

RE-USE OF ASSEMBLY SYSTEMS- A GREAT ECOLOGICAL AND ECONOMIC POTENTIAL FOR FACILITY SUPPLIERS

HARTMUT WEULE*, CARSTEN BUCHHOLZ⁺
INSTITUTE FOR MACHINE TOOLS AND PRODUCTION SCIENCE, UNIVERSITY OF
KARLSRUHE

ABSTRACT

In addition to the consumer goods, capital goods also offer a great potential for ecological and economic optimizations. In view of this fact the Project WiMonDi, started in September 1998, focuses to create a marketable Re-Use of modules and components of assembly systems by using modular design and organizationally closed distribution concepts.

The objective of the project WiMonDi is to increase the usability and prolong the life span of assembly systems through the organized rebuilding of assembly facilities as well as the refurbishment and Re-Use of their components¹. Therefore, it is necessary to develop organizational and methodical strategies and to initiate new distribution and user models between the supplier and user of assembly facilities to realize a workable Re-Use concept. WiMonDi is being conducted with tight cooperation between Industry and University.

Keywords: Re-Use, Remanufacturing, Assembly Systems, Facility Suppliers, modular systems, Reliability, Life Span, Usability

INTRODUCTION TO THE PROBLEM

General introduction

The market and companies of the leading industry nations have been situated in a profound change since the mid-80s. Until then standardization and mass production passed for stable input variables of economical action in sense of the provider market. Nowadays high and increasing velocity of innovation and the enormous variety of mutations lead to a reinforced flexibility of manufacturing processes and to out-sourcing of production-oriented services within the value chain. The so-called „tertiary civilisation“ corresponds to the vision of a society in which the attendance and ability of customer orientation besides the production is achieved by additionally offered services. Services, which are associated with the core business of a company, provide here good chances for success. Particularly Bullinger reckons the facility management as an emerging market which is granted a high economical potential². On this basis the following paper deals with the typical SME supplier of assembly systems.

Increasing requirements of customers need amplified differentiation of the offer and thus a great flexibility in the whole process of production. Especially the assembly of consumer goods is characterized by these permanently increasing demands for flexibility caused by expanding numbers of mutations, varying sales figures and decreasing life cycles of existing products.

* Correspondence: Email: hartmut.weule@mach.uni-karlsruhe.de; WWW: http://www-wbk.mach.uni-karlsruhe.de/index_de.html; Telephone: +49-721-608-2442; Fax: +49-721-696832

⁺ Correspondence: Email: carsten.buchholz@mach.uni-karlsruhe.de; WWW: http://www-wbk.mach.uni-karlsruhe.de/index_de.html; Telephone: +49-721-608-4289; Fax: +49-721-699153

Change of assembly technique

In order to satisfy the claims in technical respects modular assembly systems were developed by many suppliers and introduced to the market. These modular systems make up both a basis for a economical conversion, upgrade and disassembly as a reaction to changing guidelines concerning mutations and quantity and for Re-Use of sub-assemblys in systems with different requirements³.

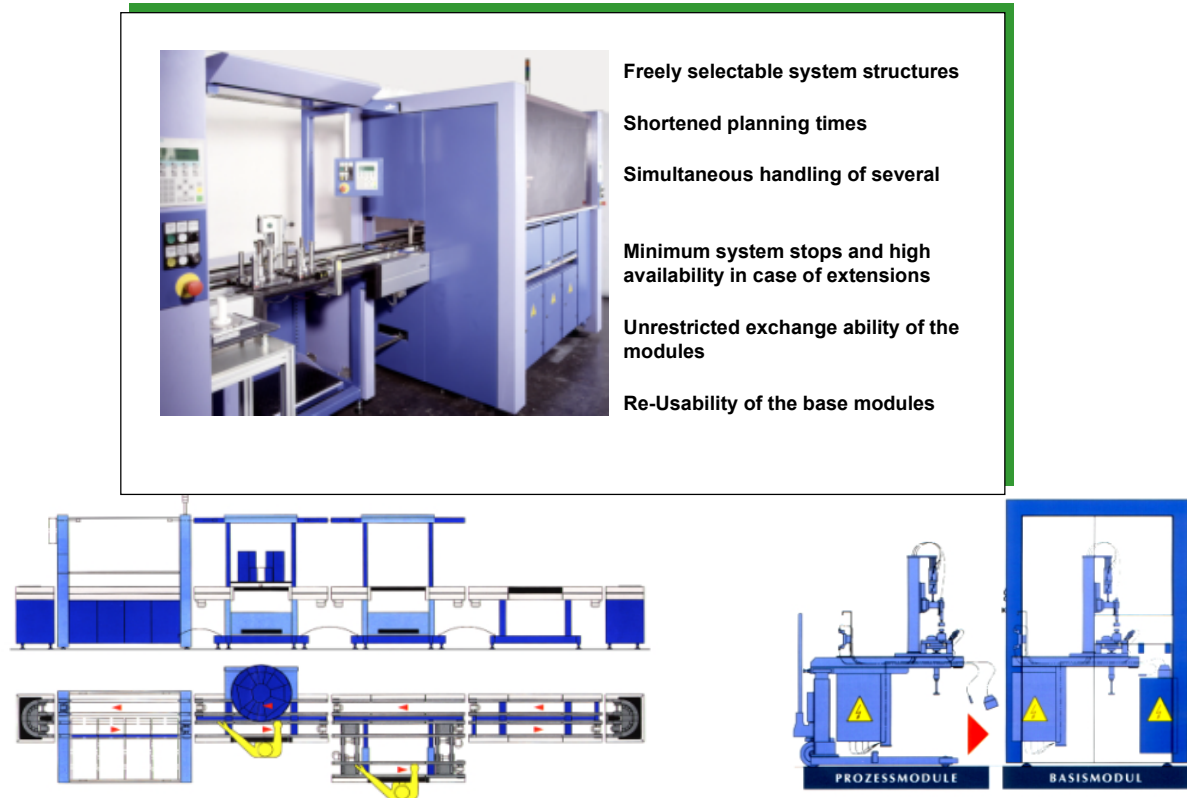


Figure 1: Modular Assembly Systems (Source: teamtechnik GmbH, Freiberg a. N., Germany)

Change of business relations

Due to increasing relevancy of services in the industrial sector the suppliers of assembly systems are about to extend existing tender for the customer. To determine the acceptance of an advanced tender a survey was carried out in companies with a high percentage of assembly systems in the value chain (Target group were 120 companies in the sectors car supplier, computers, entertainment electronics, etc.). The results of the survey show for almost all concerned sectors of Re-Use a high acceptance among customers.

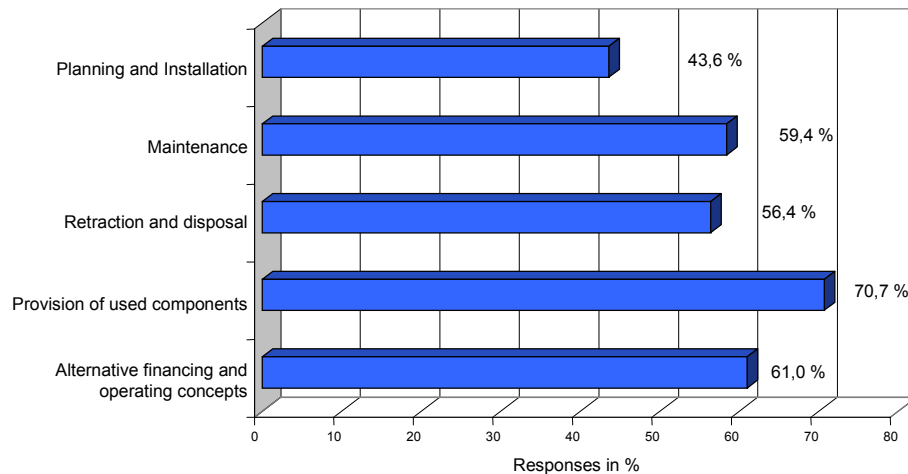


Figure 2: Results of a Company Survey about the extension of the service spectrum

Maintenance is even now a topic in bilateral agreements between supplier and owner of assembly systems. But only a negligible percentage of suppliers offer the disassembly or the Remanufacturing of the assembly's sub-units, neither after run-out nor in case of extension or partially remanufacturing as a reaction to the dynamic market conditions.

In the sense of conservation of value, flexibility and increase of utilization the take-back and Remanufacturing as well as Re-Use of used, modular sub-assemblies can establish a high potential for revenue^{4,5}. This is especially shown when you compare life cycle of products with life span of assembly systems. A life cycle of investment goods which amount to over 20 years are no rarity. Despite statements of industry and research which claim the Re-Use index of assembly systems is about 34-50 % this potential is temporarily not used due to a missing experience with used components.

Reasons for this missing Re-Use of components depend on various factors:

- ☐ Missing experience with the used components
- ☐ Lack of technical documentation of the assembly system
- ☐ Insufficient statistic declarations regarding the economical residual value as well as the technical reliability of the components
- ☐ Missing concepts for an organizational integration of the new service in the existing company

TARGET AND APPROACH

Target

Starting from the described problem, target should be to provide the supplier of assembly systems with methods and tools which permit a change of business relations from present sale of assembly systems to a provision of production ability as well as the offer for services for the whole life cycle.

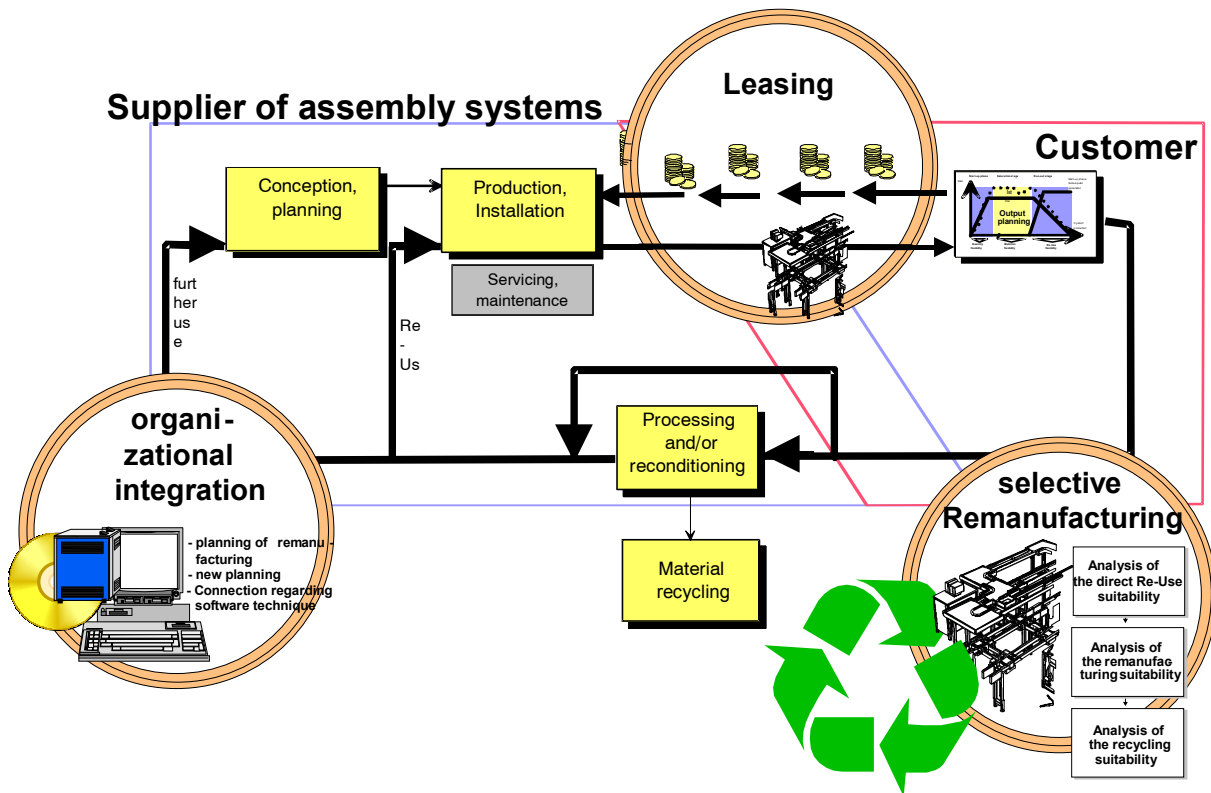


Figure 3: Detailed target for integrating a new business field into an existing company

Subset of this target forms both the sector of planning in the different phases of life cycle and the implementation of the new service in the sectors financing and organizational integration.

As modular systems include approaches for a „Design for Remanufacturing“ the following achievements focus only the sectors planning of offer and Remanufacturing.

Approach- planning of Remanufacturing and maintenance

As a requirement for Re-Use of components in the sector of investment goods the knowledge of the components' technical reliability as well as relevant Remanufacturing processes are urgently required. On basis of these data a calculation of all important process costs as well as the decision of the optimised Re-Use strategy takes place.

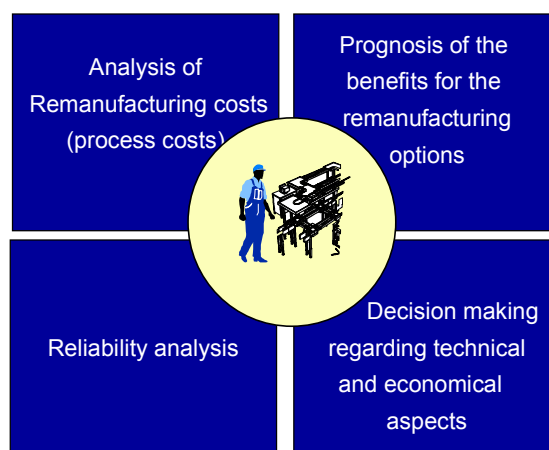


Figure 4: Partial aspects for the planning of remanufacturing

Due to the extended service of suppliers of assembly systems there are costs and benefits of the processes which have to be made transparent for the supplier to plan and control his processes.

The parameters that are used in the evaluation approaches are:

- ❑ Costs of maintenance and Remanufacturing
- ❑ Benefits of the Remanufacturing
- ❑ The technical reliability of the system and its subunits, which influences the frequency of maintenance as well as the applicability for Re-Use and the costs of Remanufacturing.

For a cost prognosis expenditures for maintenance and Remanufacturing can be determined by methods based on estimation or comparison on basis of similar objects or by time observation REFA-method or for example by analytical methods for time determination⁶.

The prognosis of benefit of Remanufacturing is, depending on the recycling strategy, based on various methods. While the evaluation of the alternative recycling is based on knowledge of material composition and the possible material-recycling-processes, the residual value of the subunits of the systems has to be estimated for the alternatives direct Re-Use and Re-Use after Remanufacturing. For this purpose the current practice of residual value determination is examined. Also procedures of the reliability technique and regeneration theory are considered regarding their usability. Especially procedures for reliability determination, which are based on component-specific failure probabilities, are practical.

Besides this different components have different wearout data in an assembly system depending on function and stress. For this reason, a study and classification of different units of an assembly system with regarding its specific function as well as the corresponding determination of the relevant characteristic values (key figures) of the assigned wear data must occur. The components can be subdivided fundamentally into three classes:

- ❑ **Units with mainly optical (passive) wearout:** All robust components that are not subject to functionally dynamic stress are designated as units with optical or passive wearout. Examples are frames or visibility covers.
 - ❑ **Units with mainly statistical functional wearout:** Units with mainly statistical functional wearout are all parts that are subject to a material wear due to their function. Examples are valves, bearings or sensors. Furthermore, these are subdivided into components with known failure behavior, an unsure behavior as well as an stochastic behavior. In accordance with the classification, differentiated parameters of the Weibull spreading are applied. The Weibull spreading (life span distribution applied in mechanical engineering) represents a failure function that, by graphical or analytical means, offer the possibility to make statements about the process of the statistical life span and the influence of different product and stress variables.
 - ❑ **Units with „economical“ wearout:** Units with economical wearout are characterized by their restricted life span due to early technological timeworn. Typical units with economical wearout are e.g. controls. This is based on shorter innovation cycles as well as drastic price decline in the processor technology.
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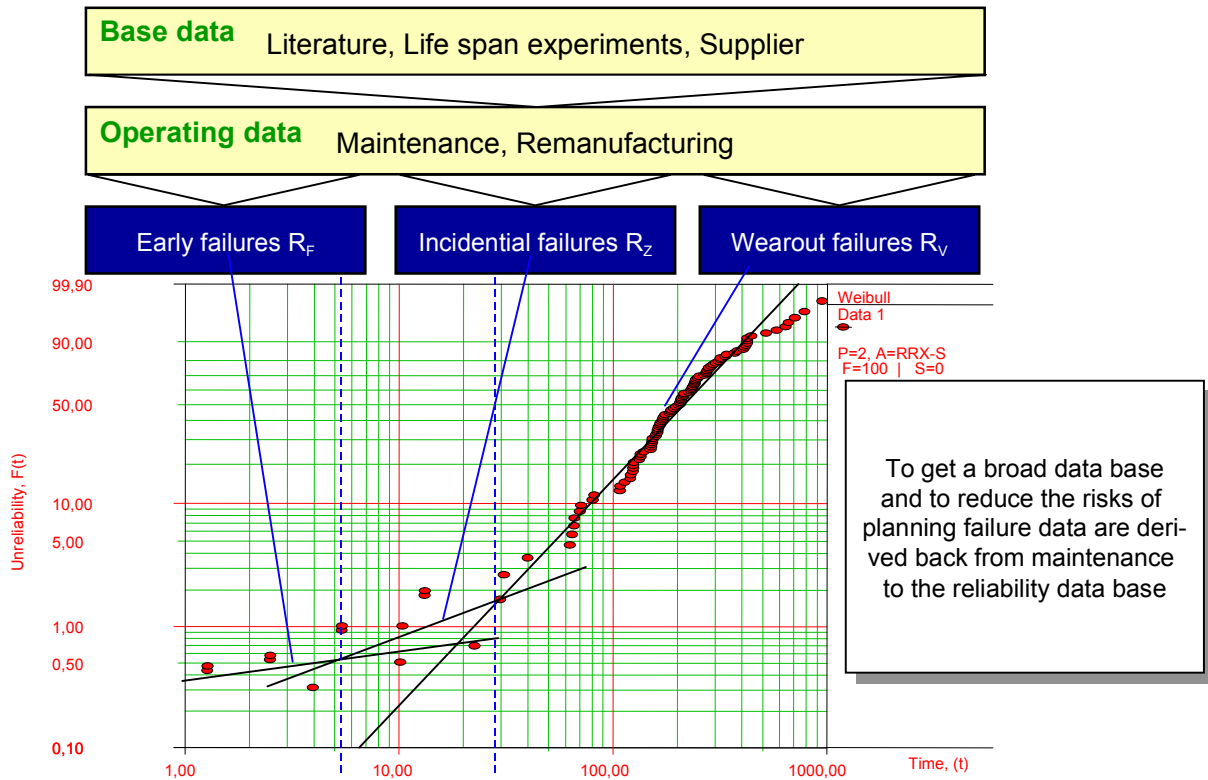


Figure 5: Setup of a reliability data base

Following the determination of the reliability of each component on base of the specific application and stress parameters the calculation of the residual values takes place on the level of components and modules. Within the area of the functional wearout parts the residual values are determined exclusively for components, whose wearout is known or assignable with a minimum uncertainty. Within the area of economically wearing parts a linear depreciation over a defined time period can be assumed.

The assignment or selection of an utilization strategy for each component / each module is executed on base of a technical-economical evaluation. Decisive criterion for the Re-Use or the Remanufacturing of a component is the maximum achievable technical reliability which must be clearly above the required reliability. But in addition to that the decision over the alternatives direct Re-Use, Remanufacturing or Recycling depends on the respective process costs, which are necessary for achieving the required reliability. This evaluation must be executed both on component level as well as module and product level, in order to consider the costs of integration (disassembly and reassembly)⁷.

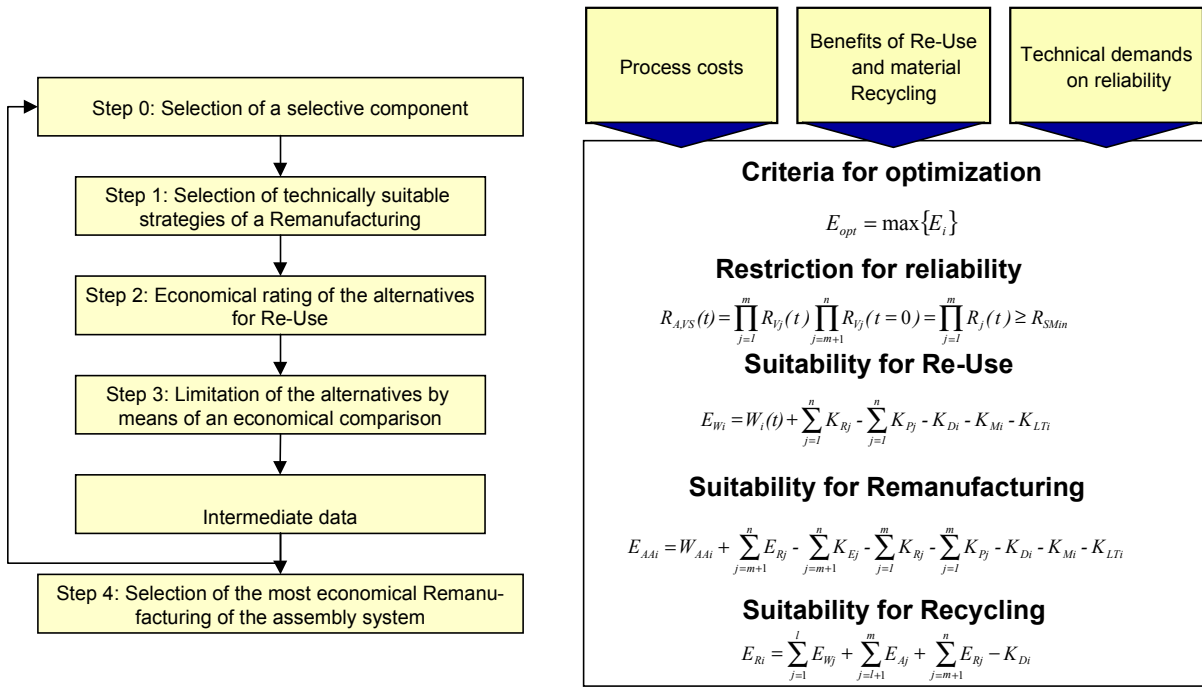


Figure 6: Methodical evaluation and selection of the strategies of utilization

For reaching the target to enable the supplier as a system provider, the costs of use must be included in addition to the costs of production and Re-Use. Among them both costs of the inspection and servicing as well as for maintenance processes are included. The costs of maintenance are determined, similarly to the costs of Remanufacturing, due to failure data and Weibull spreadings and assigned together with the disassembly and reassembly costs of the phase of use.

Cost for maintenance:

$$K_I = h_W \times K_W + h_C \times K_C + h_{RI} \times K_{RI}$$

- K_I : Cost for maintenance
- h_W : Frequency of service during a period of observation
- K_W : Process costs for maintenance
- h_C : Frequency of inspection during a period of observation
- K_C : Process costs for inspection
- h_{RI} : Frequency of restoration during a period of observation
- K_{RI} : Process costs for restoration

Derivation of the frequency for restoration:

$$h_{RI} = E(T) = \int_0^{\infty} t \times f(t) dt = T \times \Gamma\left(1 + \frac{1}{b}\right)$$

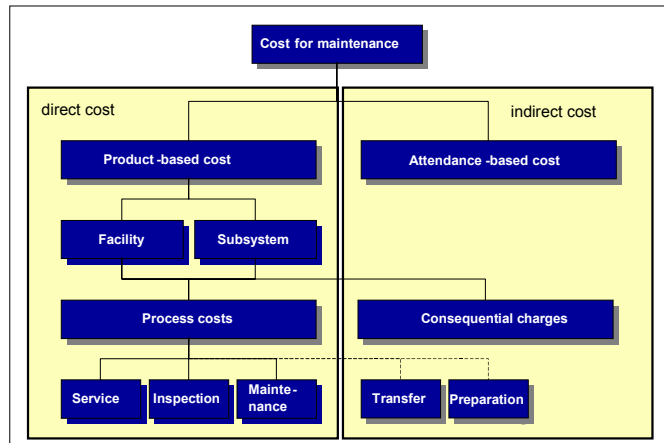


Figure 7: Calculation of the costs of use of an assembly system

Approach – organizational integration

Another decisive factor for the success of an offered new service is the organizational integration of the used machine market into the existing company. Here three principally diverse alternatives of integration are to be distinguished, whose

optimal application is dependent from company-specific criteria such as business-size, capital strenght, company philosophy, etc.

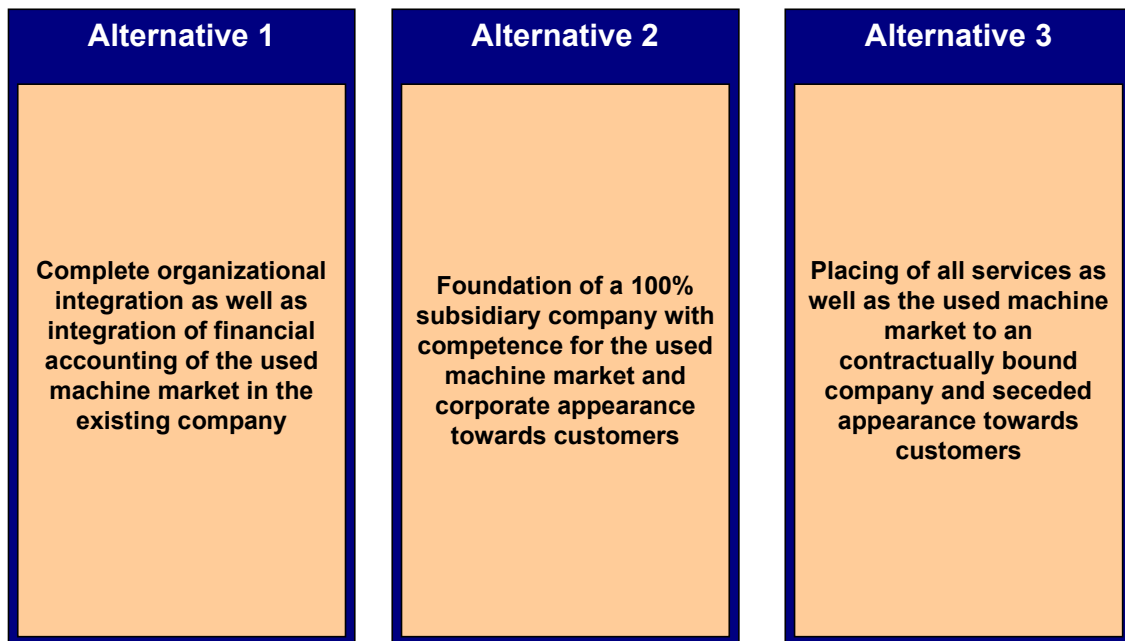


Figure 8: Alternatives for organizational integration of the new business service into an existing company

The chances and risks, which arise as a result of the selection of an alternative, are summarized in the following figure.

	Alternative 1	Alternative 2	Alternative 3
Chances	- Utilization of the internally know-how of the new machine market at the used machine market - optimized use of resources in both areas - appearance as provider of systems for the stage sale, service and disposal (=total Life Cycle)	- Utilization of the internally know-how of new machine market at the used machine market - appearance as a provider of systems for the stage sale, service and disposal	concentration upon core competences
Risks	- Is the credibility of the customers regarding reliability of new market systems still existing? - Decrease of the new machine market at the expense of the former mentioned item?	- Is the credibility of the separation of both companies still existsting among the customers - Life Cycle of the customer is ruled by two providers (no innovation)	- Migration of the internal know-how possible - marketing obviously complicated - no appearance as provider of systems for the total Life Cycle, as even used market traders offer company specific moduls

Figure 9: Chances and Risks of the alternatives

In view of the fact that in the USA already 73,000 companies gain a total volume of sales of 53 billion US\$ by means of Remanufacturing and in Germany an economical Remanufacturing of car engines, washing machines, copy machines or personal computers is already executed (the macroeconomic share of the used machine industry in the machine tool industry

amounts in Germany to a turnover share of approx. 5%, with a total volume of approx. 300 mrd. US \$ – tendency rising) the alternatives of an equity participation at a used machine trade are to be preferred.

Approach – forms of financing

The third essential aspect of the integration of the new service supply into an existing company is the topic of financing. Basically two different forms of leasing are possible: the leasing similar to a hiring contract as well as the financing-leasing. With both forms the lessor, supplier of assembly systems, for legal as well as financial reasons remains the owner of the leasing object, takes over maintenance, service as well as guarantee for the leased-out object, yet in contrast to the financing leasing the hiring contract can be dissolved at any time.

Leasing contract similar to a hiring contract

The lessor remains responsible for maintenance, insurance and repairs; this way he bears the whole risk and remains owner of the object. The lessee pays a (daily, weekly, monthly or yearly) lease. This contract can be dissolved at once or on short notice and the object can be leased out newly at any time. This version is intended for objects that are not needed for the usual life span (up to approx. 40 %).

Financing-leasing contract

Here the lessee takes over the complete responsibility as well as the risk for the object. A basic term of lease is agreed on that amounts to at least 40-90% of the usual life span. This way the lessor remains legally and economically owner of the object, also out of fiscal reasons. The contract is only dissolvable ahead of schedule or without notice, if the lessee does not pay his instalments on time. In this case the lessor also can demand damages. The lessee pays for the amortization (asset costs, factory costs and financing costs as well as the lessor's profit). According to the kind of contract he pays either only in instalments or in instalments plus deposit and final payment. There are full and partial amortization contracts.

Figure 10: Forms of leasing

Similar to the organizational integration the selection of a form of financing is dependent on many firm-specific factors and is not universally valid.

Software creation

In context of a combined project, in which the companies teamtechnik GmbH, Stein Automation GmbH, Weiss GmbH, Siemens as well as the Institute of Machine Tools and Production Science at the University of Karlsruhe are involved, a software is developed for the support of the methods described above. The goal is to determine the costs of the phase of use and Remanufacturing prognostically a minimum effort of filling data bases with the product and process data and to optimize these data by means of restitution of existing products and processes.

As the following figure clarifies, the structure of the software is modular: beside the product model, which contains all product-related data, and the process model, which contains all required processes according to the pattern of activity-based costing, exists an determination of process costs (assembly and disassembly including secondary and special expenditures of assembly/disassembly processes), a failure statistics, which contain all failure data for the purpose of data restitution and minimization of entries, as well as the algorithms for the evaluation of the Remanufacturing and maintenance planning.

A completion of the software is desired for February 2001.

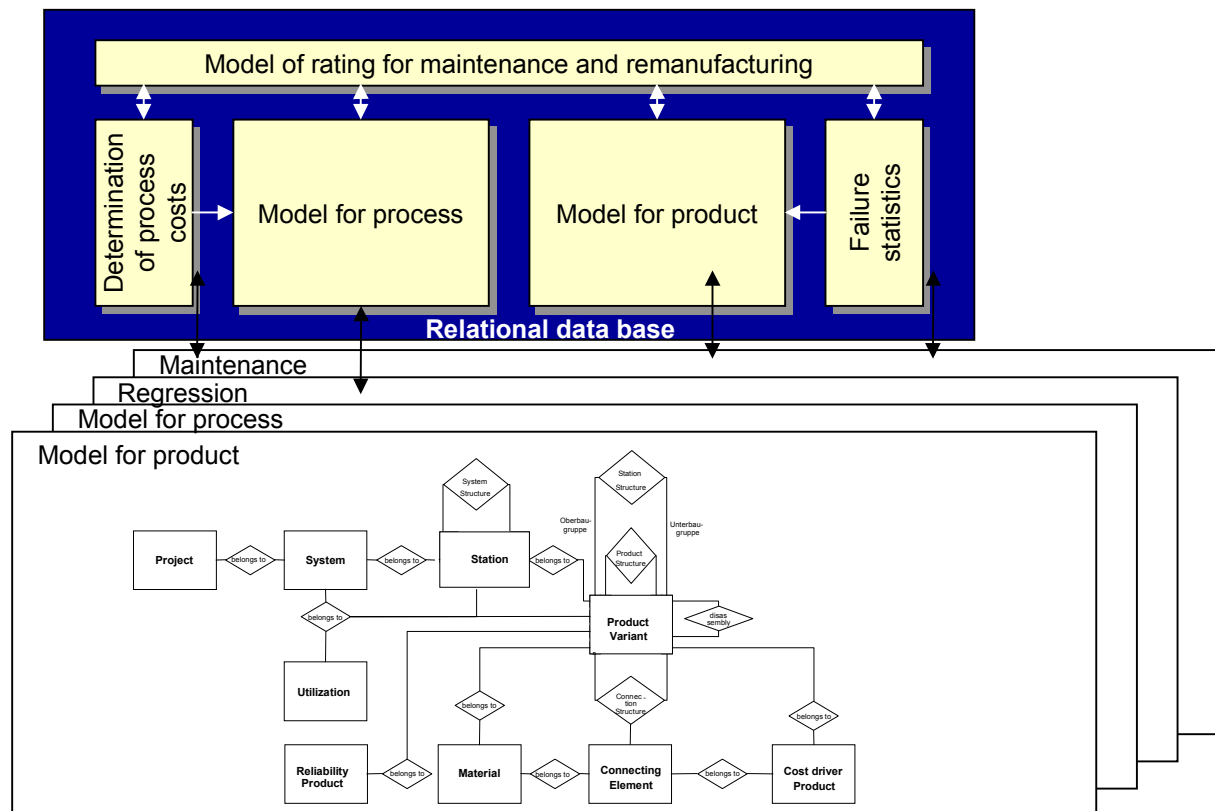


Figure 11: Creation of the software ReAsCo

Conclusion and Outlook

As presented in this paper, especially in the field of assembly systems a large ecological and economical potential of strategies of constant use can be found. These include for example the more effective utilization of performance of investments goods, no wastage of material and raw material resources as well as the creation of new jobs at the facility supplier's by initiating a new business field.

Basic condition of each economical Remanufacturing is a constant standardization and modularization of the system technology, like it is clarified in the text.

User / Lessee	Supplier of Assembly Systems / Lessor
☐ Increase of flexibility (adjustment to fluctuation in number of pieces) ☐ Possibility of technical upgrade ☐ Rationalization by decrease of production oriented service ☐ Gain of liquidity ☐ Transparency of costs (leasing rate) ☐ Saving or shift of taxes ☐ Loss of disposal costs	☐ Customer linkage ☐ Technical and economical advantages of the application of Re-Use ☐ Extension of existing business fields by the sections service, Remanufacturing ☐ Supplier for the entire Life Cycle ☐ More precise basis of calculation for leasing rate and maintenance requirements
☐ Utilization of performance of investment goods ☐ No wastage of material / raw materials ☐ Creation of a new offer in the section service ☐ Concentration of the business associates to their core competences by specific Out-Sourcing	

Figure 12: Summarized advantages of all concerned business partners

Both in the USA and in Europe companies build up sectors, that deal with the economical Remanufacturing of investment goods. This is characterized by a well developed process technique of Remanufacturing, Re-Use and Recycling, yet it shows weaknesses in the organization of the Remanufacturing, the economical estimation of used components and the organizational integration of the new business field into the existing company. Different from the production of new goods statistical information like life span, reliability and availability of modules and their components is necessary for building up a used facility system.

A substantial advantage with setting up this new business field is beside the high economical potential the introduction of alternative methods of financing and distribution and using models within the branch of facility suppliers, which enables an intensified flexibility of business relations through the concentration of the business partners on their core authorities.

Parallel to the development of modular assembly systems, the consideration of the preservation of resources as well as the necessity to appear as a system provider (sales, maintenance, retraction/disposal) in the market of suppliers of assembly systems, the area of the Re-Use of capital goods will strongly extend in the coming years.

In order to ensure an efficient integration into the company, also the economical and organizational aspects must be included early together with the technical boundary conditions.

➤ **ecological factors**

- intensified efforts in the field of ecology (Design for ReUse, Design for Remanufacturing, Design for Disassembly, Legislations like the "Kreislaufwirtschaftsgesetz" or "Altautoverordnung") lead to the amplified inclusion of these criteria in decisions regarding capital investments

➤ **economical factors**

- desire for the increase of shareholder's equity or shift/avoidance of fiscal charges leads to the purchase of used production facilities and/or financing concepts

➤ **company specific factors**

- concentration on core competences forces to outsource additional sectors
- purchase of production performance including the guarantee by the manufacturer desired
- increased customer linkage

Figure 13: Outlook for the topic of Re-Use of assembly systems

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