DISASSEMBLY OF MOBILE PHONES: REVIEW OF RESEARCH ISSUES

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Abstract
Disassembly, in the context of recycling, is a kind of product life cycle activity that could or could not be used in its end of life (or end of use) management. This paper is analyzing research issues in disassembly of mobile phones. It uses some methodologies used in review articles, such as keyword search, etc. With use of keywords "disassembly", "dismantling", "phone" and "phones" in Google Scholar was identified first around 40 articles. The articles were further analyzed and grouped in to 7 mobile phones disassembly research issues: Design for disassembly (EcoDesign), Disassembly planning, Disassembly for remanufacturing, Innovation of disassembly facilities, Country / company views of disassembly, Economic aspects of disassembly and Other issues in disassembly.

Key words
Disassembly, mobile phone, research issues, review

INTRODUCTION
Disassembly, in the context of recycling, is a kind of product life cycle activity that could or could not be used in its EOL (or EOU) management. One of the most cited work [1] in the disassembly / recycling research stated that the areas of disassembly that are being pursued by researchers are focused on disassembly process planning (DPP) and innovation of disassembly facilities. Another well-known authors Gungor and Gupta in their article [2] grouped research in the disassembly field in two major areas: (1) research related to identifying the extent to which disassembly of a product should be performed (disassembly leveling); and (2) research focusing on disassembly process planning.

METHODOLOGY
This paper is trying to answer the question: What are the main research issues in disassembly of mobile phones?
Current scientific research in general, but also specifically in the field of disassembly of obsolete products is rapidly developing in last decades, if we measure it by a number of papers/studies. These papers are focused on different issues within the topic, and a number of papers for some issues is so huge that it is sometimes hard to analyze all within reasonable time frame. Currently, we can also observe increasing number of review articles. They are great starting point for studding the selected issue, they bring broader perspective for researches, they save researcher’s time and gave them list of relevant articles. In preparation of review but also other type of papers researchers have to identify, rank and select articles for the study. In the literature (e.g. [3], [4]) we can find guidance how to prepare review article. For example Levy [3] suggests for inputs search these steps: 1st step – keyword search, 2nd step – backward search, 3rd step – forward search, and stop, if we feel that we’ve seen this before.

In our research the analysis of research issues/topics in disassembly of mobile phones is based on representation of topics in articles trackable by Google Scholar. For our article we use this Google Scholar query: “disassembly” OR “dismantling” AND “phone” OR “phones”. In this search we reach around 70 thousand results. We analyzed first 4 results pages, it means around 40 articles. The articles were analyzed and grouped in to 7 research issues in disassembly of mobile phone.

COMPOSITION OF RESEARCH ISSUES IN DISASSEMBLY OF MOBILE PHONE

Design for disassembly (EcoDesign)
We grouped to this first research issue two general articles ( [5], [6]) and a number of specific design topics articles (see below). In one of the general design articles Boks [6] has shown how scenario analyses can be used to investigate the environmental and financial consequences of technical developments for example related to PWBs.

As mentioned above, we incorporate here also a number of articles ( [7], [8], [9], [10], [11], [12], [13], [14] [15] [16], [17], [18]) dealing with specific design topics (active disassembly and shape memory alloys). From these, for example Chiodo [7] is suggesting an option to cleanly separate LCD screens from printed circuit boards, utilizing an LCD bracket made from ‘shape memory polymer’ and Arpteg [15] found that proposed model of information flows and application of a generic set of design rules is relevant to clarify the interplay between an automated disassembly system and cellular phone design.
Disassembly planning

To disassembly planning group we incorporate generally oriented articles ([19], [20]) and articles specifically focused on disassembly sequencing / scheduling ([21], [22], [23], [24], [25]) and on disassembly time ([26]). For example Splengler in his case study [19] in order to consider the interactions between choice of scrap to be recovered (acquisition problem), disassembly and bulk recycling, is presenting a mixed-integer linear programming model for integrated planning of these stages. It is applied to determine the daily allocation of products to processes for a major electronic scrap recovery center that faces limited processing capacities and market restrictions. Other study [20] is analyzing two types of decisions which must be made: how to carry out the disassembly process in the most efficient manner to “mine” the value-added that is still embedded in the product, and then how to best utilize that value-added once it is recovered. The study presents a method for making those decisions. The concept of a transition matrix is integrated with mixed integer linear programming to determine the extent to which products should be disassembled, and simultaneously determine the optimal end of life (EOL) strategy for each resultant component or subassembly. The main contribution of this study is the simultaneous consideration of selective disassembly, multiple products, and the value added that remains in each component or subassembly.

In one of the articles from second sub-group (Disassembly sequencing / scheduling) [21], the disassembly sequencing problem is solved for a cell phone case on a disassembly line, seeking a sequence which is feasible, minimizes the number of workstations (and hence idle times), provides for early removal of high demand/value parts, provides the removal of parts that lead to the access of greatest number of still-installed parts, and early removal of hazardous parts as well as for the grouping of parts for removal having identical part removal directions. Since finding the optimal sequence is computationally intensive due to factorial growth, a heuristic method is used taking into account various disassembly-specific matters. Using the experimentally determined precedence relationships and task times of a real-world cell phone, a MATLAB program is designed and a sequencing solution is generated. Other article [22] is focused on a heuristically solved disassembly line balancing problem and the determination of an appropriate disassembly sequence influenced by sequence-dependent costs, which is based on a novel combination of exact and heuristic algorithms. In other article [24] the authors are considering a sequence-dependent disassembly line balancing problem (SDDLBP) that is concerned with the assignment of disassembly tasks to a set of ordered disassembly workstations while satisfying the disassembly precedence constraints and optimizing the effectiveness of several measures considering sequence-dependent part removal time increments.

In the article from third sub-group (Disassembly time) [26] the authors are experimentally examining the reversibility and disassembly time of part connections through the actual disassembly work of some spent industrial products. The disassembly time for connections depends on the joining method, joining direction, length of product life and chemical and physical deformation.

Disassembly for remanufacturing

Articles in this group ([27], [28], [29]) are related to disassembly for remanufacturing. For the planning of remanufacturing capacities and production programs, for example Franke [27] is introducing a linear optimization model.

Innovation of disassembly facilities

In this group are articles ([30], [31], [32]) connected to innovation of disassembly facilities. These articles are more focused on technical side of disassembly. For example Kopacek [30] is presenting a new concept for modular disassembly cells based on “disassembly families”, mobile robots and multi agent systems (MAS).

Country / company views of disassembly

The articles incorporated here ([33], [34], [35]) are describing country (or company) view on the topic of disassembly of mobile phones.

Economic aspects of disassembly

In analyzed sample of articles, economic aspects of disassembly of mobile phones are analyzed in following articles ([36], [37], [38], [39]). For example in Duflou’s paper [36] a case-based review of current disassembly practices is used to analyze the factors influencing disassembly feasibility. Data mining techniques were used to identify major factors influencing the profitability of disassembly operations. Case characteristics such as involvement of the product manufacturer in the end-of-life treatment and continuous ownership are some of the important dimensions. Economic models demonstrate that the efficiency of disassembly operations should be increased an order of magnitude to assure the competitiveness of ecologically preferred, disassembly oriented end-of-life scenarios for large waste of electric and electronic equipment (WEEE) streams. It also summarized technological means available to increase the productivity of the disassembly operations. Automated disassembly techniques can contribute to the robustness of the process, but do not allow to overcome the efficiency gap if not combined with appropriate product design.
measures. Innovative, reversible joints, collectively activated by external trigger signals, form a promising approach to low cost, mass disassembly in this context.

Other issues in disassembly
In the analyzed sample are also articles ([40], [41], [42], [43]) which are related to special issues not exactly fitting to above mentioned research issues (groups). For example Stutz [40] is analyzing linking bar codes to recycling information for mobile phones. To address this problem, the authors developed a system, which links the existing bar codes on mobile phones to web sites containing disassembly information. The system makes use of the barcode label containing the IMEI (International Mobile Equipment Identity) number, which is on every GSM mobile phone.

CONCLUSION
The paper is reviewing research issues in disassembly of mobile phones. On the base of Google scholar search with the use of keywords: "disassembly", "dismantling", "phone" and "phones" was identified first around 40 articles. The articles were further analyzed and grouped in to 7 mobile phones disassembly research issues: Design for disassembly (Eco Design), Disassembly planning, Disassembly for remanufacturing, Innovation of disassembly facilities, Country / company views of disassembly, Economic aspects of disassembly and Other issues in disassembly.

Literature


This contribution was created thanks to support under the Research and Development Operational Program for the project: Univerzitný vedecký park TECHNICOM pre inovačné aplikácie s podporou znalostných technológií – II. fáza (ITMS2014-313011D232), co-funded from the European Regional Development Fund.