Chapter XXVII

Recycling and Disassembly Planning

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INTRODUCTION

For some years, the massive spreading of technically complex products as well as the shortening of product life cycles have led to a constantly rising return flow of discarded technical devices. The removal of these devices today occurs mostly through *disposal-oriented* strategies, i.e. used products are shredded and finally stored in dumps or eliminated thermally in domestic refuse combustion plants. For a long time, the product flow was a one-way street. Public and legal pressure have led to an increase in the importance of environmentally-oriented aspects in both the industrial and private sector. This leads to a rising demand for the establishment of a cycle-oriented economy. The cycle-oriented economy aims to keep materials and products in economic circulation as long as possible. The objective of the cycle-oriented economy is motivated by the shortage of resources (energy and raw materials) and the shrinking of disposal areas (air, water, soil), as well as the realization that economically usable potentials are currently being thrown away (Gupta and Veerakamolmal, 1999).

Disposal, as central component of the cycle-oriented economy, includes recycling. *Recycling* includes disassembly as a type of treatment. In contrast to other types of treatment, disassembly permits a higher maintenance of value of old products; however, it usually requires a higher expenditure as well. In contrast to alternative types of treatment (i.e. shredding), the recovery of functional components and assemblies for reuse (product recycling) and the possibility of the recovery of materials (material recycling) are possible advantages of conducting a disassembly process (Seliger and Kriwet, 1993). In general, disassembly follows the same objectives as production; thus *remanufacturing* is often spoken of (Rautenstrauch, 1999).

In general, types of treatment can be differentiated according to whether they are *additive* or *production-integrated* (Rautenstrauch, 1999). In production-integrated recycling, the *direct* reuse of products or materials is the center of attention. Systems for planning and controlling production-integrated recycling are called *production and recycling planning and control systems* (PRPC systems) (Rautenstrauch, 1997). Additive disassembly aims at the *indirect* reuse of materials or products. Systems designed for the planning and controlling of indirect disassembly are called *disassembly planning and control systems* (DPC systems).

Enterprises which are active in the area of disassembly (called *disassembly factories*), like any other for-profit organization, try to maximize contribution margins (variable gross margins). Besides a *service function*, the disassembly factory also assumes a *producer function.* On the one hand the disassembly factory solves the disposal problems of its customers (service function); on the other hand it satisfies a demand for disassembly products (producer function) (Wiendahl and Bürkner, 1998; Tritsch, 1996). In contrast to conventional enterprises, the situation of disassembly factories is characterized by a *binary revenue situation* and particularly high complexity and uncertainty. In addition to sales revenues (from disassembly products), the disassembly factory can obtain revenues through the acceptance of old devices (OD).

In connection with disassembly planning, prognoses concerning the old device return flow are of great importance. The type and quantity of the resulting old devices determine the range of disassembly planning concerning strategic and operational issues. The return flow of retired old devices is hardly predictable in terms of time and quantity. Thus, capacity load utilization and the satisfaction of specific customer inquiries are subject to a high uncertainty. More than half of the enterprises in the field of remanufacturing have no control over the old device return flows (Guide 1999, p. 105).

This chapter presents new approaches to return flow prognosis, operational disassembly planning and production-integrated recycling.

RETURN FLOW PROGNOSIS

Prognoses of returns of scrapped products are required for the planning of recycling and waste disposal. Furthermore, they are needed in material requirements planning for the calculation of the return of secondary materials from recycling processes into production. The return of products to be recycled varies depending on consumers' behavior and product life cycle. Up to now, neither production planning, scheduling and control systems (PPC-systems) nor recycling or disassembly planning systems (RPS-systems) have integrated methods for the prognosis of the return of scrapped products to be recycled (Rautenstrauch, 1997). If recycling is implemented at an industrial scale, active behavior would be expected meaning that recycling planning would be based on a forecasting of returns for the next planning period, analogously as in manufacturing program planning. Since uncertainties concerning timing and quality of returns are among the main problems (Guide, 1999), a robust and precise forecasting method is a main prerequisite for a cost-effective remanufacturing. Current forecasting methods used in the manufacturing program planning like moving average, exponential smoothing and linear programming approaches cannot be applied, because the available return data of the past which were used by these methods are insufficient and inconsistent. Furthermore, the specific product characteristics can not be integrated into the standard forecasting methods. Further difficulties arise from most companies' reluctance to provide the