Reverse logistics as a solution to growing waste

by

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ABSTRACT

The paper deals with the reverse logistics problems in the context of retrieval of worn out industrial products and materials. Increasing importance of the reverse logistics for economical and ecological problems resulting from the necessity of saving material and energy resources has been emphasized. The particular features of the reverse logistics have been characterized. Rationale for introducing reverse logistics into logistics networks of industrial processes have been described as well as difficulties in planning of the product recovery operations. Guidelines for designing of products which allow for retrieval and facilitate reverse material flows have been formulated. Factors that should be taken into account in design in order to improve management of the used products have been discussed.

Keywords: Mass production, reverse logistics, waste, reuse, recycling, design

1. INTRODUCTION

In recent decades, the world population growth, combined with the technological changes associated with our living standards, has created a greater consumptions of our resources, resulting in potential shortages, which, in turn, has stimulated shifts toward establishing other means for accomplishing objectives. Concurrently, the amount of waste has increased significally. From the logistics point of view, the solid waste is of particular interest.

Solid waste is any garbage or refuse (e.g., paper, wood, clot, metals, plastics, etc.) that cannot be decomposed and will result in a health hazard. Roadside dumps, piles of industrial debris, junk car yards, ond so on, are good examples of solid waste. Improper solid waste disposal may be a significant problem in view of the fact that flies, rats, and other disease carrying products are attracted to areas where there are solid wastes. In addition, ther may be a significant impact on air pollution if windy conditions prevail or on water pollution if the solid waste is located near a lake, river, or stream.

Adverse effects of the production rapid increase driven by greed for profit become more and more damaging. Natural resources of raw materials and energy are closed to be exhausted and ability of biosphere to absorbing the industrial production side effects has already been exceeded. Expansion of industry to developing countries nothing changes in the longer prospects.

The limited resources of our planet are not only reason of the situation; the market absorption is also limited. Increasing production capability when clashes with decreasing market absorption gives rise to the trade perturbation and creates economic conflicts. In the countries and the societes which can not use benefits of modern technology rapidly increases feeling of the discrimination.

Modern technology has been based on the paradigm that the human needs for the material products should be satisfied with excess. This, however, led to the conflict with the natural, social, and human resources. The famous report of the Roman Club turned our attention to the exhaustion of natural recources, whereas the social and human threats have been indentified only not long ago. It is depicted in Table 1.

Table 1. Threats caused by excessive production

<table>
<tr><th colspan="2">Sources</th><th>Limitations</th><th>Threats</th></tr>
<tr><td colspan="2">Natural</td><td>Materials
Energy
Environmental sensitivity</td><td>Lack of materials resources
Lack of energy sources
Detrimental changes of environment</td></tr>
<tr><td rowspan="2">Human</td><td>Social</td><td>Capability of market absorption
Transport capacity</td><td>Economic stresses
Jams of transport service</td></tr>
<tr><td>Individual</td><td>Consent to turning human functions to cybernetic systems</td><td>Over-useful products
Man will have to obey artificial intelligent systems</td></tr>
</table>

If we do not change the basis of the manufacturing industry expansion then we will have to fight against the consequences instead of the causes. It will end in failure. If we, however intend to remove causes, we must base production development on the entirely opposite principles, i.e. a different paradigm [10]. The commonly accepted *Mass Production*

Paradigm (MPP) which calls for 'better, more, cheaper, at top speed' should be abandoned and replaced by *Economical Production Paradigm* (EPP) [12].

The new paradigm requires the separation of the producer income from the increased use of materials and energy. Further, it requires reduction of amount of manufactured goods till rational size. It also calls for restriction of operating devices quantity to the amount not disturbing natural, social and personal equillibrium. Thus, production and usage should consume minimum amount of materials and energy and do not produce any waste. In order to provide producers with satisfactory profit at much reduced material needs the new types of products are to be designed [2,9].

In order to accomplish above postulates it is necessary:

(i) to develop and apply knowledge of current and future social needs;

(ii) To satisfy the needs more by means of the qualitative than by the quantitative measures of possession;

(iii) to make producing industry responsible for the whole life cycle of the product;

(iv) to make change of the ways of users needs satisfaction.

Figure 1 shows diagrams two product life cycles: the open and the closed one. The open cycle can not been accepted because it causes pollution of the environment by used product waste.

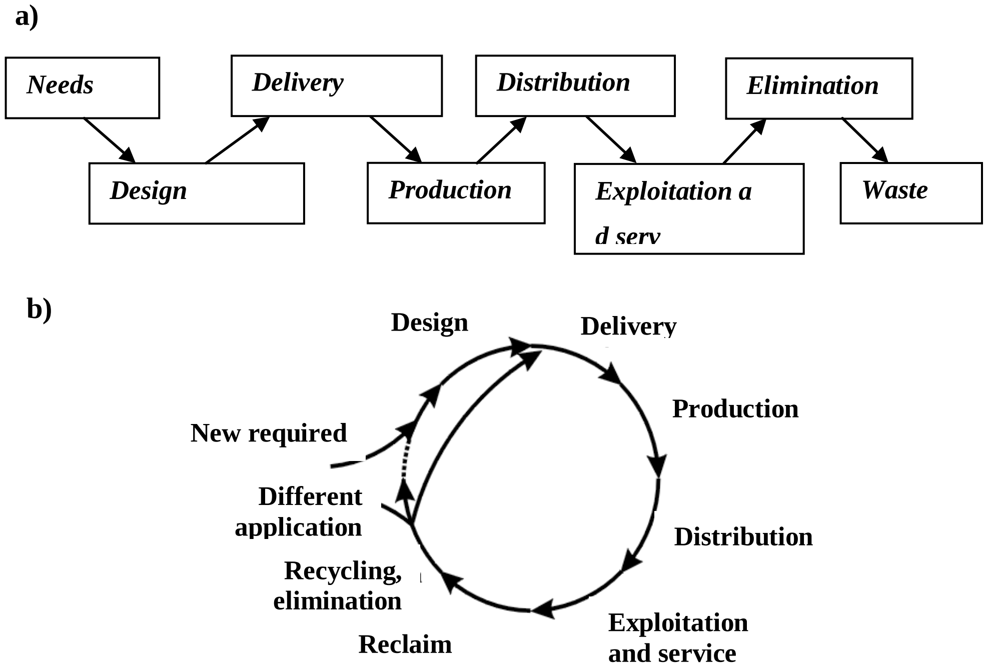

Fig. 1. Models of the product life cycle: a) open b) closed

Ideal would be the closed cycle that does not generate any waste. The law of mass conservation states that – in theory – it is possible. In reality, however, full retrieval of materials, even if feasible, would not be economical.

Most of modern products represents intermediate phase. Importance of recycling and material salvege is continually increasing. Other opportunities for the the material cycle closure are in reclaiming partially used parts, utilization of elements which are take out of service for other products, and the like. In thermodynamic processes, according to second law of thermodynamics, realization of the ideally closed cycle is not possible. Therefore, in order to avoid the energy crisis, there is necessity of efficient exploitation of the solar energy, indirectly or in the form of natural energy sources.

With the increasing concern for the environment, and the possibility of environmental degradation, more attention must be given to the phaseout and recycling stage. It must be addressed along with the design and development of the prime mission-related components of the system, the design for producibility, and the design for supportability. In other words, an appropriate level of emphasis should be placed initially on the design for disposability or recycling/reuse, and later on developing the appropriate logistics infrastructure for the subsequent processing of items to be discarded.

Thus, any physical system should be designed for recycling, reuse and disposability. From a supportability perspective the accomplishment of such an objective should result in minimum requirement for follow-on logistics resources (i.e. spares/repair parts, test equipment, software, personnel, facilities, data, etc.). The plan covers the retirement and phaseout of equipment, the disassembly and reclamation of material items as appropriate, and the ultimate disposal of residual material. In some cases the phaseout process could be rather extensive, including the requirements for logistics support. The logistics plan should identify the requirements for transportation and handling, the support equipment necessary for material processing personnel, facilities and the data necessary for the processing of items out of the inventory. The use of commercial and standard elements is preferred.

2. SPECIFIC FEATURES OF REVERSE LOGISTICS

General objective of the reverse logistics chain is retrieval material objects or disposed them without any violation of environmental requirements. Usually it involves packing and delivering an object to the point of collection for regeneration or recycling. Collecting used products from market is more like procurement than purchasing. Nature of the reverse flow is very unstable because quantity of the returned products/elements as well as their conditions are difficult to predict.

There are three prime factors to take into account in the logistics reverse design:

(i) logistics network structure,

(ii) planning of material flow, and

(iii) sorting and determining the routes of returned elements.

Most of the logistics systems are not adjusted to operate reverse flow of products. These can not be transported, stored or manipulated in the same way as new products. Cost of reverse distribution may be much greater than this of the direct one. However, efficiency of product retrieving can be very beneficial [13].

Importance of reverse logistics for modern industry and ecology is enormous it takes, however, little place in the literature [1,3]. System retirement, phaseout, and the recycling or disposal of material no longer required in the operational inventory are not satisfactory covered. It is common to address the design and development as well as the operation of a system but phaseout and subsequent disposition of the system (and its components) are not adequately considered until it is time for having to do something about it.

2.1. Industrial processes related to reverse logistics

After equipment has been in operational use for a period of time, various individual components begin to wear out. Some components (i.e., mechanical lincages, gears) wear out sooner than others. When this occurs the need for maintenance increases.

- Repair, modernization, renovation

Repairable spares that are, for one reason or another, condemned and nonrepairable parts, when removed from the system and replaced, are generally shipped to the depot or the supplier facility for disposition. These items are inspected, disassembled where possible, and can be salvaged, reclaimed or recycled. The residue will be disposed of in an expedient and economical manner conforming to environmental and ecological requirements.

Although reasonable predicting of failures for many products is possible yet right decision of returning a product is difficult because it often depends on individual point of view.

Forecasting of frequency and types of failures is usualy based on historical data, which not necessarily will turn out in the future.

If a product is under repairation, the user often expects to get its substitution. Therefore, the producer should possess sufficient repairing capability and the reserve of spare parts in order to provide quick return of the product at a low cost.

Modernization means improvement of the product or of its part in order to decrease frrequency of defects or to enhance functionality. Modernization alike repair can be performed at the user or at producer.

Renovation of the product which has been withdrawn from the operation consists in recovering it to the condition in which it can again perform its original functions. Powerful potential for renovation is in electronic industry which sells milions pieces of products.

Not many manufacturers design products for renovated elements or units [4]. Products should be customized to modernization and renovation in design stage. To do this, however, designers have to know real cost of the product life cycle.

- Retrieval of elements

In some cases it may be not worthwhile to renovate complete device whereas some parts still keep their value. Cars can be a good example: usable elements and those suitable to renovation are disassembled from old cars and then used for substitution of defected parts in cars under operation.

- Disposability and recycling:

It pertains to the degree to which an item can by recycled for some other use or disposed of without causing any degradation to the environment; i.e. the generation of solid waste, toxic substances (air pollution, noise pollution, radiation, and so on). Should this area not be addressed in the design, the requirements for logistcs may turn out to be rather expensive and costly in order to comply with the environmental requirements currently being imposed. For example, a large incineration facility may be required for material decomposition. This, in turn, may include large amounts of capital ninvestment which requires maintenance and could be very costly to support.

In many products there are units and parts not worth to be repaired, which are not suitable for any further use.The worn out product as a whole may have no value but a part of its material can have a worth. Examples are copper wires, aluminium tins or steel structures. Polymers are less convenient for retrieval because of high cost of processing, and in view of the fact that they lose properties in the recycling process – mainly for a tendency to tearing of the polymer chains. Recycling of materials is particularly important for products which have short life cycle and are manufactured in bulk.

The European Union encourages the member states to reduce polymer production yet enormous quantity polymer products still calls for more effective recycling processes.

2.2. Factors that make recycling difficult.

Product retrival process has particular character that should be taken into consideration in design of reverse logistics. A number of reasons has been indicated in literature of the subject [5, 14, 15]. Familiarity with these difficulties during design stage make possible reducing their impact and owing to that facilitate recyling and repair processes.

- Irregularity in time of returned items quantity

Occurence of used products depends on amount of earlier sale, on their expected life, and on rate of functionality loss during operation. This phenomenon makes reverse flow coordination of materials and their processing difficult.

Attention should be paid to the relative ageing o the products. If a product becomes out of date then much its quantity is withdrawn in a short time. Quick modernization of obsolete products may be unrealistic, so only real solution can be reuse or at least recycling. In case the product life time is short then prediction of its reparability, life and so on is of minor significance.

Again, anticipated time of the product obsoletness should be considered in design process. The quantity of retiring products versus time should be estimated during design in order to adjust appropriately technology of spare parts production. Valuable parts should be easily adapted for recovery. Use of lead, mercury, and other heavy metals should be avoided, unless the infrastructure for their collection is well developed. Advances of sensorics and intelligent devices increase reliability of predicting of wear and tear level and defects contributing to more precise evaluation of time and quantity of returned items.

- Balancing of customer demands with returned products

For companies dealing with retrieval of used products supplying of these is important. Quality and quantity of used products which can be obtained at a certain interval are generally not known because many companies does not check them as well as time of their returning. Quality control of used parts before returning them is necessary to evaluate material- and laborconsuming required to recover their functionality.

In order to avoid excessive storage of used products and to balance returns with customer demands companies should have an appropriate strategy. Strategies push and pull in relation to production and stocks for new and renovated elements are discussed in [6] and [7]. It was proved that choice of the rational strategy depends on the cost relationships between the stocks of new and renovated parts. It was suggested that during the product life cycle menagers should update decision rules of effective management and control of the stocks. Producers should balance reserves of returned products and reclaimed parts with current demands of the customers, unless the stockpiles can increase uncontroled, which give rise to discarding of the used products [7].

In order to balance the returns with customer demands producers have to combine forecasting of traditional demand with orders of used poducts. These products can be acquired from various sources: users, agents and servicemen.

Proper product design and understanding its lifecycle can contribute to mitigate problems of adjusting volume of returns to orders.

- Disassembly

In order to determine the need for new parts department of supply should get information from dissasembly. Products that are returned have to be disassembled before being restored.

Disassembly is the first operation in preparing elements for regeneration. The process is often difficult because still rarely the products are designed for dismantling. Disassembling of such products can take a long time, parts may be suffered damage, which results in useless waste. There is difficult to predict how much of materials will be recovered. This makes difficult planning and controlling manufacturing operations.

Companies are interested in minimization of cost while process of disassembling requires some expenditures. Usual approach to retrieval problems consists in comparing of disassembly cost with profit due to recovered material. A simpler approach relays on the expert evaluation if a given part is worth to reuse [4]. This gives a possibility to reduce expenses for disassembling of the product that has minor value for the reuse.

All products should be designed with a wiev of disassembling and further use [12]. To make it possible designers should know effectiviveness of the disassembling. Instructions with respect to this can be find in [8].

- Uncertainty as to quantity and quality of recovered parts

Amount of parts which are suitable to reuse directly or after a repair is difficult to be anticipated because before the product has been disassembled, cleaned, and inspected, it is impossible to evaluate its parts usability. Without this evaluation the planning and control of any reserve and purchasing become problematic.

Producers should anticipate amount of parts that will be renovated to be able to plan how many new ones have to be produced in order to replace the parts that can not be regenerated.

Currently producers do not regularly report data about renovation. Products may include parts of known reclaim characteristics but might as well have a number of parts without any such data. According to producers that deal with renovation of parts, dominant problems in fulfilling customer orders consist in lack of available parts, long order realization times, and high cost of original parts. Development of electronic data bases is still contributing to improving of renovation forecasting and decreasing of material requirements uncertainty. In possession of the relevant data the designer should specify upper limit of the renovation cycles after which the part material will be recycled.

Rationalization of orders is indispensable for the material flow control, inventory management, and efficient use of personnel and infrastructure. It is of particular importance for producers attempting to offer a broad range of assortment of renovated products.

- Requirements for dealing with regenerated parts

If customer wants to get back the same part which was under repair, the producer is responsible for coordination of disassembling, repair and regeneration of the part being re-assembled. In order to ensure returning the same items to the customer the parts have to be numbered, labelled and traced. This results in additional load of informatic system

If the repaired assembly consists of many various elements, the planning of the stock, production, process control and management of materials is not easy task. Accomplishment of the schedule of the unit reassembling may also be delayed because of some postponing in delivery of one part only.

The development of the industry renovating parts and units of various products is additionally slown down by a lack of cooperation between producers and firms that use regenerated products. Besides, designers rarely design products for using the renovated parts [4]. Despite of these difficulties, continuosly growing importance of material recovery gives rise to development of the reverse logistics chains, although it still falls behind the needs.

- Uncertainty of the routing and working time of operations

Uncertainty of the work routing is a consequence of unpredictability of renovated parts condition. Work and time that are necessary to restore full capability of various elements can differ one from another. Some treatments are always carrying out, for example the cleaning, other, however, depend on the part age and condition. As a result, reserve planning, production control, and materials management are significantly more difficult than for ordinary production.

In order to make the plan of load for the working stations producers have to estimate condition of the parts designated to regeneration. Bottlenecks may appear in different places because elements of the same type can be – after dismantling - in various states. In the consequence of this the routes of the elements may be different.

Files of parts working routes contain lists of the all feasible operations but not all parts need the same ones. Only for some used parts the renovating operations will be identical with those for the new parts; others will require different machining. This phenomenon is considered to be the most influential decision factor for operation scheduling and choice of production lot [13].

For the purpose of planning there is a need to evaluate necessity of a given operation. The product inspection before its dismantling can help to get relevant information.

The uncertainty can be also reduced by appropriate design. For example, during designing it is possible to suggest, on the basis of economical analysis, if a part, when worn out, should be regenerated or recycled. Also, design the product for a defined number of renovation cycles makes easier to predict of operation types and working times.

- Conditions of transportation

Real reverse distribution processes have to respect the local regulations. Dangerous and toxic materials may not be permitted for transportation through chanels of the reverse logistics. For example, in some regulations dispatching of used electronic products is considered hazardous (because of lead contents), while the new electronic products can be sent without restriction. Transport of radioactive wastes is allowed under severe restrictions only. Generally known are regulations limiting export of wastes (for avoid of illegal removal) and directives for obtaining of special permission and particular caution for transportation of used products.

Weight and size of the product have an impact not only upon the choice of transport means and its cost but also on facility of the dispatch preparation and on easiness of handling the product during the recovery process.

3. GUIDELINES FOR REVERSE LOGISTICS DESIGN

In the design of systems, all phases of the life cycle must be addressed, including the phase of retirement and material disposal. When the system and its components are removed from the inventory, either because of obsolensce they are not suitable for the purposes of maintenance or when the items are removed in order to accomplish repair, those items must be of such a property that they can be disposed of without causing any negative impacts on the environment. More specifically, a prime objective is to design components that they can be reused in other similar applications. If there are no opportunities for reuse, then the component should be designed that it could be decomposed, with the residual elements being recycled and converted into materials that can be remanufactured for other purposes. Further, the recycling process itself should not create any detrimental effects on the environment.

Assuming that the requirements for item removals/replacements have been identified, one should evaluate each of these items following the process illustrated in Figure 2. Can the item be reused as an entity for any other application? If not, has it been designed in such a way that it can be easily decomposed, and can any of its parts be used? If an item cannot be reused as is, can it be recycled and modified for use? Further, if recycling and reuse are not feasible, can the material in question be disposed of without causing a negative impact on the environment? Finally, is the process economically feasible? Cost of reverse logistics is a part of Life – Cycle Cost of the logistics system.. It includes the cost due to the obsolence or wearout and subsequent recycling, disposal and reclamation.

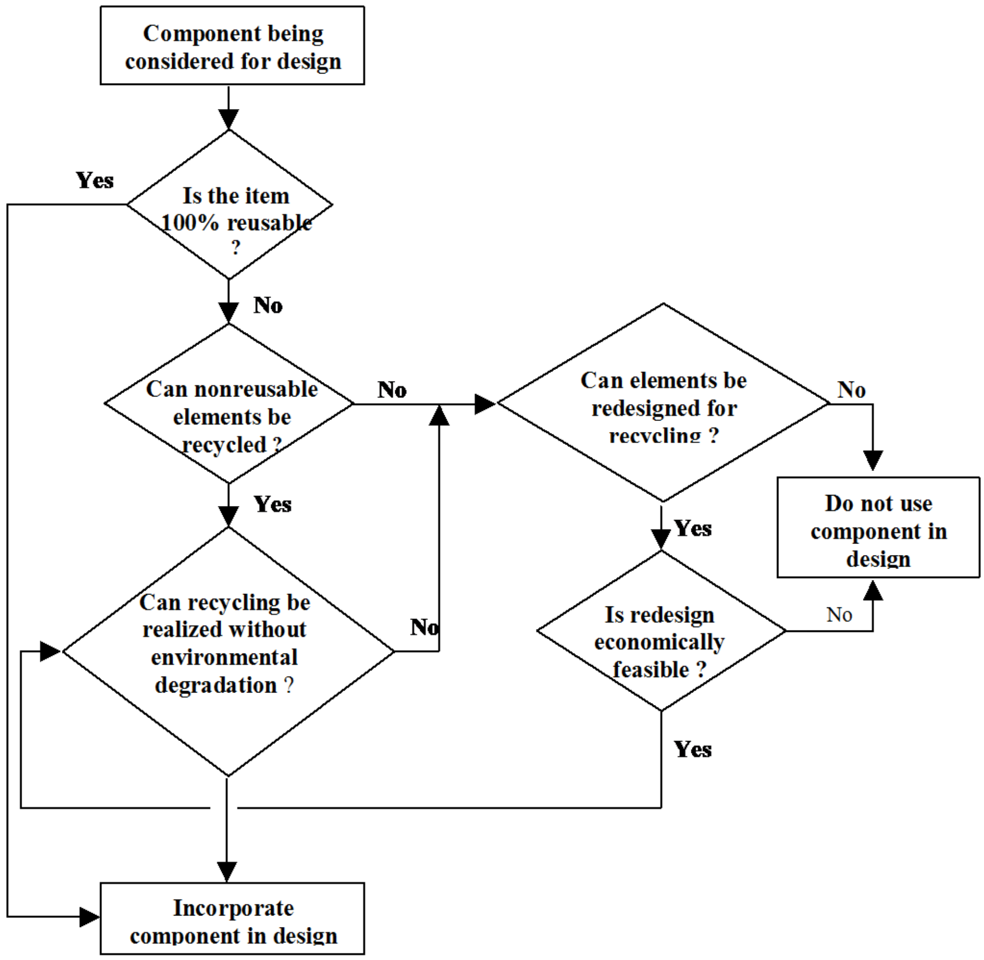

Fig.2. Evaluation of a component in respect of reverse process (according to [1])

Thus, in the development of systems and in the selection of components, the designer needs to be sure that the materials selected can be reused if possible, will not caused any toxicity proplems, and can be decomposed without adding to the solid-waste inventory that currently exists in many areas. Care must also be taken to ensure that the product characteristics do not generate the need for a nonreusable container or packing materials for transportation that will cause problems.

Figure 3 conveys a decision-making logic approach that will be helpful in the design and development of systems.

The checklist for disposability goes as follows [1]:

1. Has the equipment been designed for disposability (e.g., selection of materials, packging)?

2. Have procedures been prepared to cover system/equipment/component disposal?

3. Can the components or materials used in system/equipment design be recycled for use in other products?

4. If component/material recycling in not feasible, can decomposition be accomplished?

5. Can recycling or decomposition be accomplishing using existing logistic support resources?

6. Are recycling and decomposition methods and results consistent with environmental, ecologica, safety, political, and social requirements?

7. Is the method(s) used for recycling or decomposition economically feasible?

To sum up, the design for system retirement, phaseout, and material recycling and disposal should be responsive to the following questions:

1. What items of equipment, software, materials, data, elements of support, and so on, are likely to be phased out of the inventory, and when is this expected to occur?

2. What should be done to these items (i.e. disposition)?

3. Where should this be accomplished and by whom?

4. To what extent can be items being removed from the inventory be decomposed and recycled for reuse?

5. Are the methods used for decomposition, recycling, and material disposal consistent with ecological and environmental requirements?

6. What logistics support requirements are necessary to accomplish the requirement, phaseout, material recycling, and disposal functions?

7. What metrics should be applied to this area activity (i.e. turnaround times, recycle rates, process times, economic, and effectivenesss factors, etc.)?

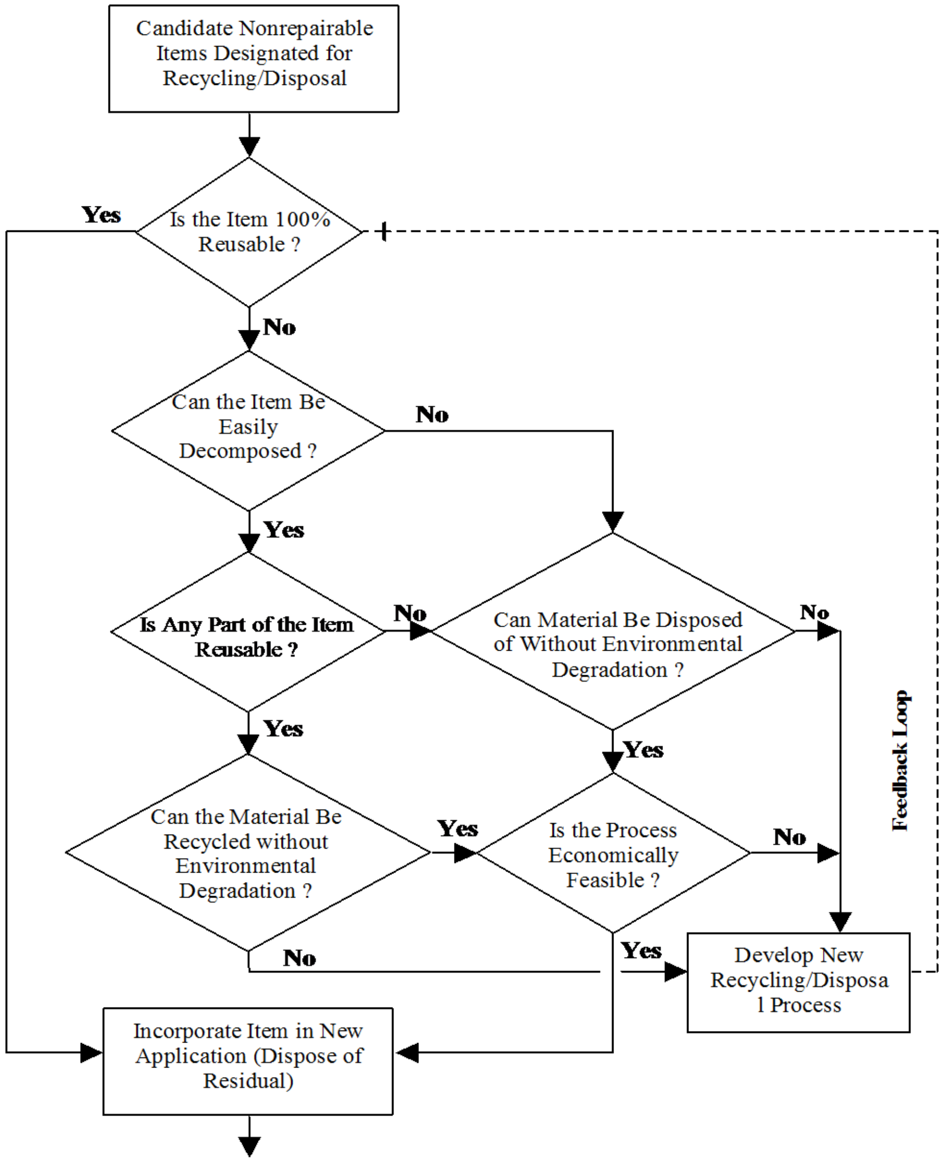

Fig. 3. Evaluation of an element for recycling or disposal (according to [1])

3.1 General Principles for the Design of Products for the Reverse Processes

Consideration of recovery matters leads to the following postulates for designing new products:

1. *Adaptation of products to remote repairs or improvements.* With the products which are tailored to remote operations, can the producer offer improvement, guaranty and servising at low cost. Owing to this a longer life time of the product can be achieved, what is appreciated by the user. Development application software and sensoric technology increases capability of remote actions.

2. *Predicting of reliability*. Product reliability should be determined in product design and during prototype investigation. The designers and producers seldom analyse and estimate the frequency of defects. It makes difficulty in prediction of the product replacement rate as well as estimation of time when the product will become outdated, which is related to the marketing and sale plans. Taking in design advantage of information of defects frequency allows better product recovery planning. It is also of advantage for agents taking part in the flow of recovered products.

3. *To design the product in such a way that it would be easier to predict more precisely its likely lifetime.* By means of little design changes it is possible – especially in electronic devices – to record time and operating conditions. It enables one to record service life of the product or its part.

4. *Modular design of expensive parts that should be retrieved*. Modularity contributes to the product value. Modular design should ensure easy replacement of the product elements that have short lifetime. It happens that the complex product loses usability but some of its parts still preserve utility. In such a case modular design offers possibility of retrieval valuable parts or materials.

5. *Avoiding of use of bothersome materials.* Detrimental substances in the product can cause particular demands of transport, manipulation and elimination. It can be ddifficult to dispose of some products for the sake of contents of undesirable materials. Such situation can rise the product life cycle cost. Thus, it is necessary, if possible, to avoid application of this kind of materials.

6. *Design of products for only one owner*. The idea of one owner means as a rule that the producer itself is the product owner. The product user has the right of using, but he/she does not own the product. The producer as the owner can easily carry out all operations aimed at right product exploitation and long cycle of life, and can plan post-life processes. The product which has only one owner during its life cycle can be easely adapted for recovery processes. These features can also be embodied to the product in design.

It is required that creation of product features related to reverse logistics and recovery processes become integral part of the design process. Usually, these features disclose themselves only after the product use. It should be emphasized that design of products that meet the reverse logistics demands is preconditioned by developing computer systems with automatic calculation algorithms, simulation programs and engineering data bases.

4. CONCLUSIONS

Pursuit of profit by means of increse material- and energy consuming production causes still growing adverse effects. This way of industrial development comes into conflict with the natural, social, and human resources. Thus, there is a need for change the current paradigm for another one that will not generate the detrimental side effects.

This new paradigm breakes the linkage of economic prosperity with the quantative measures whereas focuses on the qualitative attributes. It should ensure the economic development in spite of limited utilization of natural resources owing to innovative economic mechanisms that will promote manufacturing of products of the new kind. In order to diminish dependency of the economic growth on increasing material and energy demands the three compatible means are proposed:

- saddle the manufacturing industry with the responsibility for the whole product life cycle, in particular for attempting to close the material cycle,
- attempting to change the traditional approach to satisfying the users' needs and involve the users to cooperation in processes of the reverse logistics,
- implementation understanding of the future social needs in order to fulfil the needs not by means of the product quantity but rather by the quality of usage.

In the industry that is subordinated to the mass production paradigm much attention is focused on the direct flow of the products, i.e. on the flow from the producer to the user. At the present time there is a need for intensive expand the reverse flow chains.

There is a number of factors that hinder the retrieval and recycling of products:

- Irregularity of quantity and time of returned products,
- Difficulty in balancing demand of new products with returning ones,
- Problems with dismantling of condemned products,
- Uncertainty as to materials quality of the returned products,
- Specific demands for the reverse logistic chains,
- Difficulty with satisfying of requirements for regenerated parts,
- Renovation processes are difficult to prediction,
- Stochastic character of transport routes of parts selected for repair and recycling.

Influence of these factors can be lessen or even eliminated by proper product design. It will result in better coordination of processes of repair, modernization, regeneration, and recycling.

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