
Drinks	beer	glass of beer	environment, entertainment
fashion	clothes		life style, image
Any	any	brand	reliability, image, quality

Goods and Products

The question one should ask when designing successful products is clear: "what is the customer willing to pay for?". The answer is not unique, it depends on the needs and on the economic situation of the customer as well as on his cultural environment.

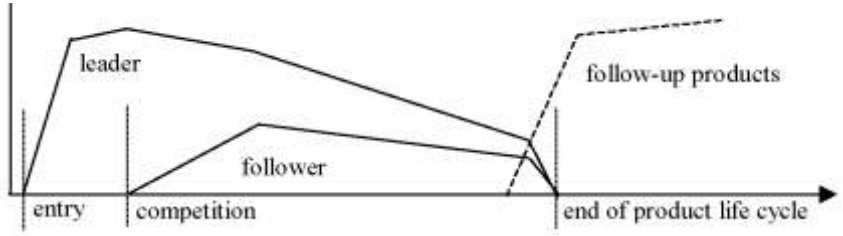
1.3 Time to Market

An important success factor for products is the time, when the product becomes available for the customer. If the time from customer's problem identification or from the technology making the solution possible to the point where the customer has access to the solution is too long, the product may be obsolete either by competition (other company's solutions) or by substitution (other ways of solving the problem).
The basic model is the following:



Tme-to market: from needs to satisfaction

In the best case, the product can be sold on the market. In any case, the follower must work with a lower price and has to fight for his market share against the leader whose product has good chances to become a brand.



Schematic turnover for leader and follower during the product's lifecycle

1.4 Phases

One of the most helpful tools in development management is the introduction of phase concepts that allow to correlate activities with decisions and documents over the curse of the development process. Any phase has its documents (models) that are created or transformed according to the decisions made within that phase.

Any development project has a set of phases that leads from a requirements analysis (needs) and feasibility research (potential) over several design stages to the final product. Most important for a successful development project are the early phases, where goals, requirements and ideas are compiled. The consequences (cost) of an error are roughly multiplied by a factor of ten for any phase the error is made earlier or detected later.

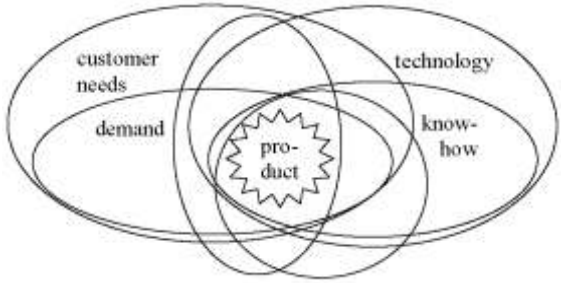
A product is finally developed only if it is approved and tested. Hence, any development phase concept must contain implementation, integration, verification and validation phases.

Product definition

The customer's needs lead to demand, which is that fraction of the needs that a customer is willing to pay for their fulfilment. To know the demand for a product is the task of market research, to turn needs into demand or to create needs is the task for sales and marketing.

The feasibility study must make clear which solutions are possible from physical restrictions and which solutions the company can handle (if necessary which the help of subcontractors). At this point, also legal restrictions or normative regulations must be obeyed.

The intersection of demand (What is needed?) and potential (What can we develop?) with the norm (which products are admissible?) defines the range of possible products.



Product definition: the intersection of many conditions

Requirements and specification

Since the product is developed to satisfy the customer's needs, it is necessary to collect and understand all customers´ needs and to turn them into product requirements. This can be done, e.g. by use-cases, by interface and function requirements, and by specifying the properties and reaction of the system.

The first transformation step leads from requirements (what the customers need) to specification (what the system should be). The more flexible and general requirements are formulated, the more freedom the developer has to choose the technologies and parameters of the system to be implemented.

Design and development

The specification only describes those external properties of the system that are necessary to fulfil the requirements. Their is a lot of freedom for selecting product properties and implementation details. Sep by step the specification is converted to a concise description of the product (plan, program, construction).

Implementation and integration

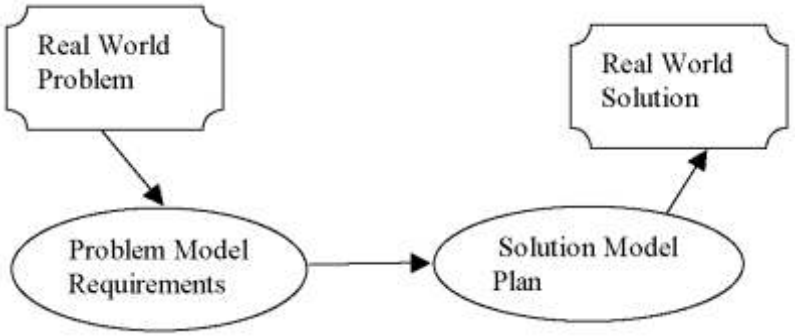
Creating the physical product and bringing it to its real world environment and to the customer is the step of implementation or production. For physical products, tools and a production plan must be created, products will be produced and stored. Software must be compiled and integrated with the hardware components or multiplied for delivery. Services must be delivered in contact with the customer.
Validation

Verification (Does the product match the specification? Did we develop the product correctly?) is part of any development process phase. Validation (Does the product match the requirements, Did we develop the right product?) is done with the final testing (acceptance test) in the user's environment.

1.5 Model Transformation

Product development is a model transformation from the first (mental) model of a researcher or a potential user (vision) to a physical realisation of the products (implementation) or a concise description (plan).

A Model is a system that is used to describe another system. Model based problem solving is based on the idea that any solution process is based on a model of the real world. The model may be a mathematical description (formulas, graphs, logic) or a more or less informal one.



Model based problem solving

Product development now can be seen as a sequence of model transformations. There is a main sequence of models within the development process (requirements, specification, design documents, construction drawings, listings, graphs) which leads to the final products while other models are derived for simulation, quality control and testing in early stages.

Models comprise e.g.:

- models of the real world problem and of the existing solution
- model of the product's environment
- models of the product's behaviour
- model of the product's structure

The models (necessary description) differ from product to product. We give several of them in the following table:

products	models
service	schedule, interaction graph, task list
software	data flow diagram, data structure, state-transition-diagram, Nassi-Shneiderman diagram, user model, UML-models, a program is a specification (model) than can run on a computer
hardware (mechanics)	construction drawing, FEM-Model, STEP-format
hardware (electronics)	state-transition-diagram, layout plan,
hardware (mechatronics)	any of the three above, interaction models, interface description
processed materials	chemical formula

Models in product development

Model classes include static, stationary and dynamic models, graphs (with a lot of different semantics), logical and mathematical models and also models which consist of (structured) text. Model building usually goes from informal models to more formal and abstract models that can be handled via formal methods. Models need some syntax (relation among the model's symbols, formal criteria) and semantics (relation between model and reality).

1.6 Decision Making

During the development phases, the product designer/developer will identify alternative solutions. Several alternative designs are compared in terms of applicability and optimal fulfilment of design criteria (requirements, quality, stability, risk, cost effectiveness). One of the methods for combining and analysing design alternatives is the morphological box. These decisions are made more or less explicitly, e.g. via a cost-benefit-analysis.
Examples:

product	decision	alternatives	criteria
hardware	material	steel, alloy, plastics	weight, cost, stability, recycling
software	user interface	keyboard, voice, thumbwheel	environment, number of choices, cost
website	structure	sequential, hierarchic	contents, user,
event	location	hotel, arena, school	cost, level, number of persons

Decisions in product development

1.7 Risk and Safety

One of the most important decisions within the development process is the trade off between resource consumption and safety. While this trade off is ubiquitous in the magical triangle for project management, development faces a more important and more challenging trade off: the risk inherent in the product. Any product has the risk to fail and to hurt people. The possibility of breaking or showing some defect or malfunction can never be excluded. When we try to develop a product free of any risk, it would not only take infinite resources and time within the development process, the product would also be so heavy and uncomfortable to use that it could not be used any more. Any security mechanism bears new risk and resource consumption and any security procedure in itself will make the use of the product more time consuming, stupid and fatiguing.

There is always a trade off between safety and resource consumption in the development and production process and in the use of the product (lifecycle cost).

Safety	zero probability of failure or malfunction, no negative influence on user and environment, stability against misuse and environmental impacts
Resource consumption within development	personnel and qualification, time, money, infrastructure
Resource consumption within use	weight and volume, energy consumption, staff requirement, efforts for maintenance

Trade off between safety and recources

Among the methods for providing safe products we have:

- Risk management using a risk portfolio and the risk management process.
- FMEA (failure mode effects analysis) as a production or product FMEA
- Statistical analysis and simulation, testing

Failures may arise from any development or production step, starting from the requirements analysis to a mismatch between the intended and the real use (by product misuse, incorrect documentation, faulty instructions, misinterpretation). This makes it necessary to test (validate, verify) the results of any development step.

2. Product Development Management

2.1 Project management

Project management means to plan and control a project over its whole lifecycle. One of the most important points to keep in mind is the so-called “Magic Triangle” of project management:

Q for the quality of the results. Good quality means not only parameters of the result but also the right (kind of) results)

R for the resources needed within the projects. The resources needed (reserved or consumed) comprise people, money, information and infrastructure.

T for time. The time taken to fulfil the plan is measured absolutely and with respects to timeliness and reliability.

2.2 Special management issues

Change Management

Management of Chance has been a buzzword in management literature for several years. In product development, we mean a rather important and critical item: to control the changes in requirements and design imposed upon the project.

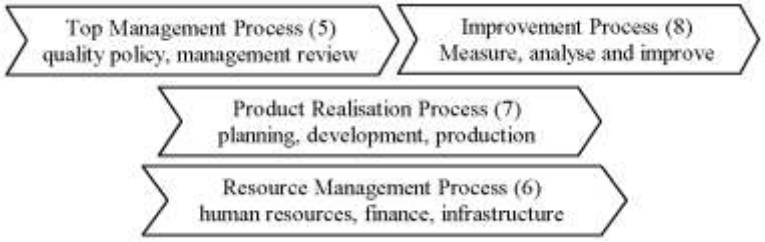
When you build a house, it may be no problem to move it (e.g. 1 meter westwards) as long as you're in the planning phase. The problem arises, when you have built the walls of the first floor an then your customer comes and wants the house to be moved. The worst case may be to continue with the new plan for the 2nd and the following floors. Change management has to control and keep track of al changes and make sure, that all plans are changed correctly.
A change control board and a system of formal change requests will help to overcome these problems. A change request from the customer must be checked and approved by the board and then given to the development team as an identifiable item.

Configuration Management

Configuration management is essential when there is more than one version of a product, a component or a plan. It has to make sure that the final product and its components including documentation, supporting tools, spare parts and supporting infrastructure fit together and have the correct interfaces.

Quality Management

Quality management has to assure that the product fulfils all customers' requirements.
One of the most popular models of quality management is the process-oriented ISO 9001. The mail processes involved in producing good products are shown in the following diagram:



Quality processes from ISO 9001

This emphasises the importance of management (top management, continuing improvement, resource management) for product quality. Within the product realisation process, not only development, production planning and production/implementation but also supply and purchasing, testing and customer interface as well as subcontractor management are important.

2.3 Phase Models

Besides the main phases discussed, several phase concepts exist that show the general course of a development project. They are important for structuring and planning a development project.

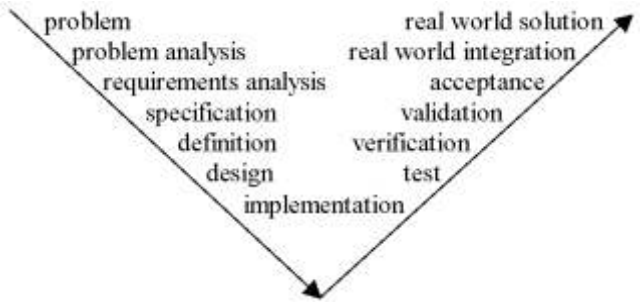
Waterfall

The waterfall model assumes a series of model documents (specification steps) from the real world problem model to the implementation model. Each document is generated from the foregoing document's requirements and then approved (e.g. via reviewing, simulation or prototyping) and it is then the basis for the next following transformation step and document. If a document is changed, all the following documents have to be modified as a consequence.

The waterfall model makes sure that documents are coherent and that all decisions are made within the right transformation step. It does not say anything about the process of transforming one (input, requirements) document to the following (output, specification) document.

V-Model

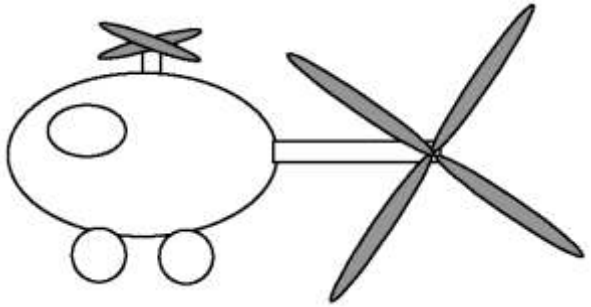
The V-model [Boehm] shows the relation between the development steps and the correlated steps in integration and testing. It is a detailed model of model based problem solving. On any step, test requirements and test cases are derived from the modelling phase.



V-Model of development project

Rapid Prototyping

Rapid prototyping means to develop products, that do not fulfil all requirements but that can be used to study selected properties of the final product. A prototype is a model, that must match the product with respect to selected properties (form-fit-function) within a given tolerance. In Software Engineering rapid prototyping is used to implement critical functions or interfaces in order to test them against the requirements. When development and coding for the prototype is done “quick and dirty” it is important not to use the code for the final product. In mechanical or electrical engineering, a prototype is a physical model, that may differ from the product in material, physical properties or quality. It must match the selected properties of product (form, fit, function) within a given tolerance. Prototypes may especially be made from another material that does not have the mechanical properties of the product. In metals processing rapid prototyping may produce a real-shape product from another material which can be used for testing or for mould-making.



Rapid prototyping the chance to regret

Evolutionary Development

Development in its original sense means evolution. Evolutionary development means to develop several stages of a product. Hence, the linear concepts of waterfall and v-shaped development process models are replaced by a cyclic model. Within any cycle, steps of analysis, design, implementation and testing are performed. The early versions of the product may also be seen as prototypes.

Evolutionary strategies in development apply the ideas of Darwinism to the product. A set (population) of products is modified subsequently by random mechanisms and then the resulting products are compared and the best ones are used for the next steps (generation). This sequence of competition/selection and mutation/randomness may be combined with recombination and can find optimal design in an efficient way.

2.4 Management tasks

Management and Leadership

Management paradigms and styles are developing and changing. Several items are remaining constant in management over the times. The first issue is the problem of responsibility: A manager on any level is dealing with other people's money (OMP) and is responsible for it. Management is always the problem of keeping the balance between control and freedom: neither paralysing necessary decisions nor risking a unethical or criminal behaviour. All the “management by ..” paradigms try to solve this dilemma.

The second one is leadership: To influence people in a personal way.
The core of both these items is confidence and trust.

Project management

Project management means to plan and control a project over its whole lifecycle.

Q The manager is responsible for the for the quality of the results. This means also to take care of the customer and of the customer's benefits (where value is added to the product and for the economy and where the sales numbers and the success of the company come from). Also, the manager has to track the customer's requirements beyond the formal work of a change control board..

R The manager has to provide the resources needed within the projects. These comprise people, money, information and infrastructure. This means also to manage the internal interfaces with other departments (research, management, human resources, finance, product and production planning, marketing, sales, procurement).

T The manager has to keep track of the schedule. In general, timeliness and reliability is more important than speed (not “as fast as possible” but “reliably in time”).

Process Management

A process is a set of activities that transforms some input to some output. While typical processes run continuously or at least on a regular basis, projects are processes that are performed only once.
Process management does not only mean to run or control the processes in

an optimal (operational) way but also to make the processes run more or less autonomously.
The manager has to make sure, that the necessary processes are implemented and integrated (cf. the chapter on quality management).

Management of Development Teams

Project managers too often see themselves in a technical role or as mere administrators. A development team needs a formal or informal leader. The role of a project manager should integrate these three aspects:

- First engineer having a good technical understanding not for details but for problems being able to decide critical questions on a meta-level and helping the team to find a solution.
- Manager that is able to control the project and to give visions, goals and tasks to the team members.
- Coach and leader for the team, giving them self esteem and playing the role of an umbrella against problems coming from customer, competition, colleagues and most important upper management.

Management of Development Departments

When an organisation runs several projects, it is important to coordinate the activities and especially to allocate the resources to projects and processes. The Triage [Yourdon] is the process or allocating resources to those projects that have the maximum benefit. This may be neither the best-running (with the green light) nor the worst-running (with the red light, which should the stopped eventually or even abandoned) but those where the amber light can be turned to green.

The project portfolio shows all projects and classifies them according to their urgency (deadlines) and priority (importance). Staff and resource allocation should prefer the important projects. The main problem of matrix management is, that the allocation of a person to too many projects makes the work inefficient. This splitting of resources paralyses the developer and jeopardizes even the important projects.

3. Selected Product Areas

We have already integrated aspects of different product types, hence, the following chapter only gives some additional remarks.

3.1 Physical products

When the product is a physical one (Hardware or processed materials) there is always some production involved, the result is a tangible item. This implies that the physical realisation must be prepared after or in parallel to the development (tooling, production preparation).
Typically we have more than one item, the range varies from one item (e.g. machine, building, plant) to millions of identical items in mass production (food).

3.2 Software

The product “software” consists of code and related documentation. SW can be multiplied and installed many times. The product class software comprises also any immaterial product (a product which is not determined by its material carrier) especially information. A book or a database on paper, electronic carrier like a DVD or hosted on a server computer is also a product and matches best the product class of software.

3.3 Services

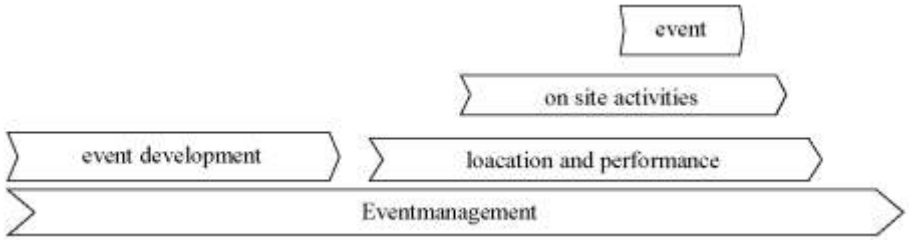
When we develop a service concept, we must consider that the important actions are done by individuals and received by individuals. Service may require other products and service products may be developed in combination with other products. Some times, hardware or software is of no value if it is not supported by corresponding service products:

original products	supporting service	supporting infrastructure
software, computer hardware	installation, maintenance	networks,
vehicle	training, driving school	roads, traffic control
telephone, telecopy	directory, phone book	telephone network

Product and supporting service and infrastructure

3.4 Event

Events are a special case of service, delivered to a group of persons and supported by a hardware event location. One of the main issues is to address people emotionally. The development of events goes from the vision goal and purpose down to the planning of contents, location, catering and logistics [Holzbaur et al].



Event management and development

3.5 Tourism

Tourism is a special kind of service that is related to a special area. That means that you can't bring the service to the customer. The basic resources landscape, culture and environment - are susceptible to the visitor's influence and this means that tourism may destroy its own basis.
To develop a sustainable tourism concept means to take into account

- land, culture, environment
- nature and indigenous people
- customers and marketing
- transportation and logistics
- influences and feedback loops

3.6 Management System

To plan the structure of a management system is also some kind of development. This may be an environmental management system or any other immaterial system such as a reservation system. Access control may also be part of a material (plant, hotel) or immaterial (event, game) product. This may also be a Technology Transfer System like the framework for the Tshumisano Program initiated by DACST and GTZ to improve technology transfer to SMMEs in South Africa. Main issues of this Framework are the cost and time accounting, controlling of results, project management, accounting and controlling system (result oriented), financial accounting, controlling and reporting system (period oriented), information transfer from/ to the related Technikon and several aspects of financial relations to the Technikon, especially payment of staff. Development comprises:

- the overall system structure (principles)
- individual system structure for a special purpose (procedures)

All the systems mentioned above may be supported by or implemented in a computer software system.

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Notes