Logistics of scrapped electronics equipment disassembly

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The paper presents the concept of a new logistics solution of scrapped electronic equipment disassembly created for a selected company processing of the electronic waste. For that purpose paper sums logistics approaches used for design of scrapped electronic equipment disassembly, analyse of the current situation of disassembly in case of the company and the concept of the proposed logistics solution. The presented example makes it possible to sum up the advantages which the search of new solutions in the area of scrapped electronic equipment disassembly offers.

***Keywords**: logistics, scrapped electronics equipment, disassembly.*

Introduction

There are considerably high numbers of products, transportation vehicles, packages and waste materials released in connection with the processes taking place in supply chain management (Malindžák et al., 2007). Their backflows must be provided as far as the organizational, information, communication and financial aspects are concerned, and the manipulation, storage and transportation aspects up to their dismantling, separation, reworking with the aim of resale, recycling or disposal must be secured as well (Pernica, 2005).

The main reason is the consumers´ behaviour in the „advanced" western world – the products have shorter and shorter lifespan or the desire to be "in", for example in case of technical incompatibility of computers, will force the consumers to put the products among useless junk.

That is why the logistics approach expanded, including the back flows, and the term reverse logistics was introduced. Reverse logistics is the process of planning, implementing and controlling the backwards flows of raw materials, in-process inventory, packaging and finished goods from manufacturing, distribution or use point of recovery or proper disposal (De Brito, 2004). More precisely, reverse logistics is the process of moving goods from their typical final destination for the purpose of value capturing, or proper disposal (Hawks, 2006).

The reverse logistics features the following passive logistics elements (Škapa, 2005):

- End of use returns – used products from a consumer.
- Production waste – waste and material waste connected with production.
- Distribution returns – goods returned by distribution net.

The products at the end of their physical or moral life make up the largest share. The reverse logistics system is further based on four basic processes (Rogers et al. 1998):

1. Gate keeping – entry inspection which decides whether to introduce the passive logistics items into reverse logistics system.
2. Collection – gathering the passive logistics items for further processing.
3. Sorting and separation – the items are dismantled and sorted according to the way they will be processed onward.
4. Disposition/Re-processing – the items are processed, i.e. repaired, partly used, recycled or disposed.

The passive logistics elements from the sphere of end of use returns, especially scrapped electronic equipment (scrapped electronic equipment) are the subject of authors interest. The amount, and therefore the importance for the processing, of scrapped electronic equipment has been witnessing an annual growth in every year. From the point of view of the reverse logistics process, the attention is devoted to disassembly.

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The aim is to design a logistics solution for disassembly of scrapped electronic equipment for a concrete processing company.

Processing of the scrapped electronic equipment in the Czech Republic

The recycling process of used electronic equipment makes it possible to retrieve ferrous metals, non-ferrous and precious metals, glass, plastic and other raw materials. Recycling meets the idea of permanently sustainable development, not only from ecological, but also from economic point of view. The more electronic equipment will be included in the recycling process, the less natural resources will have to be exploited in order to manufacture new products. The health hazardous materials contained in many appliances will be retained again and they will be eliminated in an ecological way through recycling.

The obligation concerning the electronic equipment reverse withdrawal has been valid in the Czech Republic since 2005. The reverse withdrawal of scrapped electronic equipment and other machines is secured by a collective systems which were established on the basis of the waste law. The European Union requires the Czech Republic to collect an annual average of 4 kg/person, i.e. approximately 40 000 t/year, of scrapped electronic equipment. The largest collective systems (ASEKOL, ELEKTROWIN and EKOLAMP) stated that they had collected 17 174 t of scrapped electronic equipments in 2006, 25 011 t in 2007 and 15 205 t in the first half of 2008. The Czechs have been recycling mostly televisions and computer monitors.

Disassembling scrapped electronic equipment

Disassembling, as a first stage of the recycling process, takes place in specialized sites, marked as disassembling workshops. In case of the Czech Republic, these are usually the so called protected workshops where people with changed capacity of work are employed.

The disassembling workshops most often process the following types of electronic equipment:

- Small home appliances – vacuum cleaners, irons, fryers, scales etc.
- IT and telecommunication equipment – computers, monitors, printers, photocopying machine, faxes, telephones, etc.
- Consumer appliances – televisions, radio, camcorders, video recorders, etc.

Disassembly of scrapped electronic equipment with CRT (Cathode Ray Tube) screen, i.e. televisions and monitors, is prevailing, according to this enumeration. They make up 80 to 90 % of all disassembled electronic equipment. CRT screens, plastic, wood, ferrous and non-ferrous metals in the form of sheet links, cables and coils can be retrieved by dismantling the televisions and computer monitors. CRT screens, which belong to hazardous waste, must be further processed on the screen recycling line. The outcome is clear front glass and rear cathode-ray tube funnel glass.

The disassembling process is largely a manual activity and only simple tools are used in the process – pliers, hammers, screwdrivers. The manipulation with the electronic equipment and the components can be carried out manually or by means of manipulation machinery (conveyors and fork-lift trucks). The effort to make the disassembly process more efficient lead to various designs of logistics solutions which are virtually unused in the Czech Republic or, there are usedonly specific parts of the designed solutions.

Generall the approaches towards designs of disassembly logistic solutions can, be dividend into two extreme alternatives:

1. Disassembly line – the disassembly is divided into sub-operations just like the assembly line, and it is carried out by workers in the individual workplaces dislocated around the line. The disassembled components are stored in crates located by the disassembly work areas.
2. Cellular disassembly – each disassembly plant realizes disassembly of the entire electronic equipment. The disassembled components are stored in crates or on a conveyor belt and they are sorted behindhand.

If we compare the disassembly lines with the cellular disassembly, the disassembly line is noted for a higher performance – the line enables to influence the disassembly speed by forced movement of the belt and it increases the speed of the disassembly operations thanks to their continuous repetition. On the other hand, it requires synchronisation of the employees and operations and constant presence of all disassembly workers. The regular flow of large amount of processed electronic equipment must be provided as a necessary condition. It must be possible to divide the equipment into homogenous groups and to create specialized disassembly lines.

The solution based on using cellular disassembly is suggested, for example, by Opalić, Vučović and Panić (Opalić et al., 2004). The comparison of various options combining the disassembly line and the cellular disassembly was realized within a frame of „Semi-manual dismantling of small electric and electronic equipment“ project (http://www.fabrikderzukunft.at/results.html/id4388). The solutions realized in real life conditions generally represent a combination of the described procedures.

Analysis of the current situation of disassembly in case of a selected company processing of electronic waste

The problem of disassembly of scrapped electronic equipment was solved in concrete company. Two dismantling workshops are currently used for the disassembly process. Employees with changed capacity of work are employed in the workshops. Both workshops are situated in two separate places. The scrapped electronic equipment feed is realized in containers. The dismantling, including the manipulation of the scrapped electronic equipment and its components, is carried out purely manually. The employees put the dismantled parts in baskets which, when they are full, are taken away by fork-lift trucks. Despite the fact that the television and computer monitors represent 90 % of the disassembled electronic equipment, the workshops do not have a line for processing CRT screens. This activity is provided by external companies.

With regards to the permanent increase in volume of the processed electronic equipment, it was necessary to change the existing dismantling method, characterised by low processing efficiency, demanding manual handling and unsuitable working conditions.

There is a wide variety of techniques and methods for analysis of manufacturing processes (Takala et al., 2007). In that case, the following activities have been realized within the frame of analysis of the current situation:

- Analysis of scrapped electronic equipment feed.
- Analysis of space layout and dislocation of the individual workplaces, sorting and storage areas.
- Analysis of material flows.
- Time study of the working day of the employees dismantling the scrapped electronic equipment.
- Time study of the dismantling operations of scrapped electronic equipment.

The actual evaluation of the acquired information was carried out in four steps:

1. Definition of the starting position – identification of value-added activities and activities not adding value and the definition of the outputs of realized analysis which are decisive for further evaluation.
2. Definition of the potential dismantling capacity – setting the theoretic capacity of the dismantling workshops.
3. Identification and quantification of losses – definition and analysis of the current losses and the problematic areas.
4. Checking the correctness of the calculations and entry data.

Definition of the starting position

The identification of the activities which add value and the remaining activities which bring only losses was carried out mostly by:

- Activities adding value – the only activity adding value is the dismantling of the scrapped electronic equipment.
- Activities which do not add any value – they are mostly manipulation with electronic equipment and its components, weighting, bar code reading, unloading the electronic equipment from the container.
- The main outputs of the realized analysis have been summarized in order to evaluate and quantify the losses:
- Employees intended for dismantling and their available labour fund – altogether, 12.05 employees are used for dismantling (after deducting sickness absence and holidays, and after taking into account the partial double shift operation and the work of the foreman who participates on the dismantling only in the amount of 50% of his available time). The available time of the employees is 7.5 hours·day^{-1} (450 min·day^{-1}). The number of working days is set at 21 days·month^{-1}.
- Processed volume and disassembly capacity – the disassembly capacity was set to 84.2 t·month^{-1}, based on the historical data concerning the processed volume of scrapped electronic equipment. The disassembly of monitors (M) and televisions (TV) are the predominant types of the processed electronic equipment. They represent a share of approx. 90 %, and that is why the evaluation was based purely on dismantling of M/TV. The average M/TV dismantling time, excluding the manipulation operations, is 16.89 min·pc^{-1}, the average weight of M/TV is 21.3 kg·pc^{-1} (0.0213 t·pc^{-1}).

Definition of the potential dismantling capacity

The potential dismantling capacity expresses the theoretic amount of scrapped M/TV which could be processed provided that the whole available labour fund would be focused only on the disassembly (i.e. only to activity adding value). The potential capacity of the plant is 143.6 t·month^{-1} if the available dismantling labour fund reaches 12.05 · 450 · 21 = 113 873 min·month^{-1}:

$$\frac{113873}{16.89}0.0213 = 143.6 \ \textit{t·month}^{-1}$$

If we compare it with reality, i.e. the possibility to process 84.2 t·month^{-1}, there is a theoretic loss in the amount of 59.4 t·month^{-1} in the monitored disassembly workshops, i.e. there is a potential dismantling performance increase by 71 %.

Identification and quantification of losses

The main reasons for not reaching the theoretical disassembly capacity can be seen in these areas:

- Limited performance of the employees due to their reduced capacity of work – in reality, this fact is taken into account and the daily available time of the employees is lowered by approx. 2 hours (120 min) to 5.5 hours (out of that time, 0.5 hour is devoted to cleaning), which represents a loss of 38 t·month^{-1}, i.e. 64 % of total losses (provided that this time does not include activities which do not add value):

$$\frac{120 \cdot 12.05 \cdot 21}{16.89}0.0213 = 38 \ \textit{t·month}^{-1}$$

- Performing activities which do not add value – the identified activities were divided into two groups which represent the total loss of 21.3 t·month^{-1}, i.e. 36 % of the total losses:
  - o Manipulation related to each M/TV in the amount of 1.28 min·pc^{-1}, which represents a loss of 7.4 t·month^{-1}:

$$(450-120) \cdot 12.05 \cdot 21 \cdot 0.0213\left(\frac{1}{16.89} - \frac{1}{16.89+1.28}\right) = 7.4 \ \textit{t·month}^{-1}$$

  - o Other activities not adding value which participate in the a available working time in the amount of 13.2 %, and they represent a loss of 13.9 t·month^{-1}:

$$\frac{(450-120) \cdot 12.05 \cdot 21 \cdot 0.132}{16.89}0.0213 = 13.9 \ \textit{t·month}^{-1}$$

Checking the correctness of the calculation and entry data

If we compare the real capacity of the plant, which is 84.2 t·month^{-1}, and the theoretic capacity, lowered by the above identified losses (143.6 – 38 – 21.3 = 84.3 t·month^{-1}), we can confirm that the calculation and the used entry data were correct. This procedure can therefore be used as a reliable method for the evaluation of the suggested disassembly logistics solution.

The concept of new logistics solution of scrapped electronic equipment disassembly

The processor specified the preconditions for the design of new disassembly logistics solution of scrapped electronic equipment, after analysing the starting position. The following rules had to be observed:

- Merger of the existing two disassembly workshops in order to use the advantages resulting from the centralisation of the manipulation units and the machinery.
- Preservation of the existing cellular disassembly method, i.e. the realization of dismantling of M/TV as a whole.
- Submission of CRT screen processing line in the final solution.
- Removing the demanding manipulations.
- Increasing the processing performance of scrapped electronic equipment.
- Improvement of the working conditions of employees realizing the disassembly process.
- Maintaining the daily working time in the amount of 5.5 hours.

The suggested design included:

1. Concept of the proposed solution.
2. Analysis of the M/TV processing performance.

Concept of the proposed solution

The suggested solution is located in one the existing workshops and, partly, in the production shop next door, thereby the condition of disassembly centralisation is kept. It makes the processing of electronic equipment in two separate work places possible. M/TV are processed on the disassembly line. The groundwork of the line consists of 8 working tables intended for the disassembly process. The CRT processing line is directly linked to this line. The remaining electronic equipment is processed separately, in the shop with two working tables. The whole plant should be operated by employees with lower capacity of work, except for one employee who is responsible for the initial manipulation with M/TV.

The process of M/TV processing consists of 5 production stages with the following characteristics:

1. M/TV supply – this stage is equipped with a M/TV container, scale, bar-code reader, containers for cables, wooden and plastic covers of the M/TV. One person is responsible for taking M/TV from the container on the scale, weighting the M/TV, reading the bar-code and transfer to the next production stage (working table). The total time of these operations is 0.75 min·pc^{-1}. The rhythm of this production stage is the same.
2. M/TV preparation – consists of the working table and the cleaning chamber. One worker removes the service cable, dismantles the cover, lets air in the screen, moves the M/TV into the cleaning chamber, sucks off dust, puts the M/TV on the track and shifts the track. The duration of all these operations and the rhythm are 2.09 min·pc^{-1}.
3. M/TV disassembly – is equipped with a powered roller track for supply of M/TV to the work stations, working tables and a powered belt conveyor for transferring the disassembled components. From 1 to 8 employees can work in this stage. Each of them moves the M/TV from the track on the working table, manually dismantles the M/TV individual parts and puts the disassembled components on the belt conveyor. The duration of all the operations carried out by a single worker is 15.97 min·pc^{-1}. The rhythm depends on the number of workers. When all 8 work places are involved, the rhythm of 2.00 min·pc^{-1} can be achieved.
4. Sorting the disassembled parts – includes the gravity roller track for transfer of screens to cutting, baskets and containers for the other disassembled parts. One employee is responsible for sorting and transfer of the individual components in the pre-assigned containers and for moving the screens on the roller track. The duration of the operations and the stage rhythm are 0.5 min·pc^{-1}.
5. CRT screens processing – it is equipped with a CRT screens recycling line and a line for cleaning the screen glass. This stage is operated by two employees who move the screens from the roller track (eventually from stock) to the CRT screens recycling line. They operate this line as well as the line for cleaning the screen glass. The duration of these operations is limited to 5.42 min·pc^{-1}. The stage rhythm is 3.35 min·pc^{-1}.
6. The space layout of the designed disassembly line is presented on fig. 1.

M/TV processing performance analysis

The basic preconditions for the performance calculation of the suggested solution are:

- Providing continuous feed of M/TV for processing.
- Double shift operation with 5.5 working hours per shift.
- Number of working days in a month is 21.
- Average weight of M/TV is 21.3 kg.

The fifth production stage, which is the bottleneck, is decisive for the performance of the M/TV dismantling process. With a rhythm of 3.35 min·pc^{-1}, the unit dismantling output of M/TV is 17.9 pc·hour^{-1}, i.e. 88.1 t month^{-1}. The above mentioned performance corresponds to 5 occupied dismantling workplaces (3rd production stage), when the unit performance equals 18.8 pc·hour^{-1}.

With regards to the fact that the future requests for processing of scrapped electronic equipment could be higher than the above mentioned capacity, the performance increase of disassembly must also be considered, despite the limited capacity for processing CRT screens. When all 8 dismantling work places are engaged, the 2nd production stage becomes the bottleneck (decisive for the workshop capacity). When the rhythm equals 2.09 min·pc^{-1}, the performance of 28.7 pc·hour^{-1}, i.e. 141.2 t·month^{-1} can be achieved. The stock of unprocessed CRT screens can be solved by using one of the following options:

- Extending the working hours for processing CRT screens from 5.5 hours to 7 hours, which will boost the capacity of the workshop to 112.1 t·month^{-1}. However, there will be a daily work-in-process stock of app. 25 pieces of screens between the disassembly of M/TV and processing of CRT screens.
- The storage of the unprocessed screens in containers and their processing during non-production shifts (at the weekends) or during months with lower load of M/TV.
- The storage of unprocessed screens in containers and their processing by external companies.

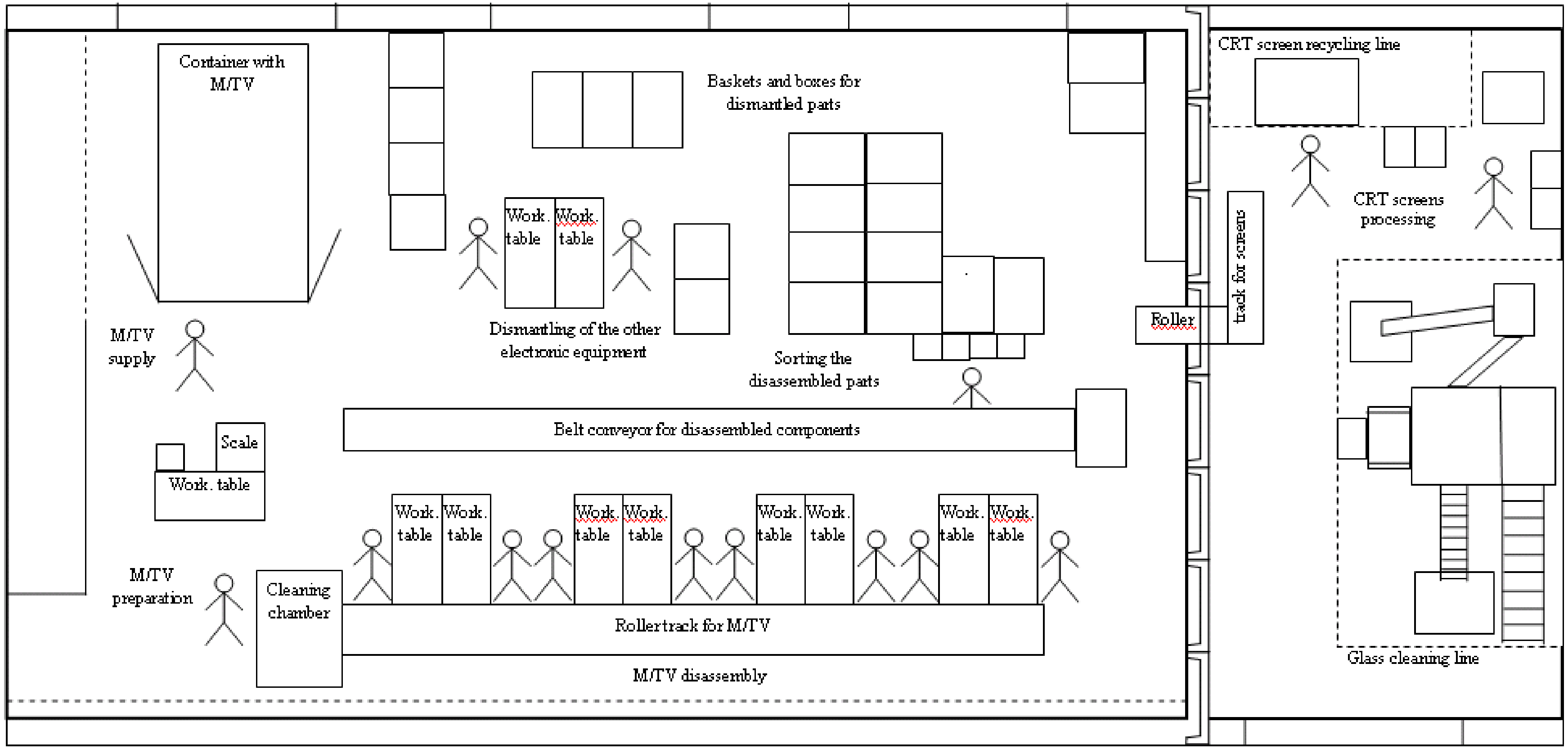

Fig. 1. Space layout of the designed disassembly workshop.

Conclusion

With regards to the ever growing amount of scrapped electronic equipment, it is necessary to look for new, more efficient logistics solutions for disassembly. The presented example makes it possible to sum up the advantages which the search of new solutions in the area of scrapped electronic equipment disassembly offers:

- Increasing the capacity due to the performing the activities not adding any value concurrently with the value-adding activities.
- Removing the demanding manipulations with heavy types of electronic equipment (televisions and computer monitors) and their components.
- Acquiring independency on external companies processing CRT screens.
- Improving the working conditions of the employees – e. g. by including cleaning of televisions and computer monitors.
- Reaching the advantage of centralisation in case the disassembly is carried out in separated plants, or the acquisition of a free work space.
- Keeping the flexibility of disassembly – cellular principle does not create problems caused by different performance of the employees. The employees can be used for solving other assignments (dismantling of other electronic equipment). Various kinds of electronic equipment can be processed in the workshop.

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