SESSION 1

How to reduce manufacturing and management costs of tractors and agricultural equipment

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Introduction

Agricultural equipment improves productivity and reduces drudgery. But to be practical, such equipment must be affordable to the users and profitable for the manufacturers. Therefore, manufacturing productivity and efficiency of agricultural equipment is an important part of the systems engineering necessary to improve our food production systems.

In his plenar presentation to the Club of Bologna in 1989, Professor Renius introduced the "Project Foundation Matrix" (**Figure 1**) representation of the processes the agricultural industries use in the development of new products **[1]**. This matrix provides a linkage between the new concepts for products that come from Product Planners or Advance Engineering groups and results in identification of a product development timeline including the influence of R&D, manufacturing, sales, service and finance. New concepts inputs to the process are heavily influenced by the state of the manufacturer in providing the capabilities to be found in new products. The output of the process is products that meet customer needs. This leads to consideration of product families (e.g, tractor series), reuse of well-developed subsystems (e.g., transmission and engine components), and manufacturing capabilities of the organizations. Strong supplier relationships have been used to provide those components that do not differentiate the manufacturer from their competition (e.g. hydraulic components). Over the years, these processes have interacted to result in a highly efficient organization for the production of agricultural equipment.

But the efficiencies that have been accomplished over the last twenty years are being further stressed to become more efficient in the face of decreased sales and changing distribution of the agricultural workforce worldwide. User requirements for additional electronics, controls and corresponding software further task the level of manufacturing efficiency while adding an ever increasing level of complexity to the management and manufacturing processes. To meet these additional requirements and because project management is an outgrowth of systems management, **[2]** traditional project management is migrating towards the use of system engineering tools. Through the application of these tools, the design, manufacture, and life cycle of products are considered early in the project development cycle. Early application of the tools reduces cost, improves efficiency and minimizes risks associated with increased electrical content. This lecture will cover some of the manufacturing methods and the application of system engineering methods used in project management that can lead to decreased manufacturing costs of tractors and agricultural machinery.

Its manufacturing organization and manufacturing processes best characterize modern manufacturing in agricultural industries.

a) Manufacturing Organizations

There are a wide variety of agricultural manufacturing situations, usually even within individual countries. For discussion's sake, the situations can be crudely categorized as more-developed and less-developed, although it should be recognized that there is a continuum, rather than clear category demarcations.

The wide mechanization of agriculture in the more-developed countries during the 20th century has been widely recognized as one of the greatest engineering achievements and a key element in producing a high standard of living (e.g., **[3]**). Industrial leaders, such as Henry Ford, built a mass production system for agricultural equipment which cheaply produced large quantities of reliable equipment.

But as those countries are now fully mechanized with large, productive equipment, the number of units of agricultural equipment to be sold annually has decreased. Manufacturing organization in those countries has to shift to greater flexibility and the ability to be profitable at lower production numbers. Smaller inventories and changing requirements also require more rapid production. Such changes are not unique to the agricultural equipment industry, as they have occurred in other industries, such as aerospace.

The ongoing agricultural mechanization of some less-developed countries, such as India and China, is the most exciting area of the agricultural equipment industry. This can be approached in a variety of ways. Local technologies can be developed. Another alternative is to import whole goods. Sometimes designs may be imported and manufactured locally. Those manufacturing organizations utilizing mature, developed designs and production methods have the advantage of securing reliable, proven equipment.
But joint manufacturing should be considered as a possible alternative. Less-developed countries generally have available low-cost labor looking for meaningful employment. So they should perform labor-intensive activities, such as final assembly. They might also perform design and manufacturing activities related to local modifications to meet regional needs, as they are closest to those needs. On the other hand, it may be better to import components which utilize high technology or require higher manufacturing precisions from the more-developed countries. Examples of such components might include fuel injectors and electro-hydraulic valves. Historically, there have been difficulties with communications and organization of such joint manufacturing. But with the advances in communications, such as the Internet and the increasing universality of the English language, such difficulties are easier overcome. It is important though not to discriminate against the less-developed countries. The design and manufacture of some high technologies in those countries may be appropriate.

b) Manufacturing Processes

The manufacturing processes represent a significant portion of agricultural equipment cost. Recent advances in these processes, some examples that are discussed below, can help reduce equipment cost.
Molds and dies are used for the rapid, cheap production of plastic and metal components. The traditional manufacturing of molds and dies follows distinct separate steps of machining, heat treatment, and finish grinding using different equipment and facilities for each step. This is time-consuming and expensive. More-developed countries have widely adopted the EDM (electrical discharge machining) process which is slow and sophisticated, but labor-efficient. Recent advances in cutting tool materials and milling machine structural dynamics and spindle speeds allow hardened steels to be cut directly into dies and molds. This technology has great potential for countries in most stages of development.
Rapid prototyping is a topic of much popularity in the more-developed countries. Direct manufacturing by those processes will likely only achieve a small penetration of the agricultural equipment industry in the more-developed countries for product development. But rapid tooling, that is the use of rapid prototyping to build tooling, may become popular.
Plasma cutting and waterjet cutting are becoming standard processes in other industries. They are achieving widespread usage in the more-developed countries and will likely spread internationally.
High-speed machining (HSM) has become a vital part of aerospace manufacturing (e.g., **[4]**). Metal cutting gains can reduce manufacturing times to as little as 10-50% of conventional machining times through a thorough understanding of structural and process dynamics (**Figure 2**). Such productivity means that less machine tools are required to achieve the needed production.
Composites are increasingly being used in equipment, including agricultural equipment. They produce light components and are feasible where the labor requirements of composites can be tolerated. There is also a potential to use local materials, such as glass fibers and biopolymers.

c) Design Issues for Manufacturing

Certain agricultural equipment design choices can reduce equipment manufacturing costs. This raises some areas in which good engineering and management can reduce manufacturing costs.
Several factors can influence the manufacturing costs. Standardization and reuseable components have proven historical value. Rising costs continue to be a problem within industry. One way to address these rising costs is through modularity. Modularity reduces costs to achieve product variety through modularity through combination and standardization. Electronics and the evolution of machines to mechatronic systems represents technological changes that can lead to a significant positive impact on increasing efficiency and reducing manufacturing costs. Other factors, like regulatory issues can result in significant costs for manufacturing if not anticipated.

4.1 Standardization

Standardization allows flexible utilization and reuse of components, economies of scale, and interoperability. Industry effort is strong in the standardization of mechanical systems. Technologies for electronics communications are also starting to make some progress. As with standardization of hitches, tires, belts, and power take-offs, the standardization of electronics and controls, such as networks and buses, will promote the advancement of agricultural equipment. But the rapid transition and impact of electronic functions require increased effort in this area. The industry is growing short of capable individuals to carry this activity forward.

4.2 Reusability of Components

Reusability of components and processes has become a central issue for design strategies. There are a number of reasons for this. The relative cost of development versus production is shifting more and more to greater investments in development. If you can go through one component design process and create a component design that can be used in a number of product variations or across product generations, or preferably both, you save tremendous amounts of money on development costs. You can also be very fast in bringing improved products based on selectively upgraded components to the market in the future.
A second benefit of reusing components is that there are economies of learning and quality improvements at the component level. With time we learn how to make reused components cheaper and better. Reuse of components also increases product reliability. The more a component is reused and the more work is directed at incrementally improving that component and its production process, the higher the components reliability.
An example of the benefits of reuseable components would allow such items as custom tillage tools (e.g., **[5]**) and machines and aids tailored to specific fruits and vegetables.

4.3 Modular Architecture

Modular design approaches used in development of mechanical, electrical, electronic, and software systems allow sharing of architectures/modules between different product lines. This modular design approach may provide economies of scale; reduced development time; reduced order leadtime; and easier product diagnostics, maintenance, and repair. Other benefits of this design approach include development of a variety of systems through component swapping and component sharing.
Backward and forward compatibility is always an issue in electronics and software because people have an installed base of equipment, programs, and files they don't want to sacrifice. Giving backward and forward compatibility to the consumer is a major benefit that a producer can choose to provide through a modular approach.
Business strategy also influences the impact of modularity. For some products, modularity can facilitate a proprietary architecture strategy in which only one company knows the critical interface specifications that make components plug-and-play compatible. Such a strategy would require fast upgradeability of a modular architecture to maintain an advantage in the market place. Another alternative is to use modularity to maintain an open architecture strategy. This transfers many of the benefits of modularity to configure product variations and upgrades to the customers.
In either scenario, it is important for the industry to recognize which aspects of a product differentiate the manufacturer and which are commodities. One example of this can be seen in GPS positioning technologies. In the short run, these systems might differentiate a manufacturer and provide benefits by maintaining proprietary architectures in the modular design. But eventually, accurate positioning might become a commodity that does not differentiate a manufacturer thus requiring compatibility within the industry.
Another example of the significant impact of a modular design strategy would be in the resale of agricultural equipment. The mechanical lifetime of a piece of equipment is much longer than that of the electronics due to the rate of technological advancements in software and electronics technology. Through the use of modular techniques, the electronics on a traded in piece of equipment could be easily upgraded, extending the equipment's effective lifespan and improving the attractiveness of the used equipment.

4.4 Electronics and Mechatronics Systems

Replacing mechanical functionality with electronic functionality might also reduce manufacturing costs. Just as electromechanical servomotors are computer-tuned to get responses based upon their industrial application, agricultural equipment components can be similarly adjusted.

For example, the same electrohydraulic valves might give different optimal performances in different applications. Recent research has supported this concept **[6]** where fuzzy control methods provided a common modular steering controller that could be used equally well on different tractor and combines.
Initially, the customer can interpret electronic content as a decrease in quality. One reason is the difference in life between mechanical and electrical components. Another reason is the serviceability. The average producer is typically familiar with the repair and maintenance of mechanical systems. The equivalent capability in electrical systems will take some time to evolve. A similar trend happened in the automotive industry in the 1980's. But today the modularity in design and component reliability, along with evolution of the service organization has resulted in customer acceptance. Agriculture will likely follow a similar trend.
In the markets of less-developed countries, it may make sense to have a slower adoption of electronic content in equipment since a critical issue is the serviceability of machines in the field. This is based on the presumption that less developed countries have an easier ability to support a mechanical-service infrastructure than an electrical-service based infrastructure. However, some developing economies will skip the traditional industrialization steps and will migrate to systems more like those used in developed countries. This is best facilitated in systems with large-scale organization of agriculture and the strong internal infrastructure to support agricultural manufacturing and production.
For agricultural equipment, there remains the issue of the life of the equipment. Modularity in design against a rigid set of product requirements can anticipate the needs for modernization and serviceability over the product life cycle for many of the electronics and control systems.
Mechatronics is the synergistic combination of mechanical engineering, electronic engineering, control engineering, and information sciences (**Figure 3**). Mechatronics characterizes a general trend of increasing automation. Previous products have treated the mechanical and electronic design as separate entities. Fusion of these systems in design will lead to decreased costs in design and manufacturing and increased functionality. In effect mechatronics becomes the implementation of systems engineering principles to result in the efficient design of electro-mechanical systems.

4.5 Regulatory Issues

Governments in more-developed countries regulate safety, emissions, and fuel economy issues. Unfortunately, unlike power, traction, etc., the costs of the technologies to solve these issues are generally not scaleable with equipment size and thereby become too expensive for the equipment in the less-developed countries. Affordable, even if not optimal, solutions are needed to these issues.
The current issue of emissions requirements to meet North American and European guidelines are creating pressures on the manufacturing of engines and power units in agricultural industries. Meeting these regulations can create difficulty in manufacturing by making certain models of equipment unprofitable. Keeping the industry healthy and profitable requires constant tracking of regulatory issues and estimation of their impact well in advance of their occurrence. This plays into the important role that university research and research organizations can play in identifying factors that will eventually impact manufacturing costs.
Safety issues have always been important for agricultural equipment. The infrastructure of manufacturers pay special attention to ensuring product meets expected regulatory guidelines for safety. But safety will be especially critical for the integration of newer technologies into the products for the consumer. Value-added features like automatic guidance can lead to increased productivity for the producer by increasing efficiency. But variations in the interpretation of guidance systems within governments will create problems if they require the implementation of safeguarding systems that are not universally affordable or supportable. And manufacturers will be entering the phase of taking responsibility for the closed-loop performance of the machine system, which has previously managed as the operator's responsibility. Decisions to increase productivity for the producer will have to be weighed against the safety requirements for products.

4.6 Optimization of Assembly, Design, and Service

Developed industries are continuously challenged by ways to become more efficient. The maturity of design and manufacturing processes allows an increased focus on making the overall system more efficient. This has lead to design methodologies to reduce the costs of assembly, design and service.

Design for Assembly is a methodology for evaluating product designs in a quantifiable way to identify unnecessary parts in an assembly and to determine assembly times and costs. The assembly time standards are based on extensive research confirmed by years of industrial usage. They cover wire harness and printed circuit board assembly as well as mechanical assembly.

Product engineers assess the cost contribution of each part and then simplify the product concept through part reduction strategies. These strategies involve incorporating as many features into one part as is economically feasible. The outcome of a DFA-based design is a more elegant product with fewer parts that is both functionally efficient and easy to assemble. The larger benefits of a DFA-based design are reduced part costs, improved quality and reliability, and shorter development cycles.

Design for Manufacturing (DFM) methods provides guidance in the selection of materials and processes and generates piece part and tooling cost estimates at any stage of product design. DFM provides manufacturing knowledge into the cost reduction analysis of Design for Assembly. The method isolates the major cost drivers associated with a wide range of processes for part manufacture including finishing.

Unlike existing parametric cost estimating models, DFM does not rely on historical data and therefore allows you to quickly generate accurate cost estimates as the parts are being designed. Alternative materials and processes can then be quickly investigated. Quantitative cost information allows product development teams to base design decisions on real-time information to shorten product development time and build consensus among the team.

Design for Service (DFS) assists manufacturers in meeting the demand for ease of serviceability. Serviceability, in particular, has become a key selling point for manufacturers of all types of goods. DFS methods allows designers and engineers to evaluate the serviceability of a product when it is in the early design stage, where changes can be made to the product design at minimal cost. The benefits of conducting a DFS analysis include reduced warranty costs, improved customer satisfaction, and more environmentally sensitive products due to longer life through economical servicing.

4.7 Systems Approach to Manufacturing

Systems engineering, initially developed and applied to the aerospace and software industries has since migrated to several other industries where products have become extremely complex. Due to current agricultural equipment complexity, some agricultural manufacturers are adopting systems engineering methods to reduce the costs of machinery and mitigate the risks involved in the design and manufacture of ever more complex machinery. A brief review of these methods and their utility will be provided. The basic goal of Systems Engineering is to provide an approach to enable the realization of high quality solutions through the effective integration of organized sets of components **[7]**. User needs and required functionality are defined and understood early in the development cycle. The approach then proceeds with design synthesis and system validation while considering the complete problem and product life cycle including disposal. In short, a systems approach considers both the business and the technical needs of all stakeholders with the goal of providing a quality product that meets the user needs. Systems Engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.

The systems approach has three major components in **Figure 4.**

"Requirements Management" consists of requirements capture and allocation. Requirements capture involves capturing and using stakeholder requirements to yield product specifications while requirements allocation involves developing systems architecture possibilities and systematic requirements traceability. The modular components of a system or sub-system are defined by form, fit, function and input/output definitions. Traceability is the ability to trace specifications back to the initial requirements to ensure that the design meets the requirements and that the product is not designed to include more than what is required. Traceability of requirements over the entire product lifecycle enables the product development team members to perform impact analysis. E.g., the project leader can inspect if the requirements in the functional requirements specification cover the requirements written in a commercial requirements document. The system architect can inspect the effect of changing a specific resource constraint. Requirements management and associated specifications set the structure and the interface definitions for a modular system architecture.

"Top Down Design and Simulation" and "Bottom Up Design and Simulation" used in the design process will improve product quality while eliminating prototypes, reduce product delivery cycle time, and optimize machine performance. "Bottom Up Simulation and Analysis" which involves simulation and analysis starting from the component level and working upward. Examples would include the finite element analysis of wheels and three-dimensional dynamic simulation of a tractor. Rapid prototyping, virtual simulation, and design for assembly and manufacture are possible methods that may be involved. "Top Down Synthesis and Simulation" involves product development (synthesis) from upper level requirements. For example, fleet system simulation and optimization, synthesis of machine systems, to synthesis of kinematics. An additional aspect of this process is the design of modular system architectures as previously discussed.

Virtual prototyping is a method of decreasing the amount of time between the design phase and the time of introduction of a new product into the marketplace, allowing simultaneously for improved quality. A virtual environment (VE) allows engineers to interact with their designs (i.e., a vehicle model) in three dimensions in real time. These simulation models require an adequate understanding of the agricultural system and the components that work in it. Although agriculture has made significant strides in this area, there is a lot to know about systems that would be useful in design.

The concept of virtual prototyping may be extended, with a future objective being an integration of design and simulation in a distributed virtual environment, including equipment design, system analysis, manufacturing design, FEA analysis, verification and validation of the complete system. Design, verification, and validation will include hardware, software, electronics, control systems and software. In this structure, many elements of the product design may be performed concurrently.

- With a human operator in the simulation loop, hidden user requirements will be captured and used to adapt control system parameters in x-by-wire systems so that they reflect operator preferences and filter environmental influences on a particular task to be controlled (human augmentation) **[8]**.
- Intelligent, mechatronic and control systems may be trained and developed in the same manner, using rapid prototyping hardware-in-the-loop technologies to train and compile the on-board software configurations and control system parameters **[9]**.

Industry is actively involved in developing and pursuing developments in virtual simulation techniques and virtual environments. Virtual training environments have been developed for complex equipment, where operators can operate a machine and learn the controls in a safe and controlled environment.

d) Summary and Conclusions

By proper consideration of manufacturing organization, contemporary advances in manufacturing processes, and related design issues, manufacturing costs can be reduced for agricultural equipment. This makes the equipment more affordable to the users and leaves a profit for the manufacturer. Consideration of the product life cycle early in the design process mitigates manufacturing risk, extends the life and value of the product. Systems engineering tools applied to the project management of design and manufacturing process will ensure manufacturing issues are addressed during the design process and that the final product meets the end-user requirements without over or under extending product capabilities. The use of virtual simulation and analysis will significantly reduce the need for prototype builds, reduce the time to market and reduce software, power and electronic issues in the equipment early in the design cycle. The overall result of the application of these methods will be improvements in overall product quality with a significant reduction in both design and manufacturing costs.

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Figure 1 - Example schedule of managing new projects (adapted from **[1]**)

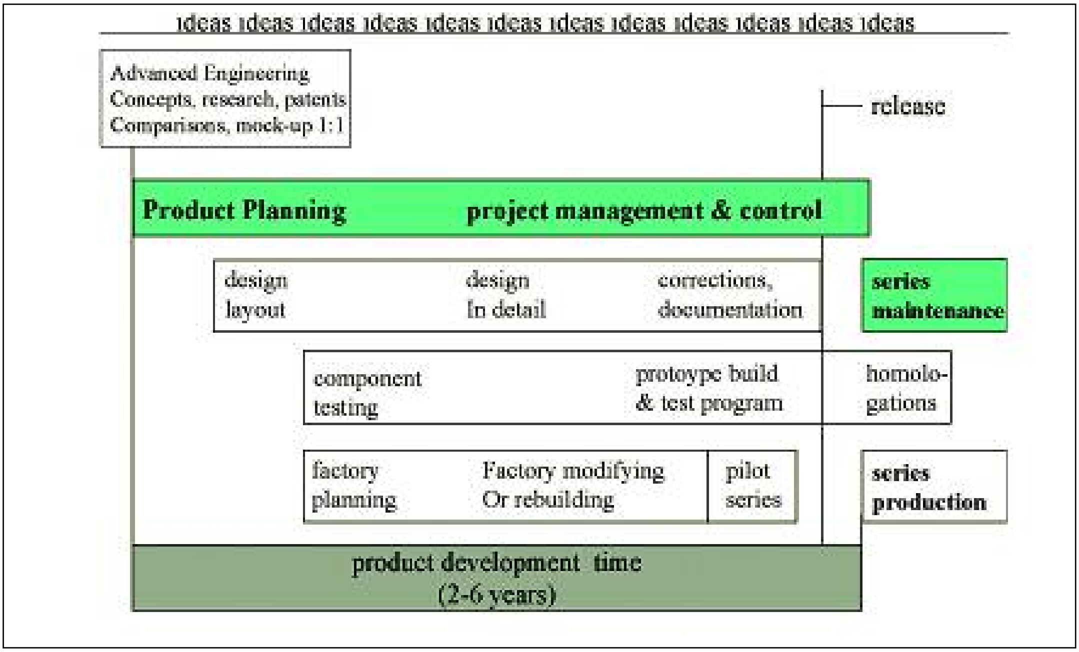


Figure 2 - Aircraft casting machined in 15% of time of contemporary commercial practice using high-speed machining **[10]**

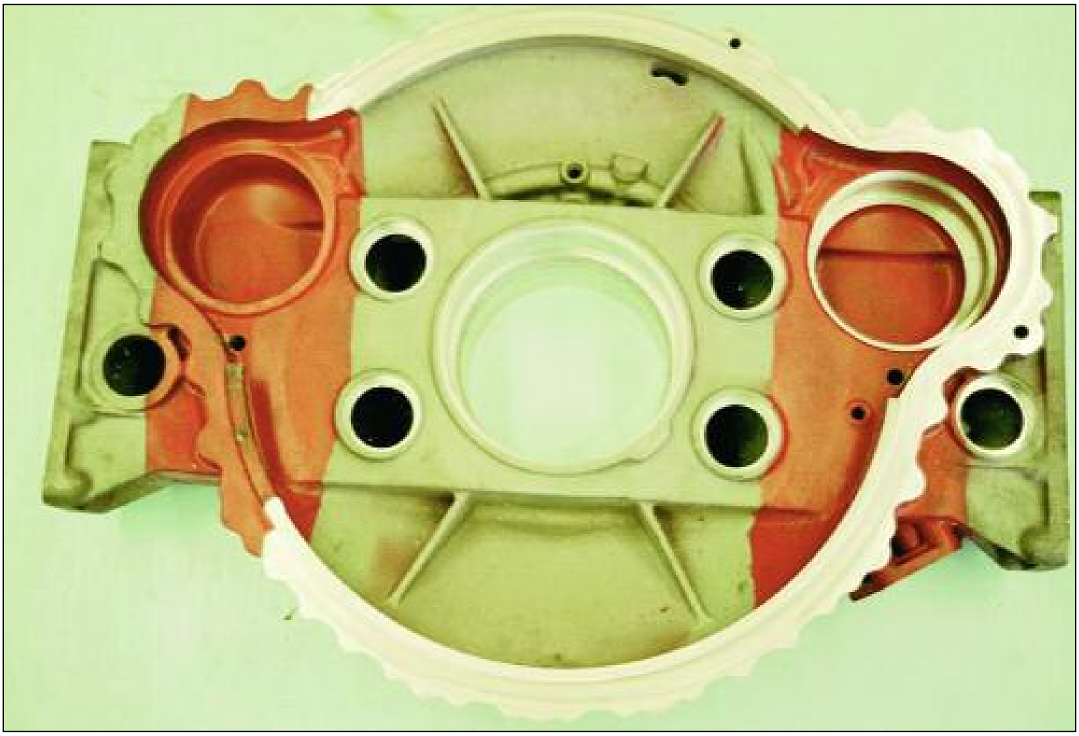


Figure 3 - Mechatronics systems combine mechanical, electrical and computing technologies to create equivalent functionality **[11]**

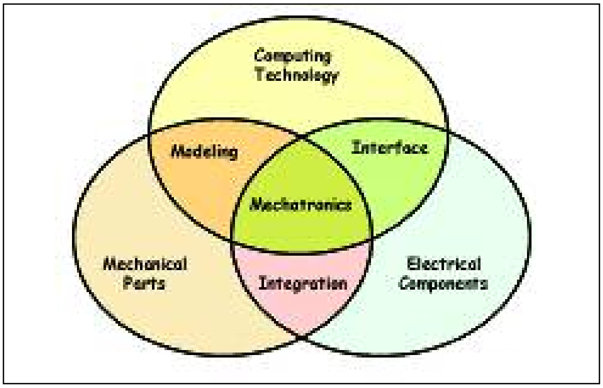
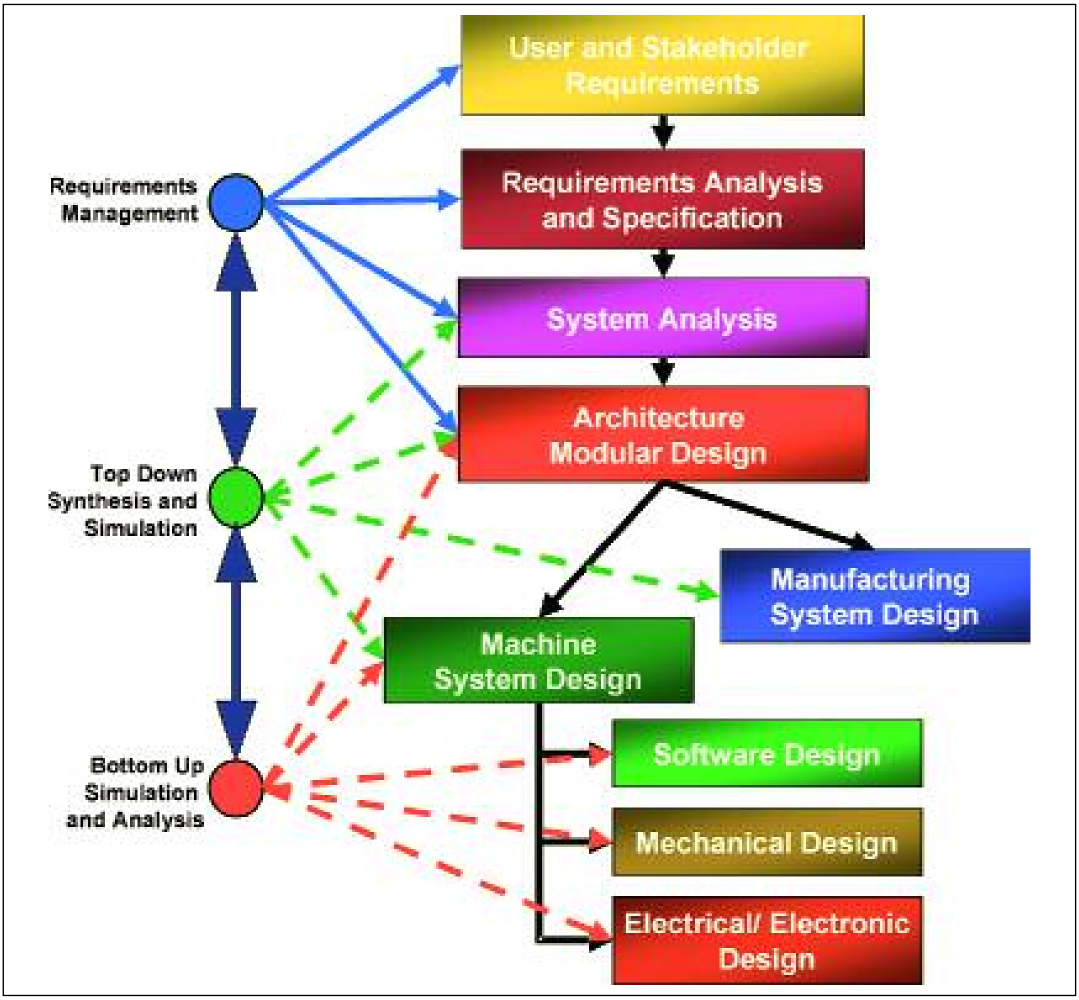


Figure 4 - Systems approach to manufacturing



How to reduce manufacturing and management costs of tractors and agricultural equipment.

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1 Introduction

The free trade and marketing across borders of food and agricultural products have reduced their prices, and has consequently been pushing down the prices of agricultural machinery. Utilizing the worldwide industrial infrastructure, manufacturing industries including agricultural machinery manufacturers have expanded worldwide sourcing of materials and components and complied with such cost reduction.

In the highly industrialized society, required missions to agricultural machinery are diversified. The missions in the past were mainly to release humans from heavy physical labor, but are nowadays for the machinery to work quickly, efficiently, precisely and easily.

In addition, the missions are increasingly to be responsible for keeping an operator comfortable and safe, for making emission noise and gases environmentally lower and for keeping food safe and reliable.

Agricultural machinery manufacturers need to cope with the two different market demands for the specifications and features; one is characterized by the high grade products in the balance of performance and price, the other is characterized by the simple specification products featuring mainly a low price.

In such a present condition, to meet the demands of high grade products equipped with high performance, high durability and low price, manufacturers need to strive, not only to reduce manufacturing costs but also to reduce developing and marketing costs.

Through the Club of Bologna we were invited to provide our comments about “How to reduce manufacturing and management costs of tractors and agricultural equipment”.

Following the invitation, we intend to explain firstly the agriculture and agricultural machinery being prevailed in Japan, and secondly our recent approach which may be along with the subject of this session.

2 How agricultural mechanization contributed to Japanese agriculture

2.1 Scale of Japanese agriculture

Historically, Japanese main agricultural products have been paddy rice as a staple food, but supplemented by vegetable and stock farming. Stock farming has been developed by introducing management and mechanization techniques from Europe and North America. The mechanization of vegetable farming excluding cultivation and pest control is far behind the international level, although some governmental support has been provided in the fields.

In recent years, rice consumption has decreased by the diversification in our dietary habits and has continuously let the rice price decrease, which has reduced the importance of machinery related to paddy rice and changed the agricultural structure as shown below.

(**Figure 1-1**. Transition of gross agricultural output and rice, vegetables, and stock farming production)

(**Figure 1-2**. Transition of delivery of agricultural machinery)

2.2 Rice farming mechanization

The working hours per hectare in rice farming have decreased to 1/5; from 1739 hours in 1960 to 330 hours in 2000. It is the modernization of the agricultural machinery; from human work to machine work, from a walk-behind to a riding type, from a small horsepower to a large horsepower machine. The typical machines are tractors, head feeding type combine harvesters and rice transplanters.

(**Figure 2**. Transition of the number of agricultural machinery and working hours per hectare)

It is proven that agricultural mechanization has contributed to a cut in working hours at each stage of rice farming. At the same time, fertilizer and pesticides technology have developed manufacturing in the agricultural machinery. Those technologies have also contributed to reductions in working hours greatly. Thus, the mechanization consistency system of the Japanese rice farming has been established.

(**Table 1**. Working hours comparison of rice farming)

2.3 Costs of agricultural machinery and its implements

Until around 1990 the proportion of the costs of agricultural machinery and implements in the total expense required for rice production had increased.

(**Figure 3**. Transition of agricultural machinery and implements cost in the total rice production expense)

After 1990, farmers' motivation to invest in agricultural machinery and implements declined greatly. Some of the reasons may be as follows;

(1) Agricultural machinery has already reached the spread limit. The replacing demand may mainly be expected,

(2) Decline of rice price. The Japanese Government politically controls the rice price to prevent its erratic fluctuation,

(**Figure 4**. Transition of the Government purchasing price of rice)

(3) The strengthened reduction of planted acreages for rice production by governmental guidance. The Japanese Government politically controls acreages to prevent over production of rice,

(**Figure 5**. Transition of paddy field of planted and reduced acreages)

(4) Decrease of farm households in number,

(**Figure 6**. Transition of the number of farm households)

(5) Increase in commissioned acreages of agricultural work.

(**Figure 7**. Transition of commissioned acreage for rice planting work)

Further, the service life of a tractor has increased to 19 years from 14 years in the last decade.

(**Figure 8** Transition of the mean service life of agricultural machinery)

3 Reduction of manufacturing and management costs of tractors and agricultural equipment

3.1 Reduction of manufacturing cost of tractors

The following are some of our cost reduction activities, which involve three phases.

- Reduction of purchased materials cost (The best location of the production base considering the logistic cost)
- Reduction of cost by module design and commonality of units
- Cost reduction related to an entire corporate activity by utilizing CAE and IT.

3.1.1 Reduction of purchased materials cost

(1) **Reduction of cost by diversification of material procurement**

- Diversification and globalization of suppliers
- Diversification of procurement system

Consolidated purchase by group headquarters
Conversion from individual parts purchase to clustered purchase

(**Figure 9.** Promotion of clustered purchase)

- Distribution cost reduction by concentrated collection and delivery
- Cost reduction of packing (container simultaneous purchase)

(2) **Reduction of purchasing cost by concurrent engineering with cooperative manufacturer**

- Pursuit of the best structure and the lowest cost
- Procurement of tractor implement at the market.

(3) **The best location of the production base considering distribution cost**

- To produce the key components such as engines in the main base, and to assemble it as a final product in the market country or the region.

We, Yanmar, manufacture the Japanese style head feeding type combine harvester in China and the walk behind tractors in Indonesia, together with engine facilities. The joint venture company of the tractor, equipped with the horizontal water-cooled engine, was started up in China.

(See **Figure 10**. Optimization of production, procurement and distribution)

3.1.2 Reduction of cost by module design and common unit

Our tractor composition was as follows compared with the competitor's.

- The number of basic models is similar.
- Too many factory options.
- A few derivative export models from domestic models.
- Too many varieties and small quantity may cause high manufacturing cost.

By module design, we can satisfy a lot of demands from the market, and at the same time we can reduce the cost by using common components and clustered parts.

Our goal is "Reduction of the total investment and the manufacturing cost by using common parts to both domestic and export models." The number of major components such as mechanical front wheel drive units, transmissions, and cabs will be reduced to 2/3, and the number of factory installed options will be kept by the combination of the units. Consequentially we can reduce the total manufacturing cost.

3.1.3 Cost reduction related to whole corporate activity utilizing CAE and IT

Examination by virtual prototype is practical in concept design, actual drawing, testing and manufacturing.

(1) Shorten development period and minimize unnecessary retry

(Figure 13. Virtual prototype by CAE)

(2) Examination on figure of stamping die and machining fixture

(Figure 14. Simulation of stamping dies)

(3) Examination of assembly process

(4) Arrangement of sales documents (catalog, operator's manual, part table, and workshop manual, etc.) from 3D data improves the accuracy, reduce manpower and consequently reduce cost.

3.2 Cost reduction of development and manufacturing of combine harvester by national project

The above mentioned is the activity that each company may execute respectively.

In Japan, "Urgent Development of Agricultural Machinery project" has been initiated by the government, the feature was reported here several years ago by Mr. Yotsumoto of Kubota. We would like to introduce a unique machine which was developed and manufactured with less manpower and less cost.

3.2.1 Organizations of the project

(**Figure 11.** Urgent development project)

(1) Bio-oriented Technology Research Advancement Institute (BRAIN)

Purpose of the project

- Development of machinery for limited market where a private company could not develop by themselves.
- Development of machinery which contributes to the establishment of the mechanized consistent systems such as vegetables and orchards farm.
- Development of machinery which contributes to environmental burden reduction such as PF.

(2) New Agricultural Mechanization Enhancement Co., Ltd. (NAME)

- Temporary load investment for parts and molds to support small amount production.
- Promotion of common usage of the parts and components and promotion of OEM supplies of machinery.

(3) Accomplishment of research and development of the project shown above are 32 efficient agricultural machines by 2002.

3.2.2 Development and commercialization of large-scale combine harvester

(**Figure 12.** Structure of YANMAR combine harvester)

There are various restrictions such as the road conditions, the field conditions, cultivation kinds, etc., which means that a combine harvester made in Europe or USA does not have propriety in the rice plant which is the staple food of Japan. On the other hand, the Japanese original head feeding type combine harvester has wonderful accuracy to the rice plant and wheat. However, the structure is complicated, and it is difficult to widen cutting width and improve durability.

Yanmar wished to develop a combine harvester with excellent accuracy for Japanese rice, which has at the same time the adoptability to other plant such as wheat, soybean, rapeseed, sunflowers, and so on, to reduce the cost of farm management. Yanmar succeeded to commercialize a medium size multipurpose combine harvester in 1986 under the technical guidance of BRAIN.

After its popularization, larger-scale combine harvester was desired to be developed. We, at Yanmar, could not bear the development cost and the manufacturing investment by ourselves. The development became possible to be nominated for this project. Moreover, temporary load of the investment by NAME reduced the load of the manufacturer in the commercialization process.

(**Figure 13.** Flow of machine and components)

Consequentially, Yanmar boarded the redemption of the development cost and the production preparation expense, supplying the whole products or major components to the other companies. On the other hand, other companies could consequently save the development manpower and facilities.

The fruit of the developed "Multi purpose combine harvester" for the farmer as follows. As mentioned above, the reduced planted acreages for rice production is almost 40% on average. In northern part of Japan, where this type of combine harvester is very popular, it is 50%. They have to grow other crops such as wheat, soybean, buckwheat and etc., together with rice. They had harvested rice by head feeding combine harvester and the other crops by reaping machines and threshers with heavy physical labor, or had harvested all crops by imported combine harvesters accepting considerable grain loss of rice.

Now they have the way to harvest all crops by one combine harvester. Their initial cost to buy it is almost same as another two cases above, without any assistance from government. If they could get the governmental assistance, the cost will be half. In addition, they frequently harvest others' crops as a contractor, thanking for the combine harvester's durability and the adoptability to the crops. Consequently they can amortize the machine cost quickly. The working hours is assumed more than twice as much as that of head feeding combine harvester, with almost same maintenance cost.

4 Summary

Japanese manufacturers have made a lot of effort in this subject area, as have manufacturers in other countries, as follows:

(1) Reduction of development cost, production preparation expense and manufacturing cost are achieved by means of module design.

(2) Reduction of material cost is achieved by diversification of procurement method.

(3) 3D-CAD system has been utilized for shortening the term and the reduction of cost through concurrent activity by related section of development, production, sales, and service.

(4) In Japan, each manufacturer can share the products and the components, which one or a few manufacturers involved in development and production, under Urgent Development of Agricultural Machinery project. NAME's investment contributes to the reduction of the total cost of the products.

Moreover, each manufacturer in Japan is developing unique products by themselves. Quite a lot of products are shared mutually by OEM supply.

Table 1 - Working hours comparison of rice farming (per hectare)

	1960	2000
Total	1739	330
Seed preparation	7	4
Raising of seedling	92	41
Tillage and soil preparation	170	42
Fertilization	85	18
Rice transplanting	266	47
Weeding / Herbicides	267	18
Control for irrigation	220	70
Control of insect / pests		9
Mowing and threshing	574	56
Drying and preparation	58	17
Production management costs		8

Source "Survey on Farm Management & Economy" Ministry of Agriculture Forestry & Fishery

Fig.1-1 - Gross agricultural production (Total,Rice,Vegetables,Stockfarming)

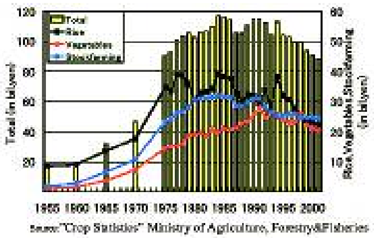


Fig.1-2 - Delivery of agricultural machinery (Total, Tractor, Combine harvester, Rice transplanter)

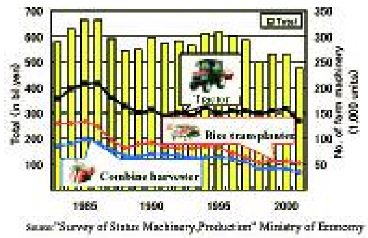


Fig.2 - Farm machinery on farm & Working hours per hectare

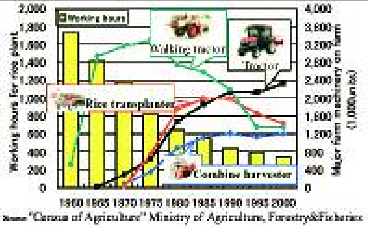


Fig.3 - Agricultural machinery & implement cost in total rice production expense

Fig.4 - Government purchasing price of rice (Brown rice)

Fig.5 - Paddy field of planted acreage and reduced acreage

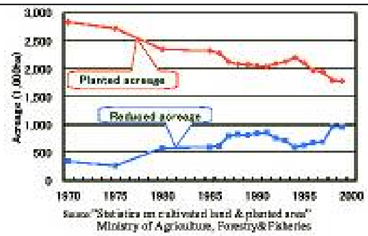


Fig.6 - Number of farm households classified by full-time & part-time

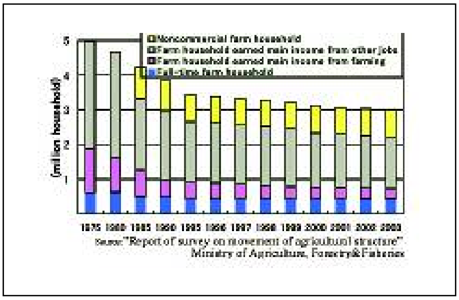


Fig.7 - Rate of commissioned agriculture (for rice farming)

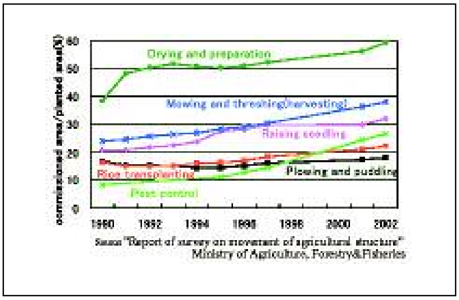


Fig.8 - Mean service life of agricultural machinery

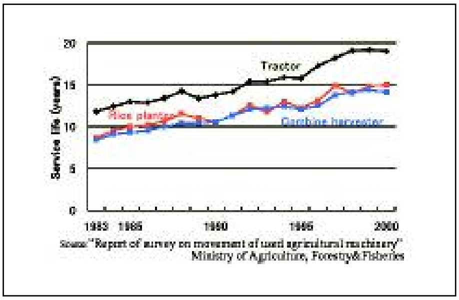


Fig.9 - Promotion of cluster purchase

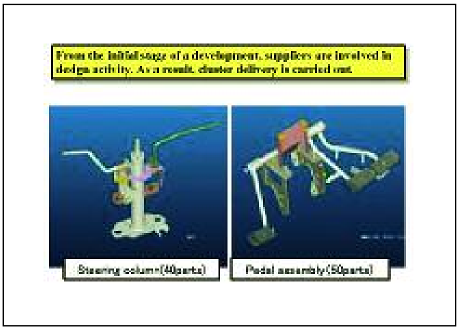


Fig.10 - Optimization of Production, Procurement & Distribution

Fig.11 - Urgent Development of Agricultural Machinery

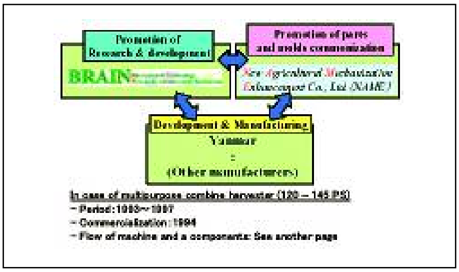


Fig.12 - Structure of YANMAR combine harvester

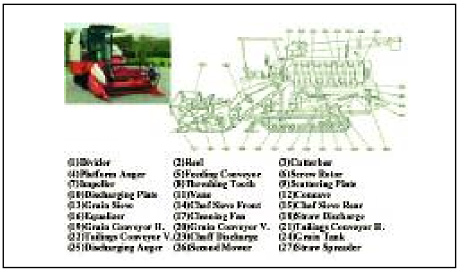
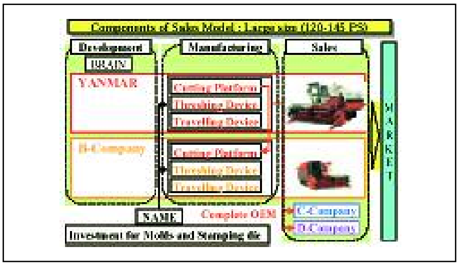


Fig.13 - Flow of machine and components



How to reduce manufacturing and management costs of tractors and agricultural equipment.

by Hans-Heinrich ***Harms*** *(Germany)*

1 Forward

Simultaneous (or concurrent) Engineering, is a concept which should be normal nowadays. Then, without early and simultaneous involvement of all departments, specialists, special suppliers and potential external consultants, you are no longer able to develop these ever more complex agricultural machines. In that case „simultaneous“ means to be faster on the market, because all manufacturers can contribute their expertise earlier, and also have the opportunity to use the expertise of the various specialists as early as possible. Thus, the product quality and the market use is improved simultaneously. By the product accompanying calculation the economic parameters are available on time too. In former times and up to now with small machines, you could afford to have them designed and looked after by one specialist. Nowadays this is no longer feasible due to the fact that machines became too complex. For the various conditions in different markets it is important to cooperate with a very high flexibility in the field of design, production, purchasing, controlling and at least in the sales field.

2 General aspects

In all parts of the industry there is a big pressure on the development departments. The main points are shown in **Table 1**.

3 Conventional procedure of development

With most enterprises, product development steps are defined by ISO or internal system processes. It is more or less a systematic description of product development activities. Task, competence and responsibility of the individual work packets are assigned to the appropriate departments. This institutional procedure is always the same and contains a large number of routine cycles. This procedure is characterized by:

- sequential working through the individual process steps
- different specialists work independently of each other
- product requests are distributed through several experts
- partial optimisation for internal department requests
- many iteration steps are necessary for product optimisation
- the number of redesign cycles affect all process steps and is directly cost - and time - intensive

4 General aspects for agricultural machines

To look for ideas in agricultural engineering is one of the most important tasks for the customers, especially in industrialized countries the search for innovative products is strictly necessary. “Customers or drivers” do often have excellent ideas. Welger e.g. (in former times one of the market leaders for agricultural balers) had 25 designers in 1990; they had been able to think during a working time of 150 h/month nearly 45.000 h/year about ideas and improvements and also had to carry out their ideas. Welger has sold between 1950 and 1990 approximately 350.000 balers of which in 1990 approximately 150.000 may have been in use; if the balers were operated only 100 h/year there are approximately 15 million hours in which a driver can think about possibilities for improvement on the machines. For the design engineers it is most important to get these ideas. Therefore a close cooperation between designer and customer is important. Unfortunately only 1-2% of all ideas will be implemented finally. Therefore it is better to get the right and successful ideas. However, the most important solution to find new ideas for the development of agricultural machines is following.Construction has to be done on the field and not in the office. That means that a designer of agricultural machines has to be more time on the field than in other parts of the industry because grass and grass or grain and grain is not the same in various conditions or countries.
Agricultural machines are characterized by a very high and complex technical standard, a strong pressure on costs, a simplicity in the construction and a permanent demand for innovations. The main problem concerning harvesting machines is the short harvesting period. The machines can on-

ly be tested during the harvesting period. For this can not be done in all interesting areas of application a special rule should be accepted. This rule implies that between two seasons the manufacturer should never increase the number of sold machines more than by factor 10. Otherwise the risk of getting financial problems is very high.

5 Economical aspects

For many year it is well known that the design can influence about 70% of the final costs of a machine. Therefore it is most effective to do the design of a machine under cost aspects and to make changes during the development phase as soon as possible. The earlier you know which problems and advantages your machine will have, the better and faster you can react.

If you look at the steps of a development you will see that there is big step possible, that can be covered by research projects in which the costs of the function does not play an important role. Normal development is completely different. If the research project shows a good result the development will lead into the same direction after a reasonable time. For a company it is very important to find the right steps to change. As a result of a too small steps to many design activities and parts are necessary. Consequently to earn money might become a problem. So it is very important to find the correct size of steps. This must be decided between all involved parties in a company and will lead to a better teamwork. This teamwork will save 20-30% of time. The main task in a factory will be to destroy the existing intellectual walls between the different departments.

The profit shrinks by shorter product-life-cycles. But the capital value remains in the minus area during the product-life-cycle despite putatively good sales. The product does not manage to amortise the invested capital (see **Figure 2**). The more often a technological redesign is necessary the worse is the capital value.

There is a very big difference in various countries and regions. Therefore an excellent knowledge of the condition and the machine as well as a good contact to the country is necessary. The experience of the driver is very important; the larger and the more professional the machine operates the more important is fast servicing and a reliable supply of spare parts; that is why teleservice might be a solution for larger machines in the future.Comparing e.g. Romania and the existing EU-countries, Romania has about 10% of the farmland of the whole EU but is running this farmland with 3,6 Mio farms (average size about 2,4 ha). Most of them are operated with horses and by hand. Accordingly there is a very big market, but there is no money. High performing machines are just possible to run on very big farms and cooperatives in these countries. The simple machines for Romania could better (and cheaper) be produced in Romania. Looking into various regions of the world the value of labour in a region is very important. In India e.g. people have to work about 7 times as long for 1 kg of rice and 10 times as long for a middle class car than in people in the United States. Despite these figures India has about 100 billion € free currency avail - able and China 320 billion €. That means that these countries are the most important markets for the future.

Table 2 gives an indication of the economical data of the 10 new states that will be integrated in the EU in 2004. The share of agriculture is rather different. These countries belong to the most important future markets in Europe. It can be expected that the share of employees in agriculture will decrease in the next years. Rationalization is necessary as soon as there is money available.

But in any case the "cheapest" solution is not the best but the cost permissible solution is acceptable for the customer. The customer is the only person whom the manufacturer will get money from. The customers success has to be the goal of a manufacturer. In other words the main goal of a manufacturer is in any case to find a solution that has advantages for the customer. The customer expects from one year to the next that the price will decrease for the same technique or that the technique will be much better for the same price in comparison with last year. As a consequence the calculation of the customers value is necessary for any new product. An example is given in **Figure 2**.

6 Central ideas of SE

The simultaneous development of product and production equipment in an interdisciplinary project team with simultaneous inclusion of users and suppliers is the so-called "Simultaneous Engineering" (SE) (in English it is often called "Concurrent Engineering"). In the meantime this

central idea is meant for all activities from the product idea to the market introduction.
In short the central ideas are:

- being faster on the market by shorter development time
- reduction of development time by organised working processes
- reduction of bureaucratic formalism resulting in shorter decision ways
- early recognition of complex cohesions by integral consideration
- target marketing by intensive cooperation with users
- reduction of expenses for tools and equipment by integration of specialists in the development process
- risk minimization by accompanying project controlling (time, expenses, cost and product requirements)

It is important that all involved departments work on the task early and simultaneously and not sequentially. Aside from the integral consideration, the development time will be reduced. Thus it is possible to make all substantial decisions together with the people responsible for the product. It is imperative to be immediately informed of any target deviation.

7 Simultaneous Engineering – practice examples

With two practical examples of SE the main advantages are obvious. Both cases involve innovative, new products from the enterprise Krone.
Example 1: The first self-propelled mower Big M
The complete time span, from the pre-study to market introduction took 2 _ years, in which the first prototype was already proof tested after one year. After this phase the motto was "test, test, test". The main development took place on the field. It was the unanimous opinion of all experts that this development period was at least 1 year shorter than with the normal development methods.
The real competence of the enterprise lays in the cutting works. Expert know-how from external specialists regarding drive, hydraulics and electronics developed simultaneously with the development of the machine was integrated. The sub-suppliers, responsible for the engine and the cabin, were involved from the beginning.
Example 2: Self-propelled forage harvester Big X
With regard to this machine an intensive market interview went ahead – as in the case of the mower "Big M" – in order to hear about problems, expectations and ideas mainly from the users and to imagine the ranking of the requirements. In this example, the time span from the vision up to the delivered series product was also extremely short, because of a parallel working of processes:
1st phase (time 1_ years)
market research/interviews, concept study, product development, prototype 1, supply- & production concept
2nd phase (time 1 year)
test phase , modification from results of test phase 1, prototype 2 (pre-series 4 pcs.)
3rd phase (time 1 year)
test phase 2 & presentation in the market, production of equipment & tools, production of new assembly line, modification from results of test phase 2, 0-series (roll-out)
Not only the development time was short, but the product cost was also steadily controlled (target costing) by tight project management and the aim oriented systematic of SE.

8 Advantages of Simultaneous Engineering methods

Shorter Development Times by parallel sequence of operation and additionally with:

- reduction of the development cost
- faster market presence "to occupy the market"!• improvement of capital value

Time can also be saved by using E-Business for rationalizing. According to Kowalewski [Capital 22/2003] the following trend can be expected in this case (the percentage indicates the number of positive answers):

• speeding up the process	91%
• satisfy the customer	85%
• more flexibility	82%
• reduce costs	80%
• higher sales	63%
• new business	58%
• better quality	35%

More and more companies are using E-Business already in the meantime.
Target Marketing by evaluation of the market and profit relevant functions and processes and their positional value compared to those of the competitors.
Cost Optimised Solution by construction accompanying calculations and early inclusion of the production and assembly managers, in order to opti-

mise the tool and equipment costs as well as to avoid expensive modifications. But if you look at the cost for developing different machines you have to look at the possible number of units for that type of machine. In case of a high volume minimizing the costs per unit is important. This can lead to special solutions for that group of machines. But in case of a very low volume minimizing the engineering costs per unit is important. In this case already known components or existing modules should be assembled. This makes the solution much cheaper and gives the management a better feeling of the economical figures for the new product.
In any case a **Target Costing Control** is necessary to have always a better sense for the performance and the result of the final product.

9 Summary of the presentations

9.1 General Aspects

Simultaneous (or Concurrent) Engineering, is a concept which should be normal nowadays; in this case products and production equipment are developed simultaneously in interdisciplinary teams and subsuppliers are involved as early as possible
Without early and simultaneous involvement of all departments, specialists, special suppliers and potential external consultants, you are no longer able to develop these ever more complex agricultural machines.
In that case "simultaneous" means to be faster on the market, because all manufacturers can contribute their expertise earlier, and also have the opportunity to use the expertise of the various specialists as early as possible.
The main advantages of the SE-method are a much shorter development period, lower development cost and earlier market presence.

9.2 Technical Aspects

As electronic and control system content escalates in agricultural products, processes need to be developed in order to build the infrastructure to support the application of the technology.
Several techniques are being applied in a wide range of industries, including automotive, aerospace, computer hardware, software and the military, that accomplish these objectives.
In former times and up to now with small machines, you could afford to have them designed and looked after by one specialist; nowadays this is no longer feasible due to the fact that machines became too complex.
Quick response on the (tighter) regulations (environment) from EU and other governments.
In Japan, each manufacturer can share the products and the components, which one or a few manufacturers involved in development and production, under Urgent Development of Agricultural Machinery project.
Moreover, each manufacturer in Japan is developing unique products by themselves.
Quite a lot of products are shared mutually by OEM supply.
Some system engineering methods particularly relating to the subtopics of requirements management, modular architecture design, rapid prototyping, virtual manufacturing and design for manufacture and assembly have to be examined.
For the various conditions in different markets it is important to cooperate with a very high flexibility in the field of design, production, purchasing, controlling and at least in the sales field.
Knowledge in agricultural technology doubles in shorter time periods and thus reduces the product life-cycle.
Product life-cycle of agricultural machines will shorten.

9.3 After Sales Aspects

Dealer networks to "truck dealer" level, round the clock service have to be educated.
The time of spare parts supply has to be improved.
Better training of the sales force, the dealers and the technicians is necessary.
Introduction of "Teleservice" will come starting with very complex machines.

9.4 Commercial Aspects

Financial programmes have to be developed.
Sales will change into "Full package deals".
Teleservice will lead to different sales contracts.
Set up investment plans with the contractors to build long relationships or partnerships.
Reduction of development cost, production preparation expense and manufacturing cost are achieved by means of module design.
Reduction of material cost is achieved by diversification of procurement method.
By the product accompanying calculation the economic parameters are available on time too.

Table 1 - Pressure on the development department

PRESSURE ON TIME	PRESSURE ON COSTS	PRESSURE ON QUALITY
short product life time	increasing complexity	realization of customers request
quicker in the market	outsourcing	flexibility of development process
accelerate development process	overhead expenses	integration of special know-how
development process must be shorter than product life time	production expenses	innovative concepts for new products

Table 2 - Economical data of the 10 “Newcomers” [agrifuture 3/2003]

	Estonia	**Latvia**	**Lithuania**	**Poland**	**Czech Rep.**	**Slovakia**	**Hungary**	**Slovenia**	**Malta**	**Cyprus**
Population [Mio]	1,4	2,4	3,7	38,6	10,3	5,4	10,0	2,0	0,4	0,8
Farmland [Mio ha]	1,4	2,5	3,4	18,4	4,3	2,4	6,2	0,5	0,0	0,2
Share of agriculture in GDP [%]	3,1	4,7	7,0	3,9	4,5	8,8	4,2	2,9	2,6	3,8
Share of agriculture in total empl. [%]	7,0	14,4	19,2	18,7	5,2	6,9	6,5	5,6	1,8	8,3
Farm infrastructure:										
large farms with > 50 ha [-]	700	620	990	7400	4800	1400	8500			
percentage of the farm [%]	24,0		75,0	33,0	76,0	82,0	59,0			
family farms [1000]		100	67		120	21	267			50
percentage of the farm [%]	50,0		25,0			9,0	35,0			
very small farms [1000]				1100			670			
percentage of the farm [%]							6,0			

Figure 1 Development of the capital value

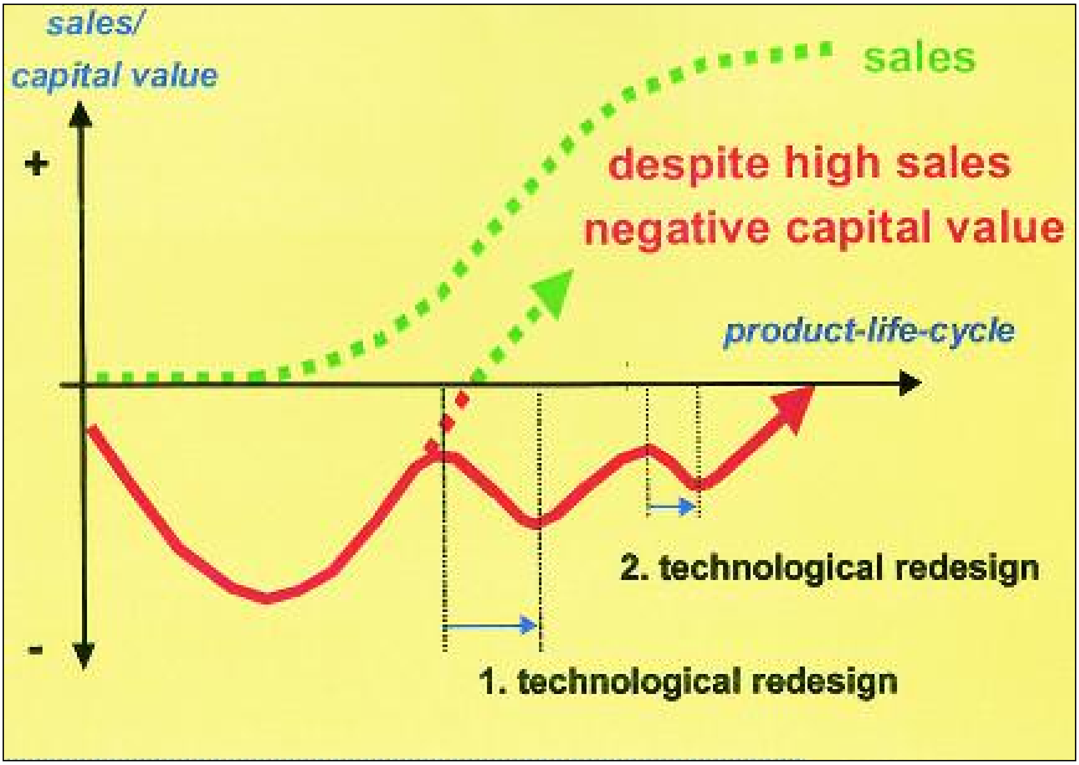


Figure 2 Calculation of the customers value