

ANALYSIS OF POSSIBLE USE OF IDENTIFICATION TECHNOLOGIES IN DISASSEMBLY

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Abstract. *The barcodes and Radio Frequency Identification tags that are being used during manufacturing, assembly, warehousing, and distribution could also be reused at the end of the product lifecycle for an identification of the correct disassembly process that would result in recycling of its components. The barcodes or RFID tags can be helpful in identifying objects in terms of sustainable development, regarding disassembly, recycling and reuse. In this paper, the analysis of the current applications of RFID Technology in the final phase of the product lifecycle will be presented. The simulation of the disassembly process supported by both barcode and RFID-enabled product sorting in Rockwell simulation Software Arena.*

Key words: *Product Disassembly, Product Lifecycle Management, Radio Frequency Identification, Wireless Sensor Networks, Sustainable Design*

INTRODUCTION

The global community wants an increase in the overall recycling rate of manufactured goods, such as electrical and electronic equipment waste, cars, toys, and all other consumer product that have short lifecycle. The other reason for this trend could be that those components are being made of materials that are hard to be dissolved after their disposal. An overall produced waste represents an enormous loss of material and energy resources in the developed world. The European Community has developed an environmental policy with the main objectives being to preserve, protect and improve the quality of the environment and human health as well as to utilize natural resources judiciously, named WEEE (Waste Electrical and Electronic Equipment Directive) directive.

The WEEE Directive is the directive 2002/96/EC on waste electrical and electronic equipment, which, together with the RoHS Directive 2002/95/EC, became European Law

in February 2003, setting collection, recycling and recovery targets for all types of electrical goods. WEEE stands for old, end-of-life or discarded appliances using electricity, such as monitors, computers, cell phones, consumer electronics, fridges, microwaves, etc which have been disposed of by their original users. The production of electrical and electronic equipment is one of the fastest growing industries. An increased waste production appears to be an inevitable consequence of today's average consumer habits. This trend ultimately increases the amount of waste from electrical and electronic equipment as well as environmental burdens throughout the life cycle of these products (Sasaki, 2004).

ELECTRONIC OR ELECTRICAL PRODUCT WASTE

Some campaigns have been conducted lately in order to change the perception about one's own "ecological footprint". The ecological footprint can be used to find out how much productive space ("nature") is required to manufacture an electronic or electrical product (EEE) and to absorb the emissions that are generated when producing and operating it. The footprint can capture the main environmental impacts that arise from manufacturing and using a product.

Action on WEEE is an urgent need in the world, especially industrialized countries since these countries consume a significant amount of electrical products. The cost related to the overall savings of material is not the only thing that drives these efforts. Viewing the production only from the cost-related perspective is shifting towards green manufacturing, sustainable product design, and realization. The costs that are involved in all phases of the product lifecycle are the ones that should be taken into account, not just the savings on the shop floor that are dealing with things such as productivity, efficiency and the usage of human and other resources. Lifestyles and the consumption of resources vary wildly from one country to another.

Waste Electric and Electronic Equipment Directive

The EU Directive on WEEE prescribes a collection rate of 4 kg per capita, although there are substantial differences among those countries regarding to their wealth. One of the projects whose goal was raising sustainable development awareness was the "WEEE man" (Fig. 1), conducted by the British the Royal Society of Arts and Canon Europe in 2005.

The WEEE man was made of electrical and electronic waste, such as washing machines, TVs, microwaves, vacuum cleaners, and mobile phones. It represents the amount of waste electrical and electronic equipment an average British person throws away in his lifetime – over 3 tones per person (RSA WEEE Man Project Team, 2006).

The WEEE Directive has ten categories of electrical and electronic equipment and they are categorized as follows:

1. Large household appliances (e.g. refrigerators)
2. Small household appliances (e.g. coffee machines)
3. IT and telecommunications equipment (e.g. computers)
4. Consumer equipment (e.g. radio and television sets)
5. Lighting equipment (e.g. fluorescent lamps)
6. Electrical and electronic tools with the exception of large-scale stationary industrial tools (e.g. drills and saws)

7. Toys, leisure and sports equipment (e.g. video games)
8. Medical devices with the exception of all implanted and infected products (e.g. radiotherapy equipment)
9. Monitoring and control instruments (e.g. smoke detectors)
10. Automatic dispensers (e.g. for hot drinks or monies) (Yla-Mella et. al, 2004).

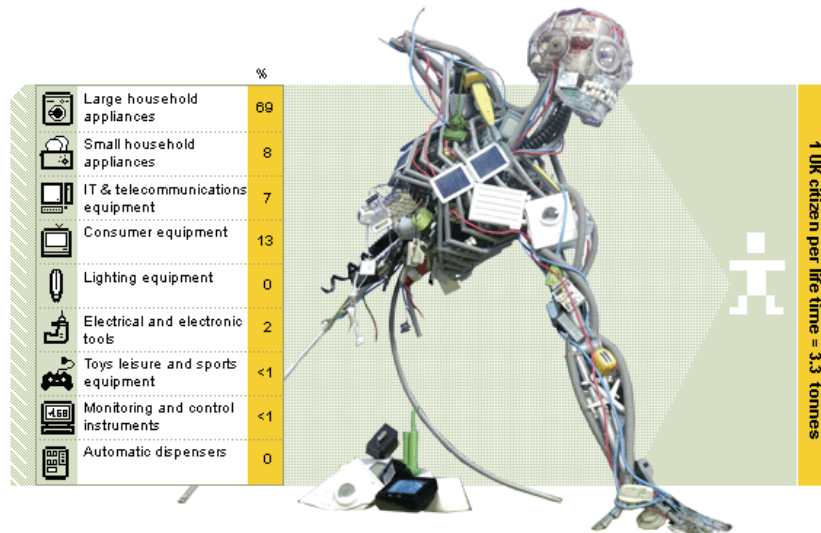


Fig. 1 WEEE Man (RSA WEEE Man Project Team, 2006)

The overall product life span and the average lifespan of household appliances outlined a range of estimates (Ballantyne et al., 2007): Refrigerators (10-25 years); Freezers (20+ years); Dishwashers (10-20 years); Washing machines (5-15 years); Clothes dryers (15+ years); Electric stoves/cookers (15-20 years); Microwave ovens (5-15 years); Hot water heaters (5-30 years); and Air conditioners (20 years).

DISASSEMBLY DATA

The collection of data about all kinds of flows of products, parts, subassemblies, and dangerous materials are necessary for its successful disassembly. By applying identification technologies to the systems for identifying an outdated product, the management of all the above-mentioned flows can be improved. Sorting before determining which disassembly processes is going to be used is an important step (Fig. 2).

Components disassembled from a product should be identified, measured, and sorted in the different phases of the process. System processes, like disassembly, are making it possible to separate selectively the renewable, non-recycling, and dangerous components from those, which are recyclable. Some chemicals that can be found in electronic equipment, including mercury, fluorine, barium, chromium, and cobalt, that either leach from the waste or are used in processing, could be dangerous for people who are working in disassembly systems. Those chemicals could be blamed for skin rashes and respiratory

problems. This can occur especially in some developing countries when the regulations are not followed.

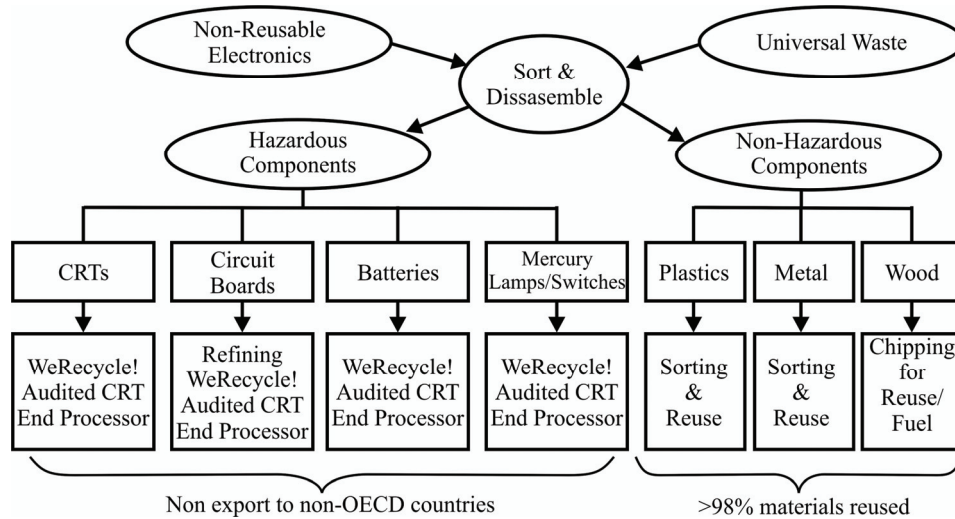


Fig. 2 Recycling Process (WeRecycle, 2007)

It is very difficult to create a disassembly system for any kind of a product. One of the most important things is the graphic explaining the explode state of a product. The other issue is a sequence of assembly operations and tasks needed to make the product from the base parts. Sometimes such necessary information is not available, so that the process of dismantling the product can even be hazardous for the disassembly worker if it is not known where hazardous materials are located.

If every company that manufactures electrical equipment could trace its products and find out where they are at the end of their life cycle the whole process of disassembly and recycle would be more efficient. Those companies would gather the products at the own collection centers and disassemble them according to the known, predefined procedures. Later, the company can also reuse these assembly parts as spare parts or as recycling materials.

Some companies, such as Canon, have built an environmental information system from product-related data spanning. Those systems were designed to cover all phases of product lifecycle, like product planning, development and design, prototype creation, quality assurance, and manufacturing. Making them available on the intranet, those kinds of systems could allow all development, planning, procurement, and manufacturing divisions to share product environmental data and to use this data to develop environmentally conscious products.

DISASSEMBLY OF TELEVISIONS AND CRT MONITORS

Monitors and televisions contain Cathode Ray Tubes (CRTs). A Cathode Ray Tube (CRT) is a video display component, containing 5-40 kg of glass. Lead and other components are

added to the CRT glass to protect the user from x-rays. National Safety Council's EPR2 (Electronic Product Recovery and Recycling) Baseline Report was released in May 1999. National Safety Council's EPR2 Electronics Baseline Report (Stanford Resources, Inc. 1999) documents the results of the first large-scale survey and analysis of end-of-life electronic product recycling and reuse in the United States. Data, given in Fig. 3, show that the number of recycled computer monitors is far from the actual number of obsolete monitors.

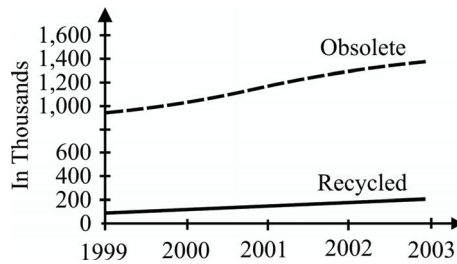


Fig. 3 Estimates of number of obsolete versus recycled computer monitors in Florida, (Stanford Resources, Inc. 1999)

The recycling process for monitors and TVs begins from disassembling. This is a manual operation. Workers remove the recyclable plastic or wooden case, metal chassis, deflection yoke, PC board, wires, and metal scrap from the CRT. These materials are all sorted for individual sales.

Different metals like aluminum, copper, iron, deflection yokes, boards, wires could be delivered to certified recycling companies (Fig. 4). Sorted plastics from monitor and TV housing depending on collected quantity can be recycled locally or exported to international markets (BSMC, 2007).

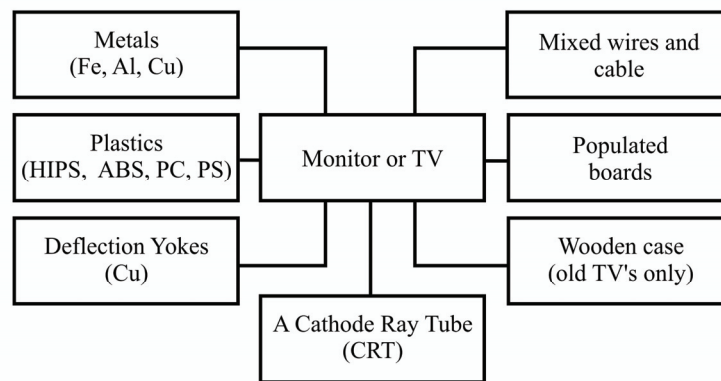


Fig. 4 Glass-to-Glass CRT recycling (BSMC, 2007)

The cabinets, CRT (Cathode Ray Tube), and printed circuit boards are dismantled by hand (Fig. 5).

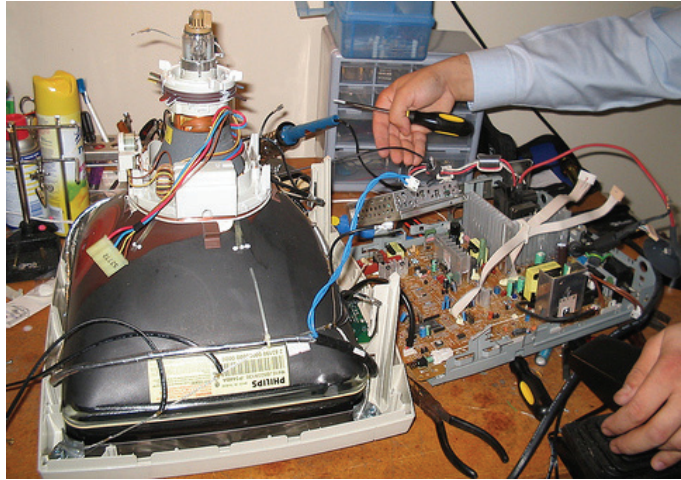


Fig. 5 Disassembly of CRT monitors

The first operation in the recycling system involves the breakdown of CRT's found in monitors and TVs. The removed CRTs are shredded and reused as glass. Fig. 6 (Sasaki, 2004) shows the current television waste treatment in Sweden. A CRT covers 53% of total television weight, 95% of it is a funnel and panel glass, and 5% is a neck glass. Thus, the CRT recycling covers 25% of total television weight. Almost all metals and circuit board, which comprise 15% of television weight are recycled. Plastics comprise 26% of television weight. It is assumed that the rear casing covers 80% of total plastic weight.

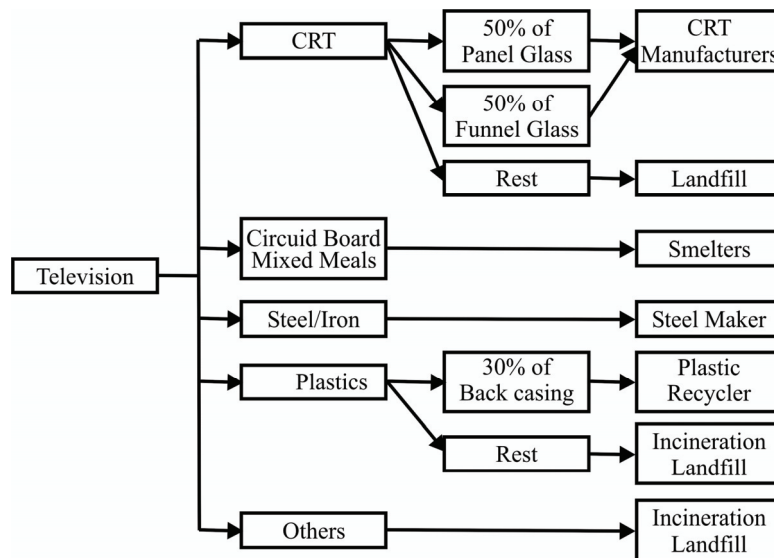


Fig. 6 Major television waste treatment in Sweden

AN OVERVIEW OF APPLICATION OF IDENTIFICATION TECHNOLOGIES IN DISASSEMBLY

Radio Frequency Identification (RFID) is a generic term for technologies that use radio waves for automatic object identification. There are several methods of identification, but the most common is to store a serial number that identifies the object and perhaps other information, on a microchip attached to an antenna, (the chip and the antenna together are called an RFID transponder or an RFID tag). The antenna enables the chip to transmit the identification information to a reader (Stankovski et. al, 2006). The reader converts the radio waves reflected back from the RFID tag into digital information that can then be passed on to computers to make use of it (Glover et. al, 2006).

RFID Tags in Disassembly Systems

An integral part of the WEEE directive is the product take-back strategy, which supports the endeavor to recycling as efficient as possible. In U.S., some projects have been developed lately in order to support the same goal. One of them is a project that involves so called "smart trash cans". Electrical engineers have developed a system that identifies a recycling bin by its household, using RFID chips embedded in the bins. The basic idea is to convert an injection-molded piece of plastic into traceable piece of plastic by embedding chips into the plastic. The readers could retrieve the necessary information from the type of ID (identification) that the plastic product carries to the chip that is located in the garbage truck. In that way, according to the identification in the chip and overall weight, the household can get rewarded for the amount of recyclables that they have collected (Science Daily, 2006). Recycle Bank in Philadelphia has seen recycling participation rise to 90 percent of the 2,500 residents who subscribed to the pilot program, up from less than 25 percent of those households when the program began (American Institute of Physics, 2006).

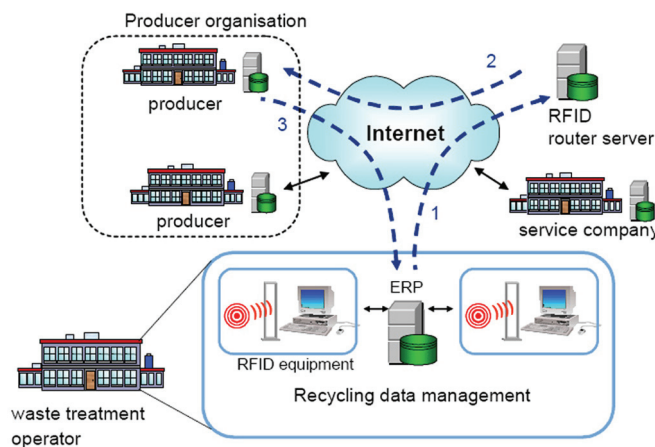


Fig. 7 Structure of an RFID information system (Hentula, 2005)

The exploded state, assembly sequence, bill of materials and other necessary data for disassembly could be stored in the server database and, by using barcode or RFID technology, the data needed for the disassembly management could be obtained from the da-

tabase. The marking of products means that in the future, RFID or barcode technology would affect the management of product information during the entire product lifecycle. Some producers are developing the information systems (Fig. 7) that would capture and provide information about products they are producing not only for the manufacturing and assembly, but for later service and maintenance, but even more important for their later disassembly, reuse, and recycling.

Information gathered on the disassembly line imply, for example, groups of products, producers, date of production, disassembled materials, disassembled parts, weight, disassembly instructions, etc. Disassembled components are stored in the warehouses or proper containers, and RFID infrastructure is well suited for the applications where: a large number of items are to be identified individually; additional data about the item need to be managed. By using this technology, recycling and environmental management can be made easier and cheaper.

RFID VERSUS BARCODE TECHNOLOGY IN DISASSEMBLY

One of the most important differences between the RFID and barcode technology is that the bar code is a line-of-sight technology. The scanner has to "see" the bar code to read it, which means that the workers have to orient the bar code toward a scanner in order to read it. Radio frequency identification, by contrast, does not require a line of sight. RFID tags can be read as long as they are within range of a reader (Diagraph, 2007). If the barcode label is ripped, soiled, has fallen off, dirty, or wet, the item cannot be scanned. Tags can be hidden or embedded in most materials. They would have no wear and tear due to its contactless nature, they can be read even if covered with dirt or submerged, and their unalterable permanent serial code prevents tampering (Infocomm Development Authority of Singapore, 2009).

Standard bar codes identify only the manufacturer and product, not a unique item. On the contrary, each RFID tag can hold more than just a unique product code. RFID tag can be read only or read-write. Nevertheless, unlike for the barcode technology, there is no global public body that controls frequencies used for RFID. In principle, every country can set its own rules, but some standards have been made regarding RFID technology. Some different classes of tags are currently not interoperable. Companies need to make provisions to collect and filter data coming from multiple sources, manipulate and evaluate the information and send it to a management system. If these steps are not taken, the accuracy of the data obtained through the RFID system cannot be validated and the management system could potentially be overwhelmed by data as the RFID system continues to read tags multiple times. The tags may be embedded inside an object such as a container or in a garment. Furthermore, RFID tags can store a lot more information than bar codes. The moment the carton reaches the warehouse or the store, the RFID reader immediately identifies all the RFID tags and information about the product such as explode state, disassembly sequence, part list and materials that the product is made of. The data capabilities of an RFID tag are superior to a bar code. Product maintenance instructions, shipping histories, manufacturing and expiry dates are just a few examples of the types of information that can be programmed onto an RFID tag. This information can help track specific products as they move through the supply chain giving a detailed snapshot of how a product was handled from the moment it enters the warehouse to when it is purchased by a consumer.

SIMULATION OF THEORETICAL APPLICATION OF POSSIBLE IDENTIFICATION TECHNOLOGY
IMPLEMENTATION IN DISASSEMBLY SYSTEM FOR CRT'S

In this chapter, a theoretical analysis assisted with the use of simulation will be shown on example of one disassembly system for dismantling of CRT monitors. The analysis had been done with the assumption that system was running for 20 days. The layout of such system that consists of four stations (Ostojic et. al, 2007), as shown in Figure 8.

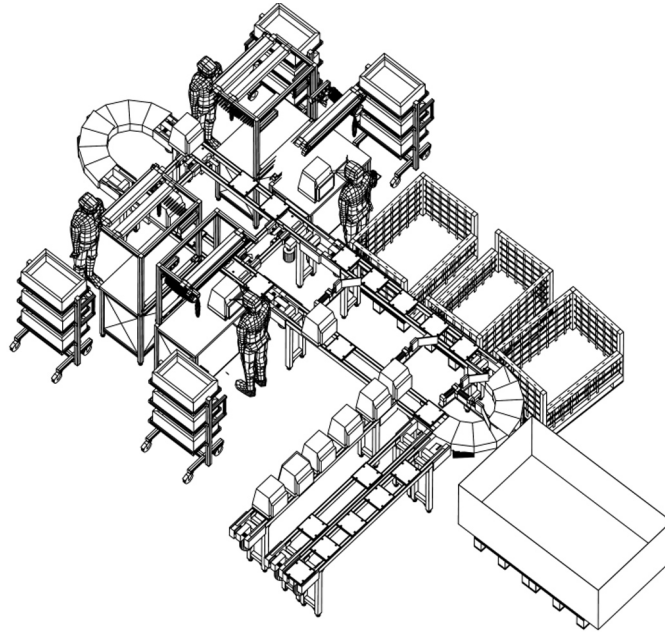


Fig. 8 Layout of disassembly system for CRT monitors (Ostojic, 2007)

The analysis of the average product time spent in one disassembly system for dismantling of CRT monitors would be simulated with the Rockwell Simulation software Arena 10. The CRT monitors (products) arrive at a four-station system according to an exponential inter-arrival distribution with a mean of ten minutes. The four disassembly stations are all different and there is just one of each. There are five monitor types, with the arrival percentages and process plans given in Table I. The entries for the process times are parameters a , b and c for a triangular distribution (in minutes).

Those five different CRT monitors each have different disassembly sequence. Some of them, like monitors 2 and 5 have only three operations in their process plan. The others have four operations, which mean that they should go to each disassembly station respectively.

The transfer time between arrival and the first machine, between all machines, and between the last machine and the system exit follows a triangular distribution with parameters: the minimum time $a = 8$, the most likely value $b = 10$ and the maximum expected value of $c = 12$ minutes. The animated model for CRT monitor disassembly is shown in Fig 9.

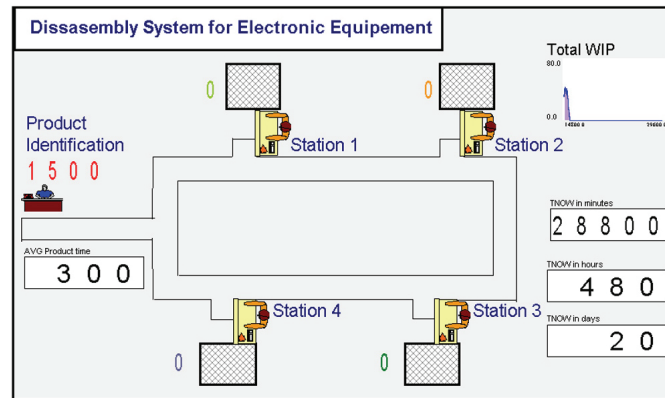


Fig. 9 Disassembly system for CRT monitors with Bar Code Identification Technology

The disassembly system was modeled as one for the RFID identification and for the barcode identification. The only difference was in operation for Product Identification. Bar code operation needs a worker to be completed. The other problem is that sometimes the barcodes could be hard to read if they are damaged or dirty.

The first pass was identification of the average product time spent in disassembly system for identification with barcode technology. The product identification was defined as triangular distribution with the minimum of half a minute, maximum of 2 minutes and the most likely value of 1 minute. The simulation was run for 10,000.00 minutes, and the warm-up time was 4,600.00 minutes. The simulation run was ten replications. Point estimates are the Average Total Time (total time in system). Average Total Time was 300.36 minutes and it was correlated to other product disassembly times. The Total average Work in progress was 15.6323 products. When the system was changed for RFID identification, the products could arrive, not one by one but in the batches of more than one product. Then, with the same length of the disassembly operations, the system became over congested at the time of 321.93911 minutes. It means that the current number of products in the system was 150 products at this moment, as shown in Fig. 10.

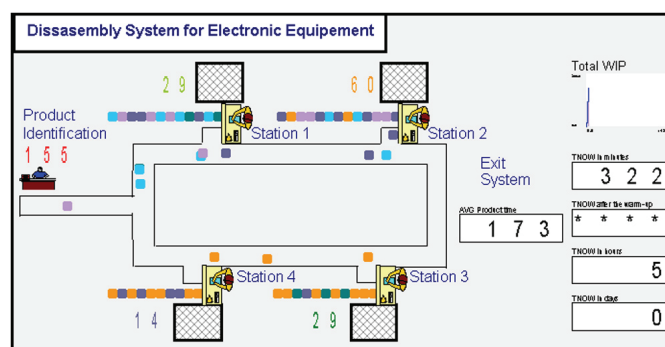


Fig. 10 Disassembly system for CRT monitors with RFID Technology

With this in mind, it would be interesting to find out when exactly the average time needed for product identification would be the most critical decision variable to determine which technology is better in this case. Dealing with the system that dismantles five different types of CRT monitors might not be the real representation of what would really happen in one disassembly facility. The number of CRT monitors that exist exceeds five so, in that case, the identification process would be different. In addition, the assumed process times that are presented in this case, might be even longer which means that the system will not be congested in this short period. Having more products in the disassembly system, of which all have complex disassembly sequence and explode state, would justify the application of RFID technology.

CONCLUSION

It is hard to distinguish which technology could be better or worse, the RFID or the bar codes. The two are different technologies and have different applications, which sometimes overlap. However, the data capabilities of an RFID tag are superior to a bar code. The disassembly instructions explode states, list of materials and hazardous materials are just a few examples of the types of information that can be programmed onto an RFID tag. The RFID technology is evolving and so are standards and systems supporting it. As the technology gains acceptance, adopters will face the daunting task of gathering and managing massive amounts of data. In case of disassembly systems, the environmental information systems are currently being developed by the companies that produce electrical and electronic equipment. In the not so distant future, those systems will be used by dismantling facilities that do not necessary have to be located in the plant that assembled those product, but anywhere it would be necessary. The RFID tags might be used in the way that they were used in the "smart trash cans" as explained previously in this paper. The containers that would collect dismantled components could carry the RFID chip inside of them. When the container would get filled, it could be carried to the scale to measure the overall weight of collected material. In this way, it would be easier to control the disassembly process.

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ANALIZA MOGUĆE PRIMENE IDENTIFIKACIONIH TEHNOLOGIJA U DEMONTAŽI

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Barkodovi i identifikacija putem radio talasa koji se koriste u toku proizvodnje, montaže, skladištenja i distribucije se takođe mogu koristiti pri kraju životnog ciklusa proizvoda za identifikaciju i odgovarajući proces demontaže koji bi rezultovao recikliranjem komponenti. Barkodovi ili RFID tagovi mogu biti od pomoći pri identifikaciji objekata u cilju održivog razvoja, vezano za demontažu, recikliranje, i ponovno korišćenje. U ovom radu, biće prikazana analiza trenutnih aplikacija RFID tehnologije u završnim fazama životnog ciklusa. Simulacija demontažnog procesa podržana barkodom i RFID baziranim sortiranjem proizvoda realizovana je u softverskom paketu Arena, kompanije Rokvel.

Ključne reči: *Demontaža proizvoda, upravljanje životnim ciklusom proizvoda, Radio Frequency Identification, bežične senzorske mreže, održivi dizajn*