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PRODUCT FAMILIES; THE PARADIGM OF THE ORDER ENTRY POINT.

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Order Entry Points, Customer Order Entry (COEP), Order Specification Entry (OSEP), Order Entry Calculation Point (OECP), product documentation.

Abstract.

The paradigm of the Order Entry Point recognizes the necessity of anticipating the external needs from the market and the internal needs from design and manufacturing, to act partly on prognosis and partly on order. The Order Entry Point may be defined in relation to any main process belonging to the primary process as there are the quotation process, the design and engineering process, the material supply, the fabrication, assembly and service. The order entry does launch the remaining activities on request respectively on order, following the actions mentioned above on prognosis. The interesting question to deal with, is what criteria do dominate the positioning of the Order Entry Point within the main processes of the value-adding chain.
In this article the Order Entry Calculation Point (OECP) will be defined as a tool to shorten time to respond to customer request.
A start will be made to search for the criteria that play a role in decision-making in these matters.

1. Introduction.

The design of a product follows four fundamental steps:

- How to create a concept of the final product that does meet the requirements of the customer and that can be produced against "reasonable cost".
- How to structure the product to components, sub assemblies and details, corresponding to the requirements in more detail derived from the total concept. Components are defined here as major assemblies of the final product, such as the wings of an aircraft. Components are constructed from sub assemblies and detail parts; both can be self-made or bought.

- How to design and engineer the subs and details, including the materials and connecting parts and the shaping and definition of the geometry of the parts and their interfaces.
- How to verify whether or not all subs and details, when put together, will fulfil the customer and the designers' requirements; how to specify tests to qualify the product.

Designing a product as a "stand alone" these steps have to be taken every time in accordance to the specified short term and long term performances, the time of delivery and the cost of investment and exploitation. In figure 1 these steps are reflected.

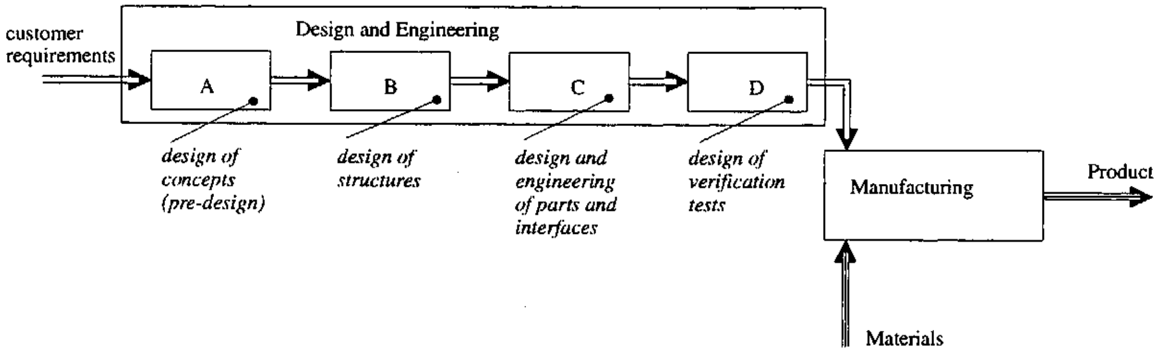

Figure 1. Basic steps in design.

Related to these steps, the responsibility of the designer also comprises the instructions and documentation for production, operation and service.

The central issues in this context are the functional performances, the producibility, the time to delivery and meeting the calculated cost. Most emphasis is given to the effectivity and the productivity of the design process on the product level. The order entry is at the starting point of the described traject.

If the demand for similar (or variant) products increases, the product family-concept asks for attention: How to rearrange the product design and the main processes of the primary activities. International a product family refers to an assortment of variant products, each of which variant is asked for at a variable frequency over the years. A product family must fulfil the market demand for customer oriented products over a certain period of time. Per situation the answers to "certain period" and the degree of customer orientation will be different.
Portofones, televisions, hydraulic pumps, fork-lift trucks and aircraft are examples of product families of which the product life cycle (the time of products being manufactured) may vary from 2-5 years to 20 years and more. In accordance to the product complexity and lifetime, the period of service for a product may vary from 5-10 years for a TV-set to 20 years or even more for aircraft and many types of machinery. The challenge in delivering product families is to maintain the product performance, to increase productivity despite product variants, to monitor product flexibility in relation to the anticipated degree of customer orientation and to maintain control on the assortment and on the order level.

2. The ideal design of a product family.

The ideal design is no longer focussed on the functionality of one product only. The product is defined on two aggregates: that of the assortment of different variants and the aggregate of all individual members of the specified assortment. Both aggregates together have to fulfil the requirements from the market and from the "business", resulting in the criteria the main processes (in particular design, engineering and manufacturing) are confronted with.

To guarantee serial production, respectively the serial production of product variants, a number of functions have to be organized more systematically, at first the basic four steps of design and engineering:

- How to anticipate in the conceptual design phase the incoming variations and how to recognize the different product functions and the variation of function requirements, which is probably asked for.
- How to structure the anticipated assortment of final products and corresponding combinations of product functions with a minimum of variation in the hard- and software and in the corresponding construction elements and the interfaces between these elements.
- How far and on which level of the product structure standardization can be justified without reduction of the specific performance and product quality. The first objective should be standardization of hard- and software on the level of product functions, which gives the opportunity to 'translate' customer requirements in product function requirements, respectively in the specifications of the required construction elements and the corresponding assembly and installation activities. With respect to this level of standardization, mostly 'modularization' is under discussion.
- How to design and engineer the modules and the subassemblies and details, to achieve optimum manufacturing conditions, so the logistic, fabrication and assembly processes do have to absorb as little product variation as possible.

2.1 The product documentation function.

Besides of rethinking the role of the main steps in the design process, the design of product families demands to attach importance to the product documentation function. This documentation reflects all effort invested in product structuring and engineering, to anticipate customer requirements in the future and to eliminate superfluous redesign or revision of already existing similar specifications. The effective architecture and operation of an "assortment library", either installed on prognosis or as a result of evaluating successive orders, depends on the quality of the product documentation which results. In figure 2 the important role of this documentation is illustrated. The Y-stream of orders can be based on reliable existing specifications. The X-stream refers to supplementary design. The balance between the Y- and the X-stream measured as the number of modules or sub assemblies specifications are needed for order specification, is a key-ratio to manage successfully the delivery of a product family. In figure 2 are also presented the main functions process engineering, order specification, material processing and manufacturing which are necessary to realize serial production.

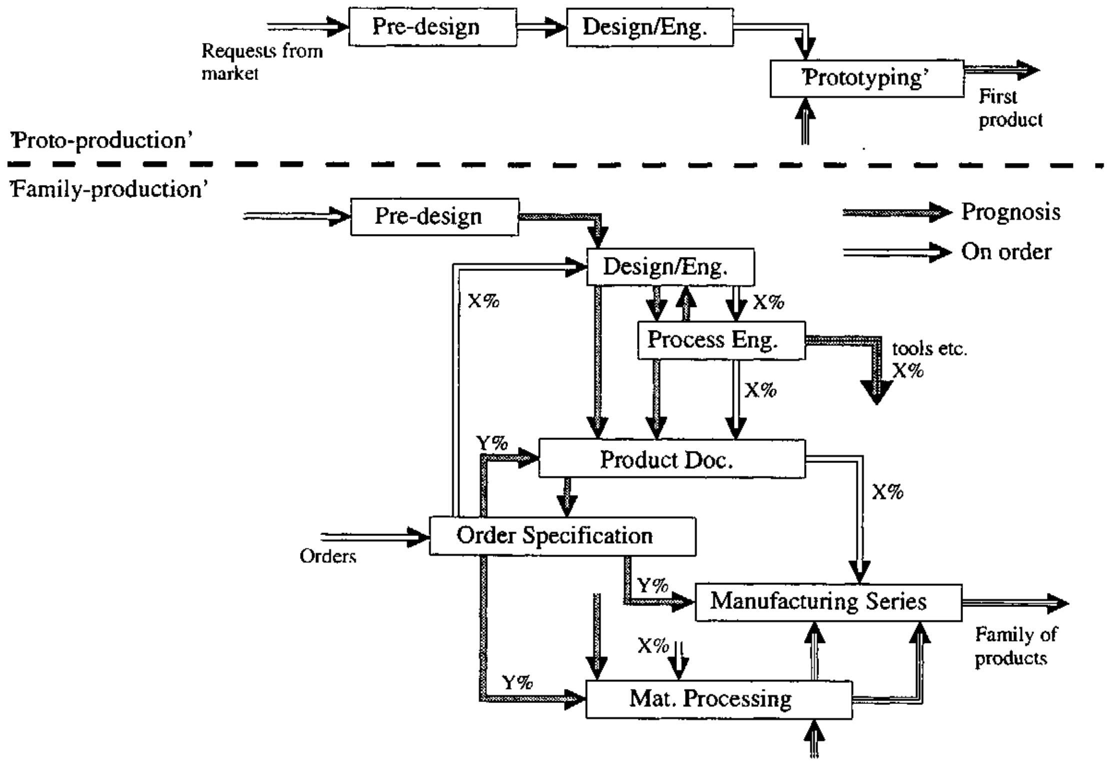

Figure 2. The role of product documentation.

Now and again, at least once a year, the anticipated developments in the market and the experiences in order specification, manufacturing and service should be thoroughly evaluated (E-functions needed) to initiate amendments plus or minus to the "assortment library" of specifications (I-functions needed). The model in figure 3 presents an overview of the main E-I activities needed to structure respectively to maintain an effective product database. In figure 3 the sketch of functions required for product family production is further extended with service, recycling and disposal.

3. The Order Entry Points: COEP and OSEP.

The situation drawn in figure 2 assumes that a serious part of the product specifications is engineered on prognosis. Only for X% of the order specification the product documentation requires supplementary action of the design and engineering department. Based on a significant Y-stream, preferably 70-90%, the manufacturing may start directly with ordering materials, the fabrication of detail parts and sub-assemblies or even with the final assembly.
The point when an order does start order-oriented activities on a process is known as the Order Entry Point. Before this point work in progress is directed on prognosis. We have to recognize that in every main process corresponding with the primary process, an Order Entry Point may be introduced, dividing the process in a part that is organized and controlled on prognosis and in a second part that is controlled on order. To make the most of the possibilities to work either to a large extent on prognosis or in order, we have to focus on the criteria that are decisive for positioning the order entry points.

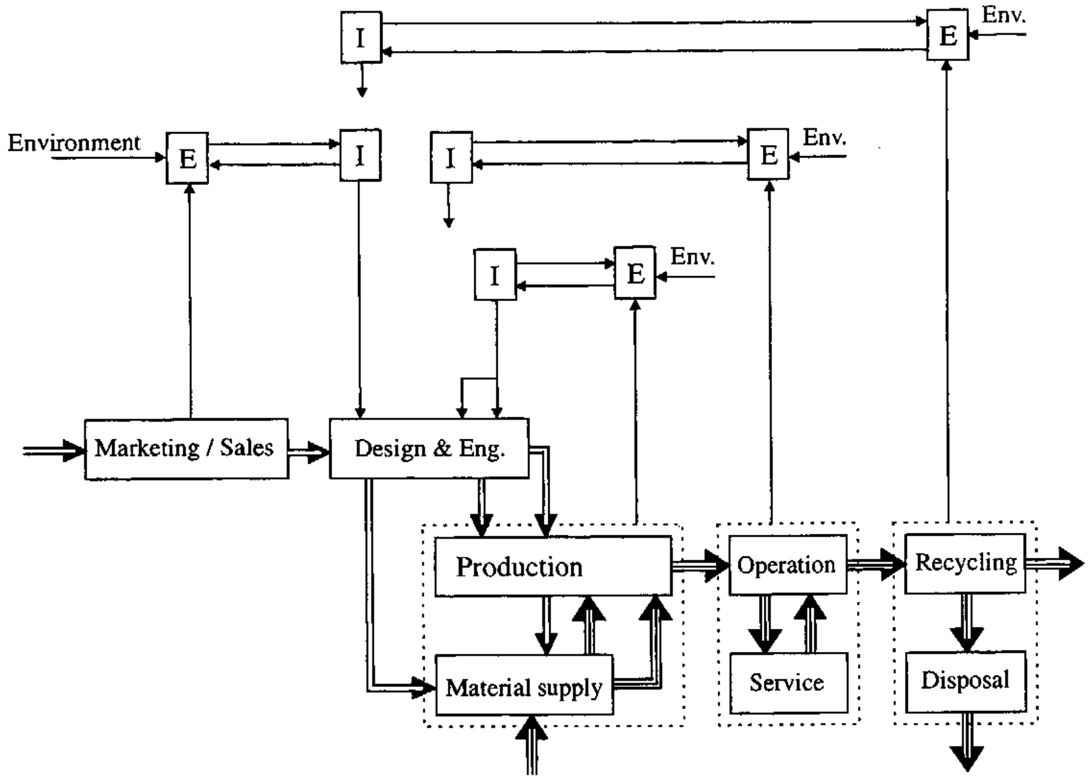

Figure 3. Overview of main E-I activities.

3.1 Criteria for positioning the Order Entry Points.

The main criterion to introduce an Order Entry Point into a process is gaining lead-time to get the order activities ready. For that purpose an investment has to be done to anticipate on product variants and orders on the near future respectively to evaluate which parts of these orders may come to the same constructions as applied with orders already passed. During the last ten years, it has become quite common to do research as far as the production of hardware and the product specifications are concerned. These points are known as Customer Order Entry Point, COEP, and Order Specification Entry Point, OSEP [1-7].

Figure 4 presents the detailed model of the different positions of COEP and OSEP in the sales, engineering and manufacturing process. Making investments in work on prognoses to shorten the lead-time of orders means also to take risk that efforts invested will not pay. To launch specifications, documentation, commitments for material supply and production of hardware before the order entry requires that the arguments pro and con of taking the financial risk of investments have to be carefully examined.

The main risk of work on prognosis concerns stocks of different entities, as there are specifications and service parts, which are not applied frequently enough.

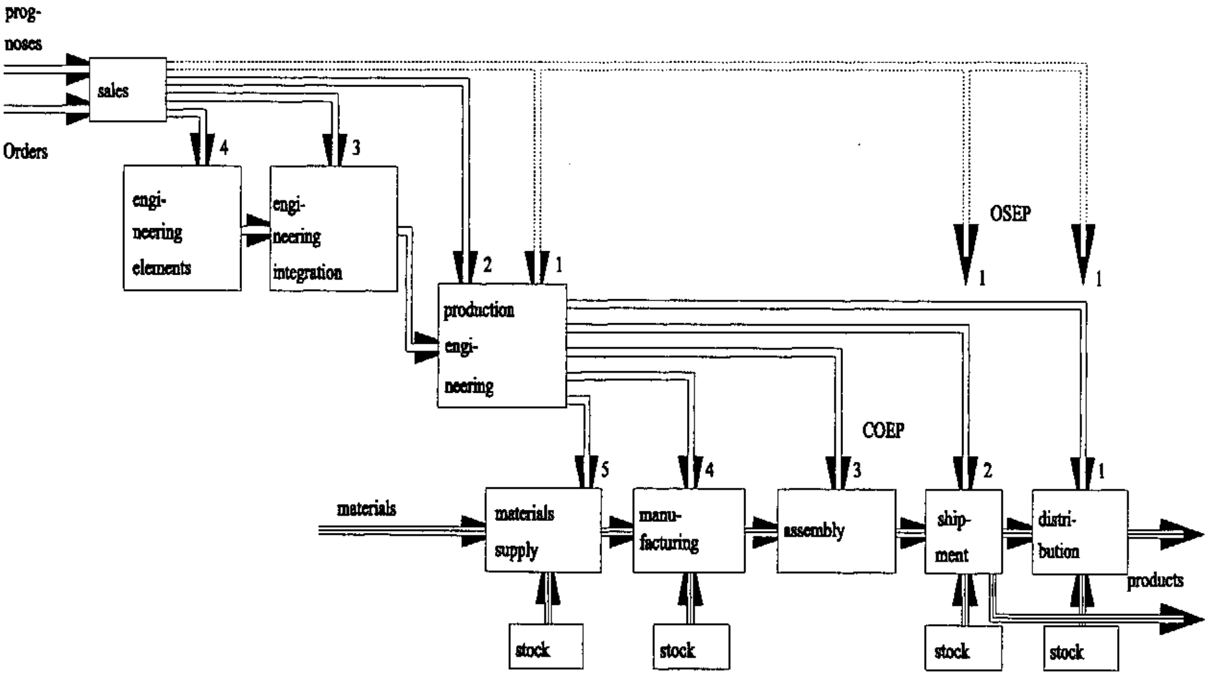

Figure 4. Different positions of COEP and OSEP in the sales, engineering and manufacturing process

For instance, it is anticipated that the number of minor variants of a module A for a specific function may develop to a total of ten over the next three years. In the first case the frequency the module is applied is foreseen on each following order. The prognosis is 75 orders over a period of three years.

number of application	engineering hrs. required	remarks
1	200	learning 70%
2	140	
3	120	
4	100	
5	80	
6	75	
7	70	
8	65	learning 50 %
9	60	
.	.	
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75	8	

Table 1. Engineering hours without investment in standardization.

In table 1 is the number of engineering hours given in the case 75 applications to the module A develop without special attention for variant limitation and renewed revision activities at each following order are exercised. The investment in standardization of the module function and module variants is estimated up to 750 hours. This investment saves roughly 2500 engineering hours during the next three years. If another module B of more or less the same complexity is only applied eight times an investment of 750 hours saves less than 100 hours over three years. The return on investments is less than 4%. From then the return on lead-time in engineering may be two weeks or more and been decisive.

Going to specification respectively to production on order calls up another risk: the risk of getting to a "high peak" or "deep valley" in the stream passing the primary process. Fluctuations on the short term of more than 15-30% in capacity are difficult to manage effectively, so deliveries are kept in time and the productivity of the main processes is not endangered. Weighing these two risks against lead-time reduction a limited number of decision steps results.

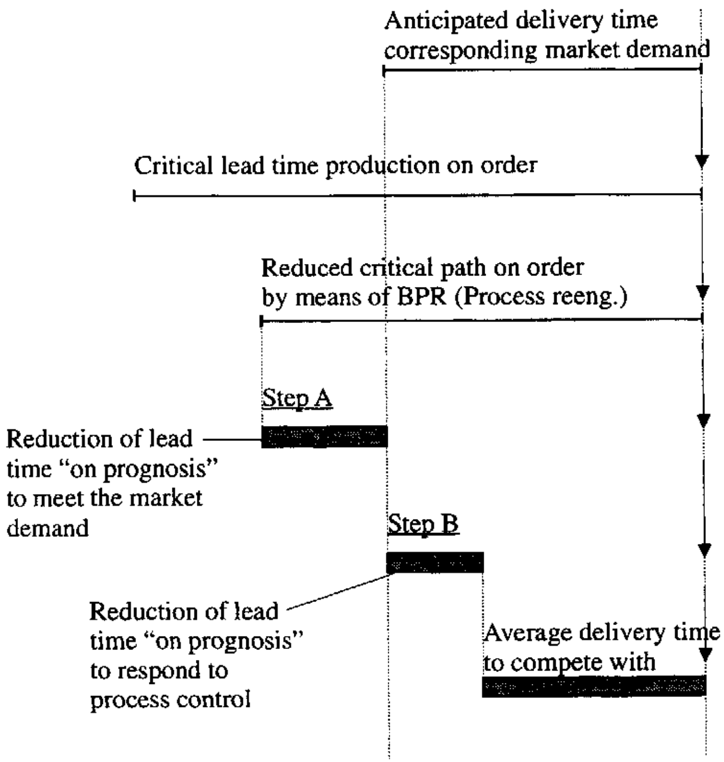

Figure 5. Steps in the introduction of Order Entry Points (COEP/OSEP).

As presented in figure 5, it may often be necessary to introduce work on prognosis in two steps: first to guarantee the required lead time - step A. Secondly it has to be made sure that the fluctuations on order entries can be controlled using work on prognosis to level respectively to set boundaries of the required men, machines and control capacities.
In practice, those activities which are less risky like the specification, fabrication and assembly of basic modules, which are required in any order, and of standard modules, which do fulfil standard

product functions in an limited number of variants, will primarily be chosen to realize step A and B of work on prognosis.

3.2 The paradigm of the Order Entry Point.

The foregoing considerations are predominantly based on the classic COEP and OSEP. The paradigm of the Order Entry Point is defined here as the decision to initiate commitments and to plan activities on any process on prognosis preceding the order and on order following the order entry.
In the material supply it is to recognize in contract reservations beforehand followed by the call out of materials and assembled parts on order. In the service documentation we find the preparation of the main structure of manuals for example for aircraft on prognosis, completed with specific subjects on order.
An application of the OEP paradigm demanding more attention, concerns the traject to deliver quotations of complex products to the customer. The preparation of reliable estimations, based on preparatory design work, does often require several weeks and quite a bit of attention and improvisation. However the delivery of product families paves way to utilize the repetition degree of well-defined modules and sub-modules to introduce an order entry point into the estimation traject.

4. The Order Entry Calculation Point (OECP).

The question on how to transfer requests of the customer into reliable quotations gets more and more attention in industry. For example, only the delivery of 50 orders per year does require two quotations a week, if the average score rate of quotations is 50%. The serial production of product families is a good argument to reconsider more systematically the quotation and estimation traject.
The main criteria of specification - and estimation activities following requests are:

- Reliability between specific limits; this demands the complete incorporation of the different cost items on a relevant level of aggregation and a specific reliability of all items.
- Quickly and easy specification and calculation of the technical and other cost items respectively of the integration activities of all items.
- Easy extension of the results for internal use if the corresponding orders are confirmed.

From these criteria the more specific criteria for the delivery of product families may be derived. The criterion of completeness requires a well-considered structure of cost items, which supports the goal to specify and estimate all items systematically. The reliability of the different items is served by standardization of items if at all possible. The criteria of "quickly and easy" point at the effort in standardization on the highest level of the cost structure as possible.
As for integration of technical entities is concerned the interface may be identified as separate "items". Extension for internal use of the cost structure results into the requirement that it should be possible to go into more detail to initiate the workstandards for the fabrication of parts and the assembly activities.

4.1 Designing a cost structure.

The foregoing criteria summarized do have a far-reaching analogy with the criteria the product structure of a product family normally starts with. Standardized modules and sub-modules and the corresponding variants and interfaces in between are related to each other within the product structure. Designing a cost structure, which conforms to the beforegoing product structure, will be of great interest to avoid a great deal of repeated specification and estimation of the process costs belonging to a specific quotation.

Main Processes			Cost structure of Product Structure oriented cost items and “other” items
Sales	X		
Engineering		X →	X
Purchasing Materials		X →	X
Material Supply Act.	X		
Process Planning		X →	X
Fabrication		X →	X
Assembly		X →	X
Transport	X*		X
Service	X*		X “other”
Project Management	X*		X cost
Additional Charges	X*		X items

Table 2. Integration of process cost into modules and submodules

Table 2 gives an overview of cost items of frequent occurrence. In the first column the cost items are classified from the process point of view. The arrows indicate those process costs, which may be integrated onto cost items based upon product parts and interfaces within the product structure. The second column gives the product structure oriented cost items and "other" items. The last mentioned items are most quickly and easily to estimate; the costs for sales and material supply activities are in most cases incorporated into the rates of the direct hours.

The cost structure introduced should not only facilitate the quotation phase but also the internal cost calculation of working hours and the internal cost control. If the lower aggregation levels of the cost structure persist to follow the product structure, both structures can be used for process planning and cost control.

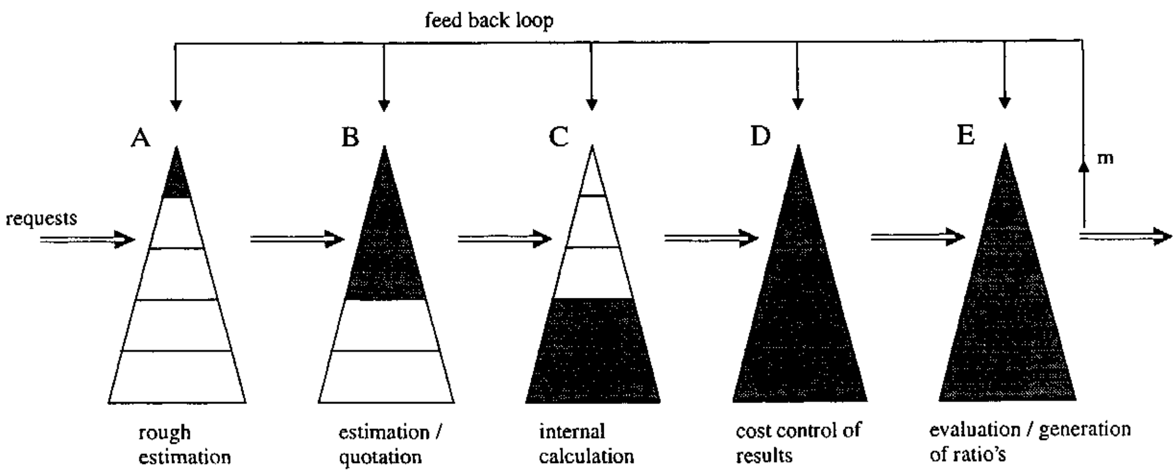

Figure 6. Applied aggregation levels of the cost structure (E.R. Spaans 1993 [8])

Figure 6 shows the product structure oriented cost data base related to the different steps of the cost cycle from rough estimation, through quotation and internal calculation to cost control respectively to the evaluation of cost data to generate suggestions for more effective "activity and module based costing". The remaining process costs, labeled with "*" in Table 2, belongs to the top level in figure 6A.

4.2 Definition of the OECP.

In figure 6 is suggested the estimation and quotation needs to go fairly deep into the product structure and corresponding cost structure to compose a reliable result. However this does not mean we have to go deep into the primary process with any incoming request. Introducing an order entry point most of the estimation work may be done on prognosis as is possible with the cost of applied modules, sub-modules and interfaces.

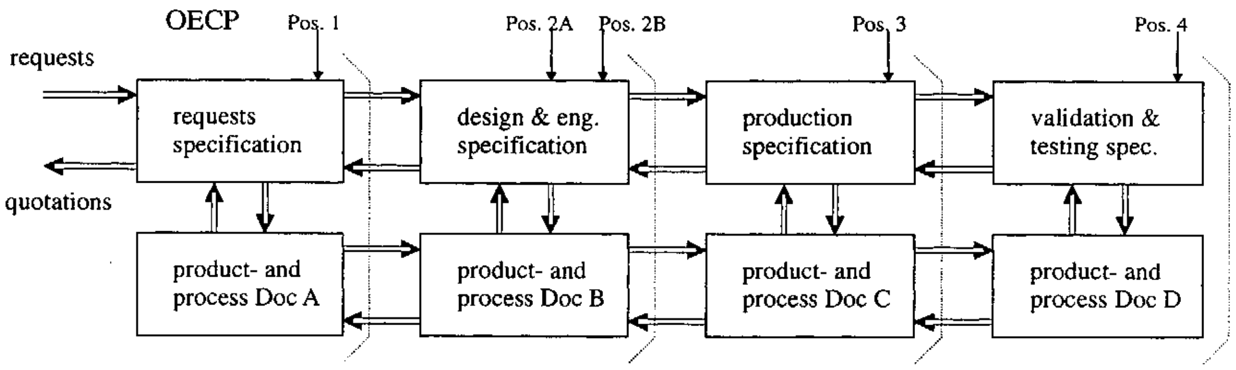

Figure 7. The quotation and estimation traject: introduction of the Order Entry Calculation Point (OECP).

Figure 7 shows a model for the specification and estimation process. Each step is supported with product- and process documentation inclusive cost data as far as possible. The cost data of cost items following the product structure and of the "other" cost items in table 2 can be situated at the first step of the total traject, the "request specification". Except specials and technical sub-problems the quotation and estimation "on order" activities can be settled at this first step. This point we define here as the Order Entry Calculation Point - Pos.1. Activities before this point are done on order; the rest of the work downstream has already been done on prognoses.

If supplementary design and engineering work has to be done the OECP shifts for that part of the quotation to the positions 2A - working on design elements - and/or 2B if design integration has to be supplemented. If it is necessary to go through process planning again the OECP shifts further downstream to position 3. In some cases, parts of the quotation and estimation do require supplementary validation and attention into service; the corresponding OECP shifts to position 4. A well-structured product family may follow with 80% or even more the OECP pos. 1. Reduction of the penetration depth of the remaining 20 % is of more and more significance, as quotation-time to market becomes a factor of competition.

5. How to control two competing streams.

More often the question is raised how to control the different designs and manufacturing streams, the first on prognosis, the second on order. For example:

- has the control, for quality, time and cost to be done in different ways with different methods,
- is continuous learning a must to support decisions in moving on "the right track" of prognosis- or order-controlled activities,
- How can both types of activities be integrated smoothly on the way to the assortment of final products.

The streams of work done on prognoses and on order do have different characteristics. The "on prognosis work" is well known as it is done before and may be planned well in advance. The "work on order" has to deal with variations in what is requested what volume is requested and further variations in the time of delivery and in the price versus cost margin.
The processes on prognosis may be planned predominantly as steady state processes. Besides effectively and productivity, simple control and continuous innovation bottom-up are the main criteria. The processes on order have much more to deal with the dynamics of the order entries, so besides productivity, flexibility and dynamics adapted control respectively continuous improvement should be recognized as being key factors.
Most often in industry both streams and the processes belonging to it are operated the same way, amongst others within the departments of engineering, material supply, process planning, fabrication and assembly. The question is raised how to come to a better admittance of the specific characteristics of both streams, without creating unforeseen problems on the interaction faces. This requires more fundamental research in particular into the opportunities of further process modularization within the primary process [9,10,11].

6. Conclusions.

Until now we became since 1985 international familiar with the COEP, the Customer Order Entry Point, in the hardware-traject of manufacturing and since 1992 with the Order Spec Entry Point in the engineering and the corresponding order specification process. The dominant criteria are in these cases the time, cost and flexible response to a variety of orders against investments in specifications on prognosis (OSEP), in materials, finished parts and assemblies, all on prognosis (COEP) and in configuration control.
Other application areas of the Order Entry Point are under development; in the logistic area, in tool fabrication, in service documentation and planning and in the quotation traject.
In this article the Order Entry Calculation Point is defined as a tool to shorten the time to respond to the customer requests. Introducing an order entry point, most of the estimation work may be done on prognosis, as is possible with the cost structure of applied modules, sub modules and interfaces within a product family.
A model to facilitate the decision making on OECP-positions is presented.

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