Product Recovery
at the
Norwegian National Insurance Administration

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Abstract

Technical Aid Centers (TACs) in Norway supply devices, such as wheelchairs and hearing aids, to people with handicaps. When a device is returned to a TAC, the TAC staff must decide whether to scrap it or to refurbish it so that it can be used again. The Norwegian National Insurance Administration (NNIA) found that decision makers were scrapping units too frequently, basing their decisions mainly on the hours of labor required to refurbish. We developed a more complete decision support system model process that accounts for the full cost of sending a unit to the landfill, the cost of refurbishing, the value of parts that can be used elsewhere, the benefits of refurbishing, and so on. Our model is quite simple and visual. Early results suggest that acceptance has been widespread and that decisions have changed, leading to fewer units being scrapped and more being refurbished for redistribution.

Norway is a social democracy that provides free health care to its citizens. People with handicaps are supplied with such devices as wheelchairs, hearing aids, and speech synthesizers without charge. Previously, the responsibility for supplying these devices belonged to the local governments in each of the 19 Norwegian counties. Over time, the local governments organized a series of 19 technical aid centers (TACs), one in each county, for the distribution and servicing of the devices. The first TAC was organized in 1979 and the last in 1995. Because service and costs varied across the country, in 1994 Norway transferred responsibility from the local governments to the Norwegian National Insurance Administration (NNIA), a unit of the national government. The TACs purchase new units at the price negotiated by the NNIA and then distribute them to patients. For example, a person needing a wheelchair gets one from the TAC in his county or from his or her hospital or rehabilitation center, which in turn gets it from the TAC. When patients return devices to a TAC because they no longer need them or because the devices have failed, the TAC staff must decide whether to scrap them or to refurbish them so they can be used again. Discarded units are cannibalized for useable parts.

The refurbishing decision falls into a general class of problems called product recovery problems that have generated some academic interest and enormous practitioner interest. The TACs *reuse* some units, *repair* others, and *refurbish* still others (Figure 1). In general, the distinction between repairing and refurbishing is somewhat blurred at the TACs and depends on the specific adjustments to be made. We use the term *refurbish* to describe the process of replacing components or otherwise fixing or modifying a unit so it can be distributed again.

Product recovery is an attempt to reuse as much of the product as economically worthwhile (Figure 1). Clearly, redesigning products so they can be reused and their components recovered in multiple ways is a powerful component of sustainability. Unfortunately, the TACs have little control over product design. We therefore focused on gaining better use of returned units. The NNIA had found that decision makers were scrapping units too frequently, basing their decisions on a one-dimensional examination of the number of labor hours required to refurbish the unit. A more complete decision process should account for the full cost of sending a unit to the landfill, and a number of other factors. Such a decision process should cause fewer units to be landfilled, thereby improving sustainability. It is possible that an economic perspective on the refurbishing decision would send more units to the landfill. However, this certainly was not the case at the TACs.

After establishing the TAC structure, the national government hired the government consulting agency, State Consult, to undertake a major study of the TACs efficiency. The primary motivation for the study was economic, but because Norway has been a leader in global environmental issues, there was an implicit motivation to further the government's environmental goals. Of State Consult's seven main recommendations, Department of Health and Social Matters, Parliament Proposition No.1, there were

- *To centrally coordinate the 19 technical aid centers,*
- *To establish better efficiency measures for the TACs, and*
- *To conduct a cost/benefit analysis of reusing returned products versus purchasing new products.* (Parliament, 1998)

Our project was initiated by the NNIA to address this third recommendation.

Literature review

Many researchers have addressed the topic of product recovery, for example, Axsäter [1993], Demmy and Presutti [1981], Diks, de Kok, and Lagodimos [1996], Fleischmann et al. [1997], Mabini and Gelders [1990], Nahmias [1981], Sherbrooke [1992], Silver, Pyke, and Peterson [1998, Chapter 12] Thierry et al. [1995], and Verrijdt [1997]. Because military applications are common, most of the original work on this problem was done in that context. Sherbrooke [1968] did some of the foundational work, developing a technique called METRIC (multi-echelon technique for recoverable item control.) Axsäter [1990], Axsäter [1993], Graves [1985], Muckstadt [1973], and Svoronos and Zipkin [1988] did subsequent work motivated by METRIC.

A number of authors explicitly consider scheduling the repair shop in conjunction with inventory and procurement policies, for example Gustafson [1991]; Hausman and Scudder [1982]; Pyke [1990]; Pyles [1984]; and Tripp et al. [1991]. Some included the possibility of cannibalizing, or "borrowing" a required part from another piece of equipment that is inoperable for other reasons.

Muckstadt and Isaac [1981] developed a model of a single location with two types of inventory: serviceable and repairable. Demands for serviceable units and returns of repairable units occur probabilistically. In addition, repairs are done on a continuous, first-come, first-served basis. Inderfurth [1997] extends the Muckstadt and Isaac model to a remanufacturing problem in which there are two decisions each period: how many returned products to remanufacture (the remainder will be scrapped), and how many new parts to procure. In this system, returned products arrive probabilistically and are either remanufactured or thrown away. Newly procured products are stored with remanufactured products in a finished-goods inventory that serves demand that arrives probabilistically. There are per-unit costs to procure, remanufacture, and dispose, and holding costs are charged against ending inventory each period. For the case in which the lead times for remanufacturing and procuring are equal, Inderfurth shows that the structure of the optimal policy is based on two parameters, an upper and a lower limit in each period. If inventory is lower than the lower limit, order up to that limit and do not dispose of any units. If inventory is higher than the upper limit, dispose of units "down to" that limit and do not procure any units. Otherwise, do not buy or dispose. Inderfurth points out that when one permits a stock of returned units waiting for disposal or remanufacturing, or when the lead times to procure and remanufacture are different, the policy is similar but much more complex. Calculating optimal values for the lower and upper limits, even in the simple version of the model, involves solving a dynamic program, and therefore, we decided that such a model was not realistic for the TACs.

Van der Laan, Salomon, and Dekker [1997] proposed a policy for a continuous review version of this problem. Heyman [1977]; Penev and de Ron [1996] studied the disassembly process, and Ferrer [1995]; Guide and Spencer [1997]; Inderfurth [1996]; Richter [1996]; Salomon et al. [1994]; Taleb, Gupta, and Brennan [1997], and van der Laan et al. [1996] studied other aspects of the remanufacturing process.

The Technical Aid Centers

The technical aid centers provide hundreds of items and services to aid handicapped people. The items range from simple hearing aids and manual wheelchairs to complex and expensive units, such as automobiles suitable for physically handicapped drivers. Also included are such items as beds, elevators, computers, medical alarms, devices that turn the pages of a book, and special shoes. Some items, such as computers with special voice synthesizers, have short life cycles due to technological obsolescence, while others, such as manual wheelchairs or beds, last many years and almost never become obsolete. For children, the TACs provide items that may be designed with fashion in mind and that can take the hard use children give. These items need frequent repair, and they become obsolete quickly. The services the TACs provide include modifications to patients' houses or apartments, treatment, and training.

As in many industrialized nations, the elderly of Norway live in their own homes as long as they can, which creates high demand for technical aids to ease daily activities. As life expectancy increases, the demand on the TACs has been increasing. The demand for the TACs' services has also increased as a result of new policies establishing private housing for the mentally handicapped. In January 1997, the 19 TACs were serving 360,000 people, of all ages, out of a population of around 4.5 million in Norway. Most of the people served are between 70 and 90 years old, although the average age is 66.

Also as in many industrialized nations, the cost and level of health care has increased dramatically in Norway. The total value of all products distributed has also increased – from 150 million Norwegian kroner (Nkr) in 1983 to 1,796 million Nkr in 1996. ($1 equals approximately 7.2 Nkr.) Part of this increase is due to more costly units, and part is due to the fact that the TACs are now meeting needs they did not previously meet. The value of refurbished units distributed to patients was 564 million Nkr in 1996, or 31.4 percent of the total. For establishing this value, refurbished units are valued at the purchase price of new units.

Performance Measures

Because of socialized health care, the TACs do not face the performance measures for distribution operations that are common among firms that compete in the marketplace. For instance, there is no explicit service objective, such as fill rate. Staff members at the TACs try to provide fast and reliable service to patients and hospitals, but they are not measured on their responsiveness. Rather, they are evaluated solely on cost. One measure is the value of distributions supplied from refurbishing, relative to the total value of units distributed. The target has been somewhat arbitrarily set at 50 percent, although in 1996, they were operating 31.4 percent. The most recently established TACs will have a lower percentage because they have fewer units in the field. Therefore, fewer will be returned for potential refurbishing. When we eliminate from the calculations the three TACs established after 1993, however, the percentage increases only to 34.8 percent. In the future, the NNIA can use our decision support system to reevaluate the 50 percent target by product group and by location.

The TAC system was established in all counties by 1995, and large variations still exist. Among the 16 TACs established prior to 1994, the percentage of the value of refurbished units to the total value distributed ranged from 18.4 to 51.9 percent. TACs that were established in 1988 and 1989 account for the minimum and maximum values, respectively.

Decisions

In general, the TACs want to keep the cost of purchases, inventory, and refurbishing at a minimum. Therefore, they focus on two related decisions, the initial purchase of new products and the subsequent decision to refurbish or dispose of returned equipment.

The purchase decision is both strategic and operational. It is strategic in that TACs decide every few years which products to buy for the next several years, taking into consideration new technologies, budgets, needs, costs, and so on. It is operational in that the TACs must decide when to replenish inventories by outside purchases. In our project, we focused on the refurbishing decision.

Structure of the System and Flow of Product

To explain the flow of a specific item, we shall assume as an example that a patient needs a wheelchair for a limited time. His doctor or physical therapist refers him to the TAC in his geographic area, or he picks up the wheelchair from his hospital or rehabilitation center. If the TAC does not have the unit requested in stock, its staff may give the patient an alternate wheelchair until they obtain the correct unit. For instance, a larger wheelchair may satisfy the patient's need temporarily. TACs can transship units to other TACs, but the rules for doing so are very informal. If the TAC cannot obtain the needed wheelchair from another TAC or from refurbishing, it will purchase a new one. The TAC often must add certain features or equipment in a final configuration process before the unit is ready for the patient.

When the patient no longer needs the wheelchair, he returns it to the TAC, which stores it briefly, inspects it, and washes it. It then puts it in a stock called pre-inventory. Units in this area wait for the TAC's final decisions to refurbish or scrap. Scrapped units generally go into a landfill. However, certain parts, such as batteries, go to recycling centers. Scrapped units are stripped of useable parts, which are put in parts inventory. If TAC personnel determine that the unit could be useful in Eastern Europe, they may give it to an organization like the Red Cross that will deliver it there. Each TAC chooses whether to landfill scrapped units or to give them away. The NNIA simply requires that the decision to give the unit away does not change the refurbishing decision.

If the TAC decides to refurbish the unit, it may leave it in preinventory for some time. Ultimately it is refurbished and put back into the TAC’s inventory of units ready for use. The TAC draws needed repair parts from parts inventory or purchases them. The TAC may do the refurbishing in-house or outsource it if it cannot do the refurbishment.

Decision Support System

Deciding whether to refurbish or scrap a returned unit depends on a number of factors that can be quite complicated. We designed our decision support system (DSS) to help TAC personnel make informed refurbishing decisions, considering the major economic trade-offs. The NNIA requried that the DSS be clear, simple, and suitable for building staff intuition about these tradeoffs.

Jointly with the NNIA, we developed requirements for the system:

- It should be easy to use and to understand, while still accurately representing the real situation;
- It should allow easy and quick data entry;
- It should rely mainly on data from existing databases;
- It should allow for easy estimation of needed parameters;
- It should engender the users' trust; and
- It should be consistent with the TAC's existing hardware and software.

We developed the system in an interactive fashion. We first visited NNIA and the TACs at Oslo and Møre og Romsdal to learn the details of their operations. We learned the terminology, the current decision processes, and the ways they communicated among themselves about these decisions.

Our first step in developing the model was to establish the form of the final output of the model. For instance, one possibility was to develop a system that made a single recommendation to refurbish or to scrap. A similar possibility was to picture the recommendation system as a traffic light – green would mean to refurbish, red would mean to scrap, and yellow would mean uncertainty. We actually used this analogy to help specify the outputs. The problem with yes or no systems is that they tend to make, rather than support, decisions. We wanted to provide a tool that, consistent with the NNIA requirements, *supported* the TAC's decisions.

The Model

Based on our conversations with NNIA and the TACs and our own analysis of the decision processes, we decided that the model should generate the approximate monetary benefit of refurbishing. This value trades off the cost and benefit of refurbishing in a single number. Staff members of both NNIA and the TACs thought this approach would effectively support their decision processes. A number of factors enter into this decision:

- The unit's age – the number of years since it was purchased;
- Its life cycle – its expected life, which is limited by deterioration and technological obsolescence (eight to 10 years for some manual wheelchairs, and three years for certain computer equipment);
- Price – the purchase price of a new unit;
- Cost of disposal – the money saved by *delaying* the disposal of the unit (not the cost incurred by disposal);
- Hours – the expected hours needed to refurbish the unit;
- Hourly cost – the cost per hour of refurbishing time (in-house or outsourced);
- Parts cost – the cost of repair parts to refurbish the unit;
- Inventory balance – the number of units of this item in inventory;
- Demand per year – the expected number of units demanded per year (assumed to arrive according to a Poisson process);
- Probability of need – the probability the unit will actually be demanded before becoming obsolete;
- Inventory cost – the cost of holding one unit of this item in inventory for one year; and
- Value of parts – the value to be obtained from cannibalized parts if the item is scrapped now rather than later.

We compute the two sides of the trade-off: the value of refurbishing the unit and the cost of refurbishing. The value of refurbishing the unit is the price of a new unit multiplied by the remaining useful life of the unit in question. The remaining useful life is 1 minus the simple ratio of the age of the unit to its expected life. We multiply this value by the probability that the unit will be demanded before becoming obsolete. Finally, we add the money to be saved by delaying the unit's disposal. This total represents the benefit obtained by refurbishing the unit.

Our choice of a simple ratio for the remaining useful life implies that the value of a unit is a linear function of time. This is simpler than what we see for many pieces of equipment such as used automobiles, for which market value is clearly a nonlinear function of time. The value of a unit in our case is the ability to satisfy a need. There is no market for resale of these units. Thus, the value of the unit is in fact a linear function of time.

The cost of refurbishing is the expected number of hours to refurbish the unit times the hourly rate for refurbishing plus the cost of parts plus the annual cost of inventory per unit times the number of units in inventory (including this unit refurbished) divided by the demand rate plus the opportunity cost. The inventory cost is a simple expectation of the length of time the unit will be held before use. The opportunity cost is the lost value of parts that could have been used for other products if this item were disposed of now rather than later.

As an example, assume that a wheelchair has been returned (Figures 2, 3, and 4). The useful life of the wheelchair is six years, and this unit is three years old. The price of a new unit is 136,500 Nkr. Therefore, a simple value of the refurbished (or recycled, in the terminology of the TACs) unit is the remaining half of its life (3/6) times the price of a new unit, or 68,250 Nkr. For this case, the probability that another unit will be needed is approximately 1.0 (because if added to inventory, this will be the sixth unit, and annual demand is 18), so the gross value of a recycled unit is the full 68,250 Nkr. The cost of disposing of the wheelchair now rather than later is 100 Nkr. Thus, the total value of refurbishing this unit is 68,350 Nkr.

Personnel at the TAC estimate that this unit will take 17 hours to refurbish at a cost of 350 Nkr per hour. Thus, the total labor cost of refurbishing is 5,950 Nkr. The parts required to return the unit to a like-new status cost 4,936 Nkr, so the total cost to refurbish is 5,950 + 4,936 = 10,886 Nkr. If this unit is refurbished, it will be the sixth unit in inventory, which implies that it will remain in inventory for approximately 0.33 years. Because the inventory holding charge is 0.2 and the value of a new unit is 136,500, the cost to hold a unit in inventory for a year is 27,300 Nkr. This means that the cost to hold this unit for 1/3 of a year is 9,009 Nkr. This yields a total cost of labor and inventory of 10,886 + 9,009 = 19,895 Nkr. If the unit is scrapped, the TAC could gain parts worth 10,000 Nkr, so the total cost of refurbishing this unit is 29,895. The net value of refurbishing is therefore, 68,350 – 29,895 = 38,455 Nkr.

The focus of our model is on economic parameters; it does not explicitly account for more general environmental concerns. Clearly, environmental issues are important as well. However, the NNIA would have difficulty quantifying the promotion of environmental concerns apart from economic realities. Our model helps users at the TACs to develop their intuition about the real costs and benefits of refurbishing. In fact, over time, the NNIA should provide guidelines for incorporating more of the full cost of disposal so the model can also reflect the costs for future generations. The NNIA can also perform sensitivity analyses to show, for instance, the environmental value of changed product designs.

The Software

Instead of organizing the screen in the traditional way in columns of text and numbers, we organized it to help people to visualize the model itself. The screen shows the arithmetic operators so the user can develop their understanding while using the system (Figure 3). Users can adjust input data easily by simply clicking on the appropriate number or on the sheets that contain product and parts data. Users can change any value on the screen to perform what-if analyses, building their intuition about the trade-offs and drivers of the decision.

There are many options in the software, including some visual tools that aid the decision-maker. For instance, by specifying an option in the setup screen, the user can direct the system to color the net value box green if the net value of refurbishing the unit is above a specified number (that is, it is a clear candidate for refurbishing), red if it is below a specified negative number (a clear candidate for disposal), and yellow otherwise. Another feature is a sheet of parts data. Users of the prototype at the TACs encouraged the NNIA to create a standard set of parts data that would be consistent across all 19 locations. Currently, only product data is centrally maintained, but we expected that the NNIA will centrally maintain parts data in the future (Figure 4).

Users must understand and carefully define the input parameters to accurately represent the actual situation. In the first prototype, for example, users were expected to enter the “value of price” (Figure 3). When presenting the prototype to the TAC at Møre og Romsdal, we discovered that users typically entered 90 percent of the new purchase price because "we distribute only products that are as good as new." However, if the unit is eight years old and its expected life is 10 years, only 20 percent of its useful life remains. Their mistake is that their figure reflected the value to the user, rather than an internal opportunity cost. Note that in valuing the total distributions of refurbished units for external reporting purposes, the NNIA values them at the purchase price of new units. In cooperation with the NNIA and the two prototype TACs we agreed that our final design choice was a good combination of simplicity and reality.

Implementation and Benefits

Because the NNIA managers thought that improved competence was perhaps the most important potential benefit of this project, we held a full-day workshop for 35 participants from all 19 TACs. In this workshop, we covered the fundamentals of decision processes and then solicited participant input to develop the actual model. Finally, we trained the participants in using the system.

The general feedback was extremely positive. Many stated that the system was "exactly what we need." In several cases, participants stated that the system would change the way they made decisions. Some used cutoff values on the time required to refurbish an item. For instance, "we will scrap the item if it requires more than two days to refurbish." When they examined the broader set of factors on the screen, they could see clearly that the two-day value was too simplistic. An electric wheelchair that is very expensive to purchase usually should be allowed more than two days of repair time. The obvious benefit, aside from sound economics and the associated benefits to the

Norwegian government, is that fewer units will be sent unnecessarily to landfills. Our system can also be used in a strategic way to reevaluate the current 50 percent refurbishing target. The target should be different for different product groups and for different locations. For example, more durable products with long life cycles and low refurbishing costs should have a higher target value. All 19 TACs are in the process of implementing the decision support system.

What can managers learn from this experience? It seems to us that discussions about environmental issues tend to be polarized. Some feel that the environmental movement has gone too far and will only impoverish them and their countries. Others feel that without immediate action, the planet is doomed. As we listen to these discussions, we notice that many managers are not proactive about these issues. Rather, they wait for government regulation and then respond at the minimum level. Simple models like ours allow managers to examine the economic consequences of their decisions, even if they have no broad environmental concerns. Clearly, the cost-accounting issues associated with the refurbishing decision are extraordinarily complex. A simple model, however, allows managers to move beyond inaction, to move beyond waiting for the government to mandate certain actions. They can consider economic trade-offs in a simple and direct way. As users gain experience with making these decisions, they can work to make the input data more accurate, and they can explicit try to account for the cost of their decisions to future generations.

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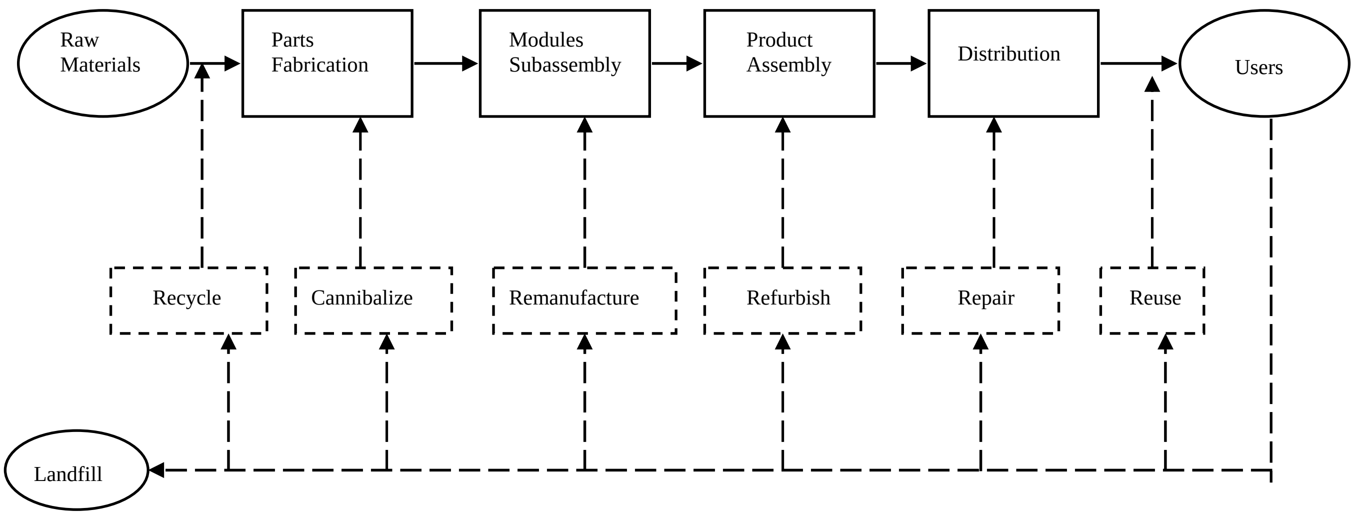


Figure 1: A general framework for product recovery options shows the many ways portions of a product can be recovered. Using these definitions, the NNIA refurbishes discarded units. (adapted from Thierry et al. [1995].)

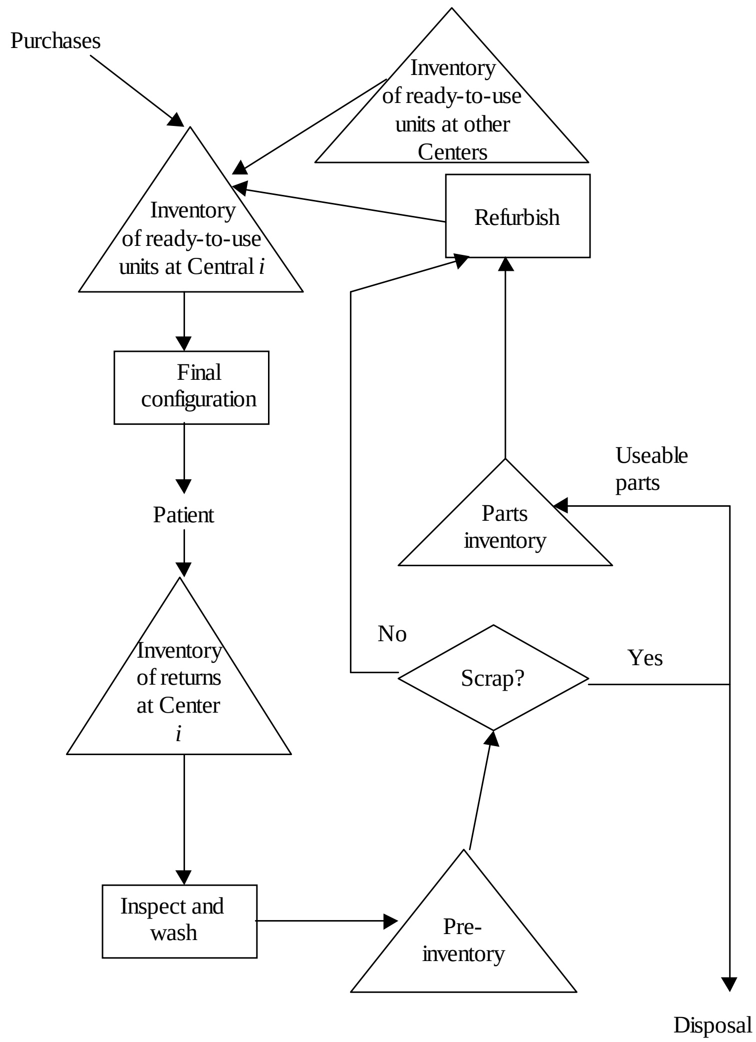


Figure 2: Distribution and product recovery at the TACs, including purchases, patient use, returns to the TACs, and the decision to scrap or refurbish.

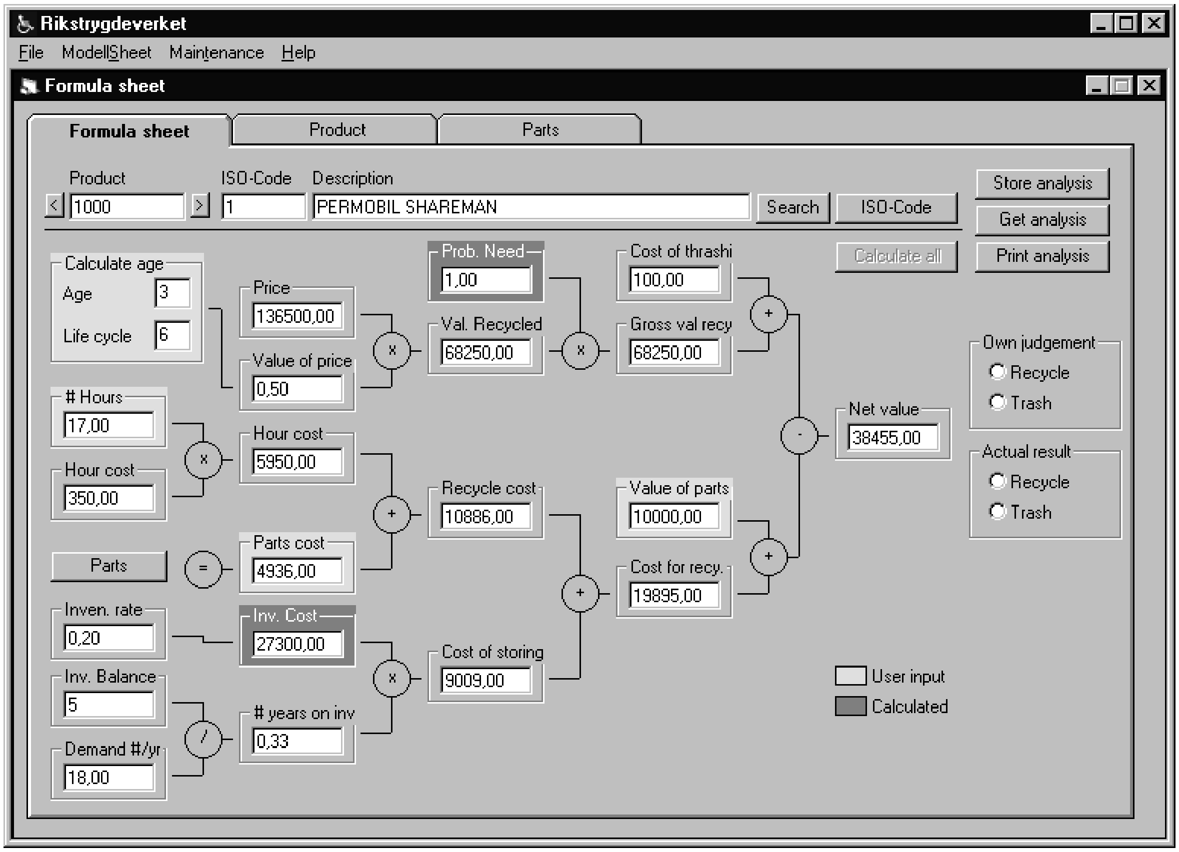
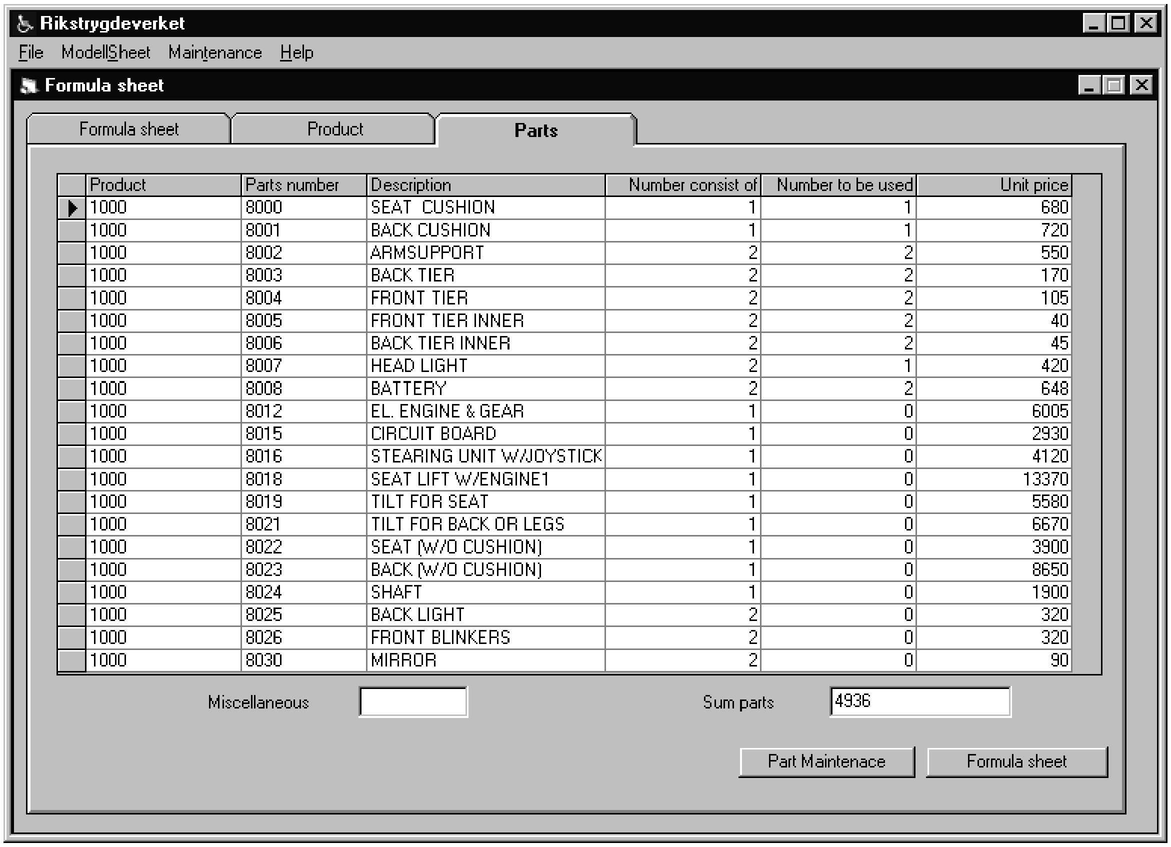


Figure 3: The model as pictured on the computer screen.



Product	Parts number	Description	Number consist of	Number to be used	Unit price
1000	8000	SEAT CUSHION	1	1	680
1000	8001	BACK CUSHION	1	1	720
1000	8002	ARMSUPPORT	2	2	550
1000	8003	BACK TIER	2	2	170
1000	8004	FRONT TIER	2	2	105
1000	8005	FRONT TIER INNER	2	2	40
1000	8006	BACK TIER INNER	2	2	45
1000	8007	HEAD LIGHT	2	1	420
1000	8008	BATTERY	2	2	648
1000	8012	EL. ENGINE & GEAR	1	0	6005
1000	8015	CIRCUIT BOARD	1	0	2930
1000	8016	STEARING UNIT W/JOYSTICK	1	0	4120
1000	8018	SEAT LIFT W/ENGINE1	1	0	13370
1000	8019	TILT FOR SEAT	1	0	5580
1000	8021	TILT FOR BACK OR LEGS	1	0	6670
1000	8022	SEAT (W/O CUSHION)	1	0	3900
1000	8023	BACK (W/O CUSHION)	1	0	8650
1000	8024	SHAFT	1	0	1900
1000	8025	BACK LIGHT	2	0	320
1000	8026	FRONT BLINKERS	2	0	320
1000	8030	MIRROR	2	0	90

Figure 4: The parts data sheet

Appendix

Notation:

- Age, a.
- Life cycle, T.
- Price, p.
- Cost of disposal, C_T.
- Hours, H.
- Hour cost, C_H.
- Parts cost, C_P.
- Inventory balance, I.
- Demand per year, D. We assume demands arrive according to a Poisson process.
- Probability needed, Pr. Pr = probability that a Poisson random variable during (T – a) years with demand rate of D units per year exceeds I.
- Inventory cost, C_I.
- Value of parts, V.

Equations:

The value of refurbishing the unit is therefore

$$p(1- a/T)(Pr) + C_T$$

The cost of refurbishing a unit is

$$HC_H + C_P + (C_I)(I + 1)/D + V$$

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