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Author(s)	Karvonen, Iris; Jansson, Kim; Vatanen, Saija
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Development of an Assessment Model to Increase the Understanding about Remanufacturing Applicability

Iris Karvonen[1§], Kim Jansson[1], Saija Vatanen[1]

[1] VTT TECHNICAL RESEARCH CENTRE OF FINLAND Ltd, Vuorimiehentie 3, 02044 VTT, Finland

[§]Corresponding author

Email addresses:
IK: Iris.Karvonen@vtt.fi
KJ: Kim.Jansson@vtt.fi
SV: Saija.Vatanen@vtt.fi

Abstract

Remanufacturing can offer benefits to manufacturing companies and service industry, as well as for customers and the society. However, to make progress, the awareness of this potential and understanding of the applicability is too low both in industry and society. Customers also often do not have a confidence in remanufactured products as they do not know the quality principles of remanufacturing. Thus remanufacturing activities are still quite uncommon. This was seen also in a Finnish research project, in which new industrial resource-efficient collaboration forms, including remanufacturing were studied.

It is clear that not all products or parts can be remanufactured in a reasonable way, but so far remanufacturing is far from its potential. One reason is that companies do not know if remanufacturing would suit to their business, if the products can be remanufactured or not, and if the customers would accept remanufactured products. As a whole, it is not known what needs to be taken into account to start remanufacturing business.

To support manufacturing companies, which have an interest in remanufacturing, in a Finnish research project an assessment model outline has been developed to support decision making. The model reviews the remanufacturing potential first through profitability and market potential, and then through the suitability of a single product/ component for remanufacturing. Both product characteristics and manufacturing and logistics are considered. The aim of the model is not to give final "go-not go" decision but more to give understanding about the factors affecting the success in remanufacturing. For example, it is important to get the message that even if remanufacturing is currently not applicable for a specific product or the business the situation can be improved through new business model approaches and design for remanufacturing.

Introduction

Background and Objectives

This paper is based on the developments in a research project "DemaNET" – "Dematerialization and Sustainable Competitiveness through New Models for Industrial Networking" which was carried out as part of the "Green Growth" program of Finnish national funding organization Tekes in 2012-14. One of the focus areas of the project was remanufacturing and the high level objective was to study how remanufacturing could be applied and promoted in Finland.

In the project, in the collaboration with companies and other organizations, it was identified that remanufacturing is currently known weakly in Finland. In a survey performed during the project less than half of the respondents knew the Finnish term "remanufacturing" [1]. The terms "refurbishing" or "factory refurbishing" were known somewhat better and in many cases they are used instead of "remanufacturing". In fact, the APRA Remanufacturing Translation Matrix [2] currently uses "factory refurbishing" as the translation of "remanufacturing" into Finnish. To progress with remanufacturing, better understanding of the terms and the concept is needed.

The main industrial fields currently operating in remanufacturing in Finland are machine industry and heavy vehicles, but also office furniture is remanufactured. The volumes are still quite low but a recent report [3] states that in Finland in machine industry remanufacturing is one of the promising models of circular economy which is estimated to have a potential of 300-450 million euros yearly turnover in future.

To realize the potential, awareness of remanufacturing needs to be raised in Finnish industry and society but additionally also other actions towards different stakeholders are needed [4]. This paper is focused on supporting companies when they are assessing the potential to apply remanufacturing for their products or components.

Suitability of remanufacturing

Remanufacturing is not applicable, profitable or sustainable for all types of products or components. Through design for remanufacturing the applicability can be improved. However, in addition to challenges related to the technical remanufacturing process, there are also challenges related to the collection of used products and demand and distribution of remanufactured products [5,6], as well as the business, management and legislation issues [7].

The technical remanufacturability of products has been analysed for example in [8] and [9]. According to [8] the most significant properties of products regarding remanufacturing are the following: ease of access, ease of identification, durability and ease of handling. In [9] the following criteria were identified: Technology exists to restore the product, the product is made up with standard restorable parts, cost of a core is sufficiently low and the product technology is stable over more than one lifecycle.

Justham et al. [10] have analysed the suitability of an End of Life product for the second life and developed a framework to identify the most appropriate end of life treatment for a product. The method includes three phases: information phase for data collection, analysis phase to define the decision criteria and the decision phase. The decision criteria are product- and customer-specific; most often cost, time and quality need to be considered. A spectrum of business scenarios are analysed from "one-to-one" (from single used product to single remanufactured product) to "many-to-many" (from many used products to many remanufactured products) relationships.

In addition to technical challenges also the challenges related to logistics and business need to be solved. Thus, when developing remanufacturing, it is not enough to solve single problems but an integrated approach and an organizational and cultural change is needed [11]. A combination of economic and environmental benefits should be derived from remanufacturing. The customer needs must be known (relating to price, quality, upgradability) and negative cannibalization should be avoided. The product needs to be designed for remanufacturing, the uncertainties in the reverse supply chain should be decreased and the actions of the different actors in the network require coordination [11].

Subramoniam et al. [12] present a remanufacturing decision-making framework to support automotive aftermarket industry, that is, the activities after the initial sales. The framework is particularly directed to automotive suppliers in their decision-making about remanufacturing. The framework is built with a set of questions relating to financial viability, environmental impacts, reverse logistics and the organization's technical ability. The framework is recommended to be integrated with the sustainability strategy of the company.

The successful examples of remanufacturing may encourage companies to develop remanufacturing but it is not recommended to copy directly the implementation models. Similar solutions may be appropriate for similar types of products, which operate in a similar environment and the same type of customers. However, customization of the solution may be needed even for conditions seeming similar. For example, local cultures may affect to the customer behaviour and the acceptance of remanufactured products.

To support companies having low knowledge about remanufacturing, an assessment model outline was developed in DemaNET project. The idea is that companies could assess the applicability of the concept to their business and products. The model reviews different viewpoints to remanufacturing, to support decision making and to identify further development actions. The model is not only focused on technical aspects but it also covers the market viewpoint, finance and logistics. The model, which is still under development, is presented in the next chapter. The approach for the development is described in the end of the paper.

Results

The purpose of the Assessment Model is to serve as a supporting tool for decision making in companies, when assessing the applicability of remanufacturing business for their products. In the model first the product's suitability for remanufacturing is assessed with respect to profitability and market potential. After that the products are analysed from the remanufacturing process point of view. The suitability is assessed regarding product features, profits, markets, remanufacturing process as well as logistics. In this context the product refers to the end product, a subassembly or a component. The product can thus be a component in the final product. The assessment model in Finnish language can be found as a whole in [13].

The assessment is performed through a number of statements. Each statement addresses a certain aspect of remanufacturing as described above. The statements are bundled into the following groups; profitability, market potential, product and process, and logistics. Each statement can be answered by three alternatives; *Yes, Don't Know* or *No* depending on the state in the company.

If there are more ticks in the "Yes" column, then we can assume that there is a business potential for remanufacturing.

If there are more ticks in the "No" column, then we can assume that there are challenges related to remanufacturing of the product. This does not necessarily mean that remanufacturing cannot be profitable.

If there are many ticks in the "Don't Know" column, then a large number of uncertainties are present.

If a statement does not realize (a tick in the No column), then it is an indication that something has to be done to the issue and that there are some costs associated. The company must further evaluate the costs and assess if the costs are reasonable in comparison with the business potential.

The Assessment Model has been implemented as a MS Excel application, currently in Finnish language. It can also be used as a desktop paper version [13]. The following Figure 1 is a translated example extract from the Assessment Model.

	Yes	Don't Know	No
New business strategies can be built on Remanufacturing			
Remanufacturing is a strategic decision to which the entire company commits.			
Other companies already operate profitable on the markets, there are existing markets.			
A third party is already active on the market and the operation is profitable.			

Figure 1. An example from the Assessment Model.

Below, the main groups of the statements as well as some main topics of the Assessment Model are presented:

Profitability

(*With the statements in the Profitability group we try to assess the motivation for remanufacturing as a whole and the background for starting the remanufacturing business. With the help of the statements we can make conclusions about profitability of remanufacturing.)*

Cost saving potential
Influence on new product sales

Market potential

(*With the statements in the Market potential group we try to identify factors in the companies' business, business model and business environment that act as drivers and enablers for a profitable remanufacturing based business activity.)*

Business model e.g. leasing, product service systems
Customers
Market

Products and remanufacturing process

(In this subsection we assess the suitability of the production process and design principles and identify matters in the production process that need development efforts.)

Product structure
Modularity and configurability
Engineering and design
Supply chain
Recycling and use of precious raw-material
Life-cycle length
IPRs

Logistics

(Logistics are important in successful remanufacturing based business. The reverse logistics is of special importance. Efficient collection of used products must be organised.)

Business model
Markets geographically
Product physical size
Delivery logistics
Return of used products (core supply)

Interpretation of the Assessment results

In total, the Assessment Model consists of thirty-seven statements. The statements are formulated in a positive format. This means that a "tick" in the Yes-column refers to a positive signal towards remanufacturability of the company's products and feasibility of the business model utilizing remanufacturing.

The assessment results can be visualized in different formats. As an example two different formats are presented in Figure 2. The figures present the proportion of different types of answers (yes, no, don't know) for each group of questions (profitability, market potential, manufacturing, logistics).

There is no direct correlation between the number of "ticks" in the Yes-column and the future profitability of starting remanufacturing operations. The model serves as a check-list of items that have to be considered. The Assessment model can also work as a group working instrument and facilitator. The level of detail can be increased through multiple usage of the model. First a rough estimation can be made and if an indication of potential for profitable remanufacturing is identified, iterations with increased confidence can follow.

Also other sources of information can be used, e.g. what are the competitors and other companies in the industry branch doing, legislation and legal issues, import-export restrictions etc.

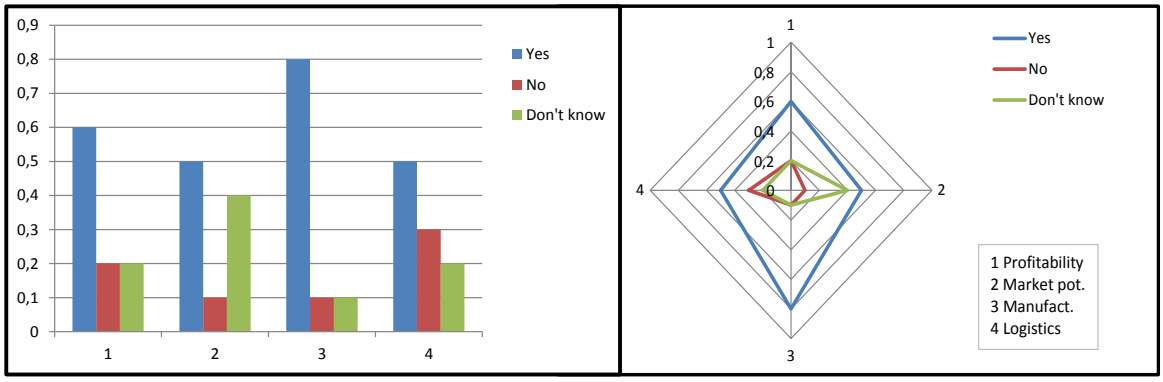

Figure 2. Examples of result visualization

Discussion

The Assessment Model has been developed based on a real world questionnaire and comprehensive literature study and remanufacturing feature analysis. More details on the development methods can be found below in this paper. Thus, relying on the current body of knowledge, we can anticipate that the model contains the essential elements related to remanufacturing. The model will guide the user, from potential future remanufacturing company, through a series of statements giving the user a holistic and critical view of future business potential. However the Assessment Model has not yet been applied in any

real business case. This lack of experience of course may raise some doubts among new users. To overcome this, the authors suggest activities to enhance the model including the following;

- Model application in a real world and realistic business setting. Based on the cumulated experience the used statements in the model can be more focused and in some cases enlarged. Care must be taken not to make the model complicated and difficult to use.
- The terminology of the model should be made clear to SME users who are not familiar with remanufacturing knowledge or even the terminology. This also requires interaction with SME users. For example, in addition to the term "remanufacturing" also the term for "core" is not established in Finnish.
- In order to get a wider user community the model needs to be translated into languages that are spoken in SMEs. Now it has been implemented in Finnish. A first action is to translate the model into English and later possibly into other major European languages.
- A web interface to the model would also increase the number of possible users. Accessing the model as an open source model is a must.
- The analysis of the answers could be automatic to some degree, thus supporting the user in the analysis process by giving some appropriate hints. However all business cases are individual and have their own constraints; a fully automatic model will not be feasible.

Conclusions

Remanufacturing is still in its infancy in the Finnish manufacturing domain. The objective of DemaNET project, conducted by VTT, was to increase the awareness and knowledge about remanufacturing business potential and sustainability.

Remanufacturing is not applicable, profitable or sustainable for all types of products or components. This paper was focused on supporting companies when they are assessing the potential to apply remanufacturing for their products or components. The paper presents the motivations for the development work as well as the used methodology. As a result we have a first version of a tool that supports mainly SMEs to give basic understanding about the factors affecting the success of remanufacturing.

In the model the product's suitability for remanufacturing is assessed with respect to profitability and market potential. After that the products are analysed from the remanufacturing process point of view. The suitability is assessed regarding product features, profits, markets, remanufacturing process, and logistics. The aim of the model is not to give final "go-not go" decision but more to increase understanding about the factors affecting the success in remanufacturing.

Methods

The research was performed as part of the project "DemaNET", belonging to the Finnish Green Growth programme which is funded by the governmental funding organization Tekes. The high level research questions of the project were related to the application and promotion of remanufacturing in Finnish industry and society. The study included the analysis of the current situation, benefits, drivers, challenges and practices as well as the creation of a development path towards the promotion of remanufacturing in Finland [4].

Five industrial companies interested in remanufacturing participated in the project. Part of the companies were already active in remanufacturing business while the others

were still assessing the potential and looking for partners to build up the remanufacturing system. In the research, the companies operated both as sources of real-life information and giving feedback to the research findings.

Collection of information

For the information collection different methods were used:

- In the beginning of the project semi-structured interviews with the representatives of the industrial companies were carried out to gain understanding about the industrial status, views, experience, challenges and their visions for the future. To identify the significant topics about remanufacturing and to develop the interview structure, previous research and case studies about remanufacturing were reviewed [5,6,14].
- In the following phases, the consolidated observations from the interviews were further discussed and elaborated with the companies in workshops.
- To extend the information base, a web survey collecting information from Finnish companies was also carried out in collaboration with the Brazilian-German research project BRAGECRIM [1]. The survey mainly followed the structure of a survey by Berlin Technical University and Sao Paulo University for companies in German, Brazil and some other countries in Europe and the Americas. The Finnish version of the survey was translated into Finnish language and slightly adapted with additional questions relating to the awareness about remanufacturing. The invitation to the Finnish survey was sent via e-mail to approx. 250 professionals and a total of 33 replies were received.

Feature analysis

To analyse the applicability of the remanufacturing concept for manufacturing companies the challenges and obstacles of remanufacturing were further analysed. The aim was to identify factors and features which affect to the implementation of the concept. The features are related to the object to be remanufactured (product or component), but also factors from the company business perspective, environment, location etc. need to be considered. The following groups of features were analysed:

- Product related
- Product manufacturing
- Material related
- Value and cost issues
- Company characteristics
- Customer related
- Networking and collaboration status
- Geographical location related features

The idea was to go through each feature and analyse if it has a positive, neutral or negative impact on how well the products are suited for remanufacturing and how remanufacturability is supported. Each class of features included 1- 21 characteristics. For example, the product related features included modularity, technological rate of change, size and volume etc. and the customer related customer attitudes, differentiation of customers etc. As a whole, about 50 features were identified.

The technical reconditioning is not enough to make remanufacturing happen. Additionally reverse logistics and sales and distribution of remanufactured products or components are needed. It is possible that even if a product suits technically well for remanufacturing, it is challenging to build up the logistics and the sales part.

Correspondingly, in some cases the technical reasons may create the obstacle for remanufacturing. Thus, even the same feature may influence the application potential in different ways in different remanufacturing processes.

To take this into account, the features were analysed separately for different remanufacturing processes [15,16]:

- External Remanufacturing process taking care about the core collection, including needed transportation and storage.
- Internal Remanufacturing processes: Inspection, disassembly and cleaning, reprocessing, assembly, testing and storage.
- External process towards customers: sales and distribution, transportation and storage.

This resulted in a table of 50 features x 7 subprocesses. For each table cell (feature and process phase) a note about positive/ negative / neutral impact was entered, and based on them, an overall comment of the feature impact was given.

Development into an assessment model

The resulting table was further analysed to build up an assessment model which is not too heavy and difficult for industrial companies. The factors / features having a neutral impact were excluded. The features were regrouped into 4 main groups:

- Profitability
- Market potential
- Products and production
- Logistics

To make the assessment easy, the features were turned into statements that the user of the model can assess from his/ her own company perspective (yes, no, I don't know). The model is described in chapter Results.

Authors' contributions

All the authors have participated in the information collection through interviews and workshops with the companies and the development of the assessment model. IK is the responsible author and has been managing the DemaNET project. IK and KJ have contributed to the feature analysis. SV has contributed to building of the Assessment Model and statement formulation. All the authors have read and approved the final paper.

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