

# DECISION SUPPORT FOR A WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT TREATMENT SYSTEM

Milan VERDEV<sup>1</sup>, Marko BOHANEČ<sup>2</sup>, Sašo DŽEROSKI<sup>2</sup>

<sup>1</sup> Gorenje, IT Department, Partizanska 12, SI-3320 Velenje, Slovenia  
Tel: +386 3 899 2342; fax: +386 3 899 1700, e-mail: milan.verdev@gorenje.si

<sup>2</sup> Institut Jožef Stefan, Jamova 39, SI-1000 Ljubljana, Slovenia

## ABSTRACT

This paper presents the current state of the project *Decision Support for the Waste Electrical and Electronic Equipment Treatment System in Slovenia*. The aim of the project is to design a decision support system to help decision makers of the Waste Electrical and Electronic Equipment (WEEE) treatment system in the development of incineration, disposal, treatment and recycling integrated programs. In the paper, we describe the WEEE, taking a broad view of various types of decisions in the field of WEEE. A detailed explanation of the decisions in the WEEE Logistics is given in the main part. We present two decision models, developed to support decisions in the WEEE Logistics. We also explain the role and activities involved in the management of the WEEE Treatment Decision Support System, which is implemented as a supplement to the decision support model.

## 1 INTRODUCTION

Waste management is one of the priority issues concerning the protection of environment and conservation of natural resources. As a significant treatment part of the waste management is the waste of electrical and electronic equipment (WEEE) [7].

WEEE (also called electronic waste or "e-waste") is waste consisting of broken or unwanted electrical or electronic appliances. It is a point of concern considering that many components of such equipment are toxic. E-waste includes computers, entertainment electronics, mobile phones and other items that have been discarded by their users. While there is no generally accepted definition of e-waste, it in most cases consists of expensive and more or less durable products used for data processing, telecommunications or entertainment in private households and businesses. Despite its common classification as a waste, WEEE is a considerable category of secondary resource due to its significant suitability for direct reuse, refurbishing, and material recycling of its constituent raw materials.

The Waste Electrical and Electronic Equipment Directive (WEEE Directive) is the European Community directive on waste electrical and electronic equipment which, together with the RoHS Directive [8], became European law, setting the collection, recycling and recovery targets for all types of electrical goods.

Slovenia has accepted the WEEE Directive and already transposed it into the legislation in November 2004. Like many other European Union member states, Slovenia has

postponed the responsibility of producers and importers. The implementation is required until 1st January 2007, when all the activities should be prepared.

Producers and importers are individually responsible for the WEEE treatment. Because of the common activities, optimal processes and therefore expectations for minimal costs, they have joined in several non-profit collective schemes. One of them is called ZEOS, which includes the majority of most representative producers and importers. Gorenje, a household appliances producer, is a member and also one of the 8 founders that hold shares in ZEOS. In ZEOS, there are around 100 companies included. It covers about 80 percent of the WEEE market, which means approximately 80% of the WEEE material flow. Experiences from some other countries indicate there is a large quantity of material to process and ZEOS's expectations are very similar. *Those quantities demand optimal and clearly defined handling of all WEEE treatment processes.*

The aim of the WEEE Treatment Decision Support project is to create a decision support system [1] in order to help decision makers of the WEEE treatment system in ZEOS. A case study, relevant to the WEEE treatment system in Slovenia, is presented in this paper.

## 2 WEEE TREATMENT DECISIONS IN GENERAL

There are many decisions involved in the WEEE treatment system, so they need to be structured first. The main groups of decisions are related to:

**Information technology:** Almost every business today depends on information technology. There are decisions about software and information infrastructure.

**Partners:** A proper selection of various partners means long term cooperation and stable operations. There will be partners for collection sites, recyclers, logistics partners and partners for material disposal.

**Recycling:** A very important decision to be made is whether to build our own recycling center or not. In the case that we decide to build our own recycling center, we must also select its location. Besides, we need to decide about and select locations for the warehouses and disassembling plants.

**Technology:** For almost every task we need to decide which technology to use and what kind of machines to buy. Another decision is whether to use machines or people for some kind of jobs, e.g. disassembling, where both are possible.

**Materials:** Materials are the core of the whole recycling business. We need to decide how to recycle each type of materials, when to stop processing it, how to use it or bring it to the market.

**Economy:** There are many decisions concerning finances and economy. They are hidden in the various other buying or renting decisions. But the most important ones are decisions about prices to be set for WEEE treatment services and for recycled materials on the market.

**Logistics:** Logistics has an important role in the WEEE treatment business. There are many locations included in the transport network all over Slovenia and everything will be transported among them all the time. Section 3 focuses on decision support in logistics.

**Environment:** We should constantly assess our environmental burdening. Besides, there are various partners' environmental evaluations and decisions about their acceptability concerning environmental impact.

**Energy:** There are decisions about acceptable energy consumption of the system or each part of it.

**Human resources:** Human resources management has to take several decisions. All of them are extremely sensitive, because they concern people: decisions about new employment needs, employee selection and decisions about wages.

**Knowledge transfer to the production process:** There is a decision about whether it is necessary or reasonable to transfer knowledge gained during the WEEE treatment to production. Better knowledge of the recycling process and business overall can lead towards constant research and development of household appliances in the whole life cycle. Knowledge gained in the recycle business will be used in the R&D and production of new appliances in Gorenje.

### 3 WEEE DECISIONS IN LOGISTICS

The whole WEEE treatment system includes several different types of locations. At the beginning there are *collection centers*, where WEEE materials are collected from the users and WEEE material producers and importers. Then we can find *warehouses*, where WEEE material is temporarily stored, and *disassembling plants*, where it is partially disassembled. And at the end there are *recycling plants* or *recycling centers*, which recycle all of the WEEE material. Logistics has an important role in this business because all WEEE material must be transported between the numerous locations, more than 100 are expected, which are located all over Slovenia. It means that each location is like a node in a big network and must be continuously connected to the others and especially to the recycling center.

In WEEE logistics, there are three levels of decisions: *strategic, tactical and operational* [3].

#### 3.1 STRATEGIC DECISIONS

**Decision about recycling center need:** At the beginning there is no recycling center; material is recycled in various

small recycling plants, which can be found elsewhere. This means that the majority of recycling part of the WEEE treatment business will be outsourced. At the moment, we can only predict the annual material flow. But in the future, when the quantity of material recycled per year is known, adequate and certain, the *decision about the recycling center need* will take place.

**Decisions about the storage capacity and recycling capacity of the recycling center:** When the decision for the location center has been accepted, a decision about its capacity would become necessary. In fact, there are two decisions. First, there is a *decision about the storage capacity*, which is about the dimensions of the building that can be used for storage, internal logistics and recycling processes. The second one is a *decision about the recycling capacity*. Recycling capacity means how much material can be recycled over a given period of time, e.g., one day. It must be sufficient to cover recycling needs in the near future.

**Decisions about supported types of recycling:** Supported recycling types means specific types of material or types of recycling, which can be handled by the recycling center. It depends on the market; firstly what kind of materials there are in the majority of the electrical appliances; and secondly, what kind of materials are needed on the market. But the most important attribute is the profitability of the particular material or type of recycling.

**Decision about the location of the recycling center:** This decision is very sensitive. It's true that it depends on business parameters, like the optimal distance from the other locations in the WEEE treatment system, proximity of the recycling materials' consumers and availability of appropriate experts in the region. But there is also the very important social aspect of the problem, which means how society in the region will accept the recycling center. The possible motivation for the community to accept the recycling center is an expected rise of employment and potential development of the region. The reason against is the potential environmental risk to the region.

**Decisions about the need for disassemble plants and warehouses:** There will be no recycling center at the beginning and therefore some other facilities might be used for partial disassembling and warehousing. This decision will certainly take place very soon. Even when a recycling center is built, it will still be desired to have some more warehouses and disassembling plants.

**Decisions about the locations of the disassembling plants, warehouses:** As soon as the decision for a disassembling plant or warehouse is taken, some new decisions are needed. Those are *decisions about the location of the disassembling plant or warehouse*. Those kinds of facilities should be at the locations where they fit perfectly in the whole distribution network. The decisions depend on the geographical characteristics, social and environmental parameters.

**Decision about the capacity of disassembling plants and warehouses:** For all the facilities, mentioned above, a

decision about the capacity is also important. For disassembling plants, there is also a disassembling capacity decision.

### 3.2 TACTICAL DECISIONS

**Decision about the logistic partner selection (or evaluation):** Before the first transport, a proper transport partner should be found. Therefore, the selection of the logistic partner is one of the earliest decisions. A proper partner can substantially influence the business success. The partner should be reliable, flexible, but what is the most important is the quality of its service. The decision parameters used for this decision can also be used for periodical evaluation purposes, but including some additional attributes. We could evaluate and compare partners annually or more frequently.

**Decision about own vehicles need:** When the quantities of material per time unit become stable, we should decide whether to use our vehicles or even fleet. We can expect a lot of locations and very frequent transports and our own vehicles and drivers could be the cheapest solution when used properly and frequently.

**Decision about our own vehicles selection or even fleet:** It is important what kind of vehicles we should use. The decision about the vehicles characteristics depends on their consumption and pollution, but also on the capacity and ability to load and unload the cargo.

**Decision about the transport units or caissons selection:** One of the fundamental decisions is the decision about the transport units. They must be big enough to contain a sufficient amount of material but not too big, because then they are seldom full and they are hard to transport. They should also be durable and easy to handle.

### 3.3 OPERATIONAL DECISIONS

**Decision about the transport need:** Before any transport is made, a decision about the transport need must be taken. There are a lot of locations and all of them should be monitored to find if there are units ready for transport. On the other hand, there is recycling, which can also be called production, with its needs, for recycling or for disposal. The decision about the transport need means constant optimization between those two demands.

**Decision about the transport provider:** Transport provider must be selected for each transport separately. Every transport is different and not all the transport providers are good for all the transports. It depends on trucks suitability as well as availability at a particular time.

**Optimal path selection:** One of the attributes for transport provider selection is also a previously selected optimal path. This selection can substantially contribute to the optimization of costs of the transport. The optimal path also depends on the locations of the vehicles.

There are four of the listed decisions, which will be made continuously. First, there is logistic partner selection, which will be used for annual partner evaluation as well, but with some additional group of attributes. The other three are all operational decisions, transport need decision and transport

provider selection combined with optimal path selection. Decision models for two of them are presented in the following two sections.

## 4 DECISION SUPPORT FOR THE LOGISTICS PARTNER SELECTION AND EVALUATIONS

At the beginning of the WEEE project, proper transport partners should be selected. This selection will take place every time a new partner is needed. The management will decide which partner to contract and which not, but on the basis of a decision support system [5]. For this purpose, we have designed a multi-attribute model (Figure 1) using the DEXi decision modelling software [4]. Figure 2 shows an example of evaluating four potential transport providers. The success of the project will pretty much depend on those partners as well. That is why annual partner evaluation is also planned. Almost the same decision support model could be used for that task as well: only history data should be added to the model.

| Partner                          | Partner evaluation, suitability                 |
|----------------------------------|---|
| <b>Company</b>                   | Company of the logistics partner                |
| <b>Market position</b>           | Position and recognition on the market          |
| - Tradition                      | Company's presence on the market                |
| - Number of clients - References | Number of clients and market share              |
| - Income                         | Annual income of the company                    |
| <b>Employees properties</b>      | Parameters that concern employees               |
| - Human resources care           | Human resources treatment and possibilities     |
| - Number of employees            | Number of employees in the company              |
| <b>Service &amp; Environment</b> | Services and their impact on environment        |
| <b>Vehicles</b>                  | Description of the vehicle                      |
| - Number of vehicles             | Number of suitable vehicles in the company      |
| - Average Age                    | Average age of the fleet                        |
| - Vehicles tracking system       | Use of Vehicles tracking and controlling system |
| <b>Operation</b>                 | Area of operations                              |
| - Operational area               | Range of operations in Slovenia                 |
| - WEEE treatment services        | Possibilities for other WEEE treatment services |
| <b>Environmental Evaluation</b>  | Environmental value of the company              |
| - Vehicle Fleet Environm. Value  | Environmental value of the vehicle fleet        |
| - Environmental influence        | Environmental value of the entire company       |
| - Environmental certificates     | Environmental certificates?                     |
| <b>Costs</b>                     | Expected costs for the service                  |
| - Contract costs                 | Costs by the contract                           |
| - Costs Sensitivity              | Potential costs rise                            |

Figure 1: Logistics partner DEXi model

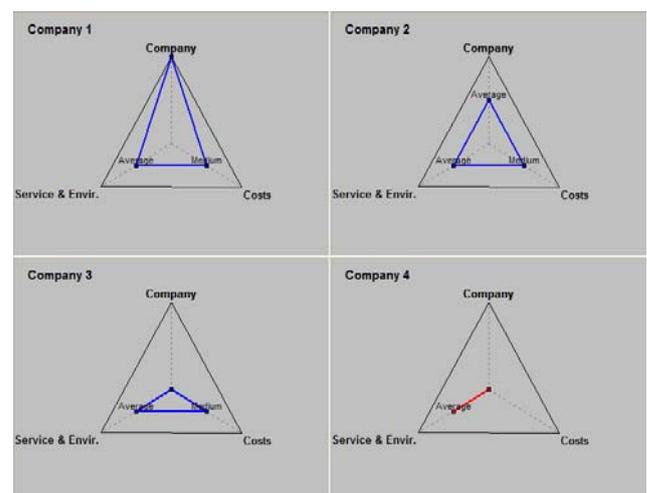


Figure 2: Logistics partner evaluation

## 5 DECISION SUPPORT IN THE TRANSPORT PROVIDER SELECTION

When the decision about the transport need is taken, a decision about the transport provider is needed immediately. That is why the transport provider selection is an operational decision which will take place very frequently, which means practically every day. The person responsible for this decision is the operator in the Call center. This model (Figure 3) has been developed to help this person to decide optimally. It is a combined decision about an optimal path selection and an optimal partner or even a vehicle for the particular transport. An example evaluation is shown in Figure 4.

| Transport provider                     | Transport provider evaluation                         |
|--|---|
| Vehicles adequacy                      | Proper vehicle attributes and its position.           |
| - Truck suitability                    | Proper vehicles dimensions and load capabilities      |
| - Vehicle position - path length       | Position of the truck concerning selected locations   |
| Costs                                  | Expected costs of the transport                       |
| - Contract costs                       | These are planned costs, e.g. regarding the contract. |
| - Additional costs - costs sensitivity | Additional costs probability                          |
| Availability                           | Availability of the truck in the near future          |
| History - Flexibility                  | Our general impression about its previous jobs        |

Figure 3: Transport provider DEXi model

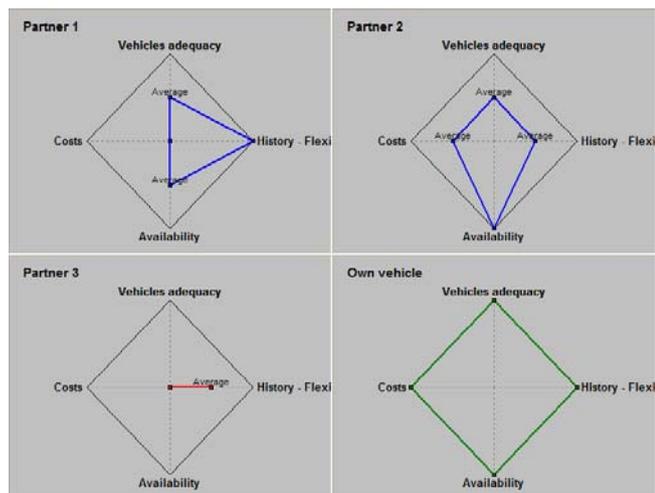


Figure 4: Transport provider evaluation

## 6 MANAGEMENT OF THE DECISION SUPPORT SYSTEM

Constant evaluation and improvement of the decision model can be very helpful in business improvement. The first requirement is that decisions as well as performance of the decided options are closely monitored. We should keep track of decisions being made as well as their performance after being implemented. Thus, we can group monitoring and logging into two groups:

- Monitoring and logging of the decision process, which includes all the possible alternatives, their attributes, utility functions and the results.
- The most important data are data gathered from the performance of the selected option in the decision

process. We should measure time, costs, service quality, quantity of transported material, number of transports, its frequency, distances, number of kilometres covered, etc.

These data may be analysed by using data mining algorithms [2] to extract useful information, which are the basis for the management of the decision support system [1]. The plan is to be carried out using the Plan-Do-Check-Act (PDCA) cycle [6], which is becoming a standard mechanism in management systems.

## 7 CONCLUSION

The WEEE directive requires that providers and importers are responsible for the waste of electrical and electronic equipment. Large quantities demand optimal and clearly defined WEEE treatment. We have presented the current results of the Decision Support project, relevant to the WEEE treatment system in Slovenia.

So far, the identification of the decision processes has been made and two of the models in logistics, which are presented in Section 4 and Section 5, have been developed. Also, we have designed the management of the decision support system.

The implementation of the WEEE Treatment Decision Support System in Logistics is expected in 2007, followed by the extension and adaptation of the decision support system into other fields (Section 2) of WEEE treatment.

## 8 REFERENCES

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