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*Gernot Lechner, Marc Reimann*

## Working Paper 2015-01

*February 3, 2015*

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**Keywords:** Reprocessing, reuse, independent manufacturer, case study, social economy – work integration social enterprise

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**Keywords:** Reprocessing, Reuse, Independent remanufacturer, Case study, Social Economy - Work Integration Social Enterprise

# 1 Background

During the last decades, conventional manufacturing approaches have been extended by combined manufacturing/reprocessing or even replaced by exclusive reprocessing solutions to manage reverse logistics processes. According to leading companies' decision makers, managing such closed-loop supply chains is one of the crucial future key issues [11]. This trend can already be observed these days, with diverse characteristics regarding the implementation of remanufacturing, refurbishing, reuse, or recycling activities in many industries, e.g., automotive industry and (re)manufacturers of electronic equipment, white goods, or heavy machinery. Exemplary companies acting in the field are global players like Caterpillar, Xerox, Vickers, and Sony (see [2], [10], [35], [44]). However, not solely original equipment manufacturers (OEM), but also independent companies like ATP Industries Group or Flection Group entered the market and provide reprocessing capacities ([4], [17]).

As mentioned in the introduction, manifold endogenous as well as exogenous factors cause this change. On the one hand, reprocessing of used items to prolong their usage phases often gives the opportunity for an increased profitability due to reduced production costs. Therefore, this can be considered as an effective incentive for companies to reprocess used products. This stimulus is presented in both scientific literature (e.g., [3], [26], [29], and [38]) and work closely related to practice (see, for example, [20], [21], [23], and [35]). Another endogenous factor - mentioned, e.g., in the CopyMagic case study [48] - is the green image, which can be gained by reprocessing and remarketing of used products. The interrelated well-being of 'green consumers' may lead to raised profits.

On the other hand, several causes force companies to rethink their solely-forward logistics solutions and to transform their production processes. An increasing demand for resources in many countries, but particularly in the BRIC (Brazil, Russia, India, China) and MIST (Mexico, Indonesia, South Korea, Turkey) economies, leads to raised costs for resources due to global competition [52]. Additionally, the example of rare earth elements shows the vulnerability of entire continents in the case of resource scarcity due to limited resources or monopoly suppliers ([30], [32], [36], [49]). Firms can succeed in overcoming these potential supply risks by reusing resources.

Resource consumption without preparation for reutilization of used resources is also jointly responsible for global climate change and regional environmental problems ([25], [43], [51]). These problems bring legislative authorities to put pressure on companies by enacting laws which are aimed at environmental and, in particular, natural resource protection. A well-known example is the 'Waste Electrical and Electronic Equipment Directive' (WEEE) in the European Union, which targets the collection, recovery and recycling of electrical and electronic products. Also Japan [1] and China [54], for instance, legislated for the collection and reprocessing of electrical and electronic equipment. An overview of the global situation of WEEE-management is presented in Ongondo et al. [33].

Besides to common profit-oriented companies operating in reverse logistics or closed-loop supply chains, non-profit-organizations (NPOs) and environmentally/socially concerned companies entered the market for reprocessing goods. The activities of these companies acting in a non-profit or social-economy way are spread over various sectors, countries, and different business segments relating to reverse logistics. In Austria and Germany, for instance, both private and public collection services for waste collection exist. Another example is Rehab Recycle, operating in Ireland,

the United Kingdom, The Netherlands, and Poland; Rehab Recycle provides 'a range of innovative recycling solutions, information security management services and asset recovery services for businesses' [37]. Regarding the textile industry, exemplary companies are Carla [7] or Kolping Recycling GmbH [27], which both provide second-hand clothes. Another example is R.U.S.Z, an independent reprocessor of white goods located in Vienna, Austria.

## 2 Case description

Repair- and Service Center R.U.S.Z (Reparatur- und Servicezentrum R.U.S.Z) is a Work Integration Social Enterprise (WISE) focusing on reprocessing, repairing, and servicing of used products. Founded in 1998, the company pursues goals in economical, ecological, as well as social directions. Particularly, the objectives include cost recovery, reprocessing/repairing of about 8,000 used products/year, reduction of problematic waste due to prolongation of product usage phases, and reintegration of permanently unemployed persons.[1]

One of R.U.S.Z' main businesses - besides offering repair services for household appliances, consumer electronics, and computers - is reprocessing of used white goods, mainly washing machines, dishwashers, ovens, dryers, and washer-dryers. Used white goods come from different sources of supply: on the one hand, private persons can donate their (even not working) products to R.U.S.Z. Recurring media campaigns remind the Viennese public of this possibility. As it is sponsored by the Viennese municipality, R.U.S.Z can offer a low-priced collection service. This enables the acquisition of used machines which are at the end of their first usage phase and therefore sorted out by private persons. By offering a collection at the customer's home, staff can already pre-sort and pre-classify the white goods as reusable/non-reusable by identifiable characteristics (e.g., visual inspection of the condition of the casing, indication of malfunction). On the other hand, R.U.S.Z cooperates with commercial collectors of electrical and electronic equipment, which provide them with used items. However, as these cooperations currently result in negligible quantities of used products, we do not consider them in this work.

After transportation to the reprocessing site, the machines are manually tested and sorted with respect to their further usability. Reusable products are classified in one out of three categories based on specific quality criteria, while non-reusable items are either determined for spare parts recovery or disposal/recycling. Up to the result of this sorting/grading/test procedure, the products are remanufactured and optionally upgraded, refurbished, cannibalized to extract spare parts, or recycled. The option to upgrade a product results in an improved energy efficiency category of a washing machine, based on an energy-saving method developed by R.U.S.Z. After reprocessing, the reusable white goods are offered in the R.U.S.Z-shop as second-life products. Thus, customers can buy, e.g., a reprocessed washing machine with a life expectancy of - according to R.U.S.Z - ten years at a reduced price which is comparable to a new, low-quality washing machine.

[1] In this work, we consider acquisition and reprocessing of white goods. Apart from that, R.U.S.Z was one of the main initiators of Austrian mobile phone collection system 'Ö3-Wundertüte'. Used mobile phones can be donated by sending them to a collection center free of charge, where permanently unemployed persons sort the mobile phones and classify them into reusable and recyclable. Thereafter, the mobile phones are sold in an auction. Additionally, for each reusable or recyclable mobile phone, aid organizations receive a donation of €3 or €0.5, respectively. In 2012/2013, 457,000 mobile phones were donated [6].
Additionally, R.U.S.Z established a repair café [39] named 'Schraube14' in Vienna. In the course of this event, competent staff of R.U.S.Z assists to repair broken products by the owners. Besides providing the infrastructure for the repair café, this service is free of charge.

In Figure 1, a process map concerning the reverse logistics at R.U.S.Z is shown. All of the activities and processes are discussed in detail in Section 3.

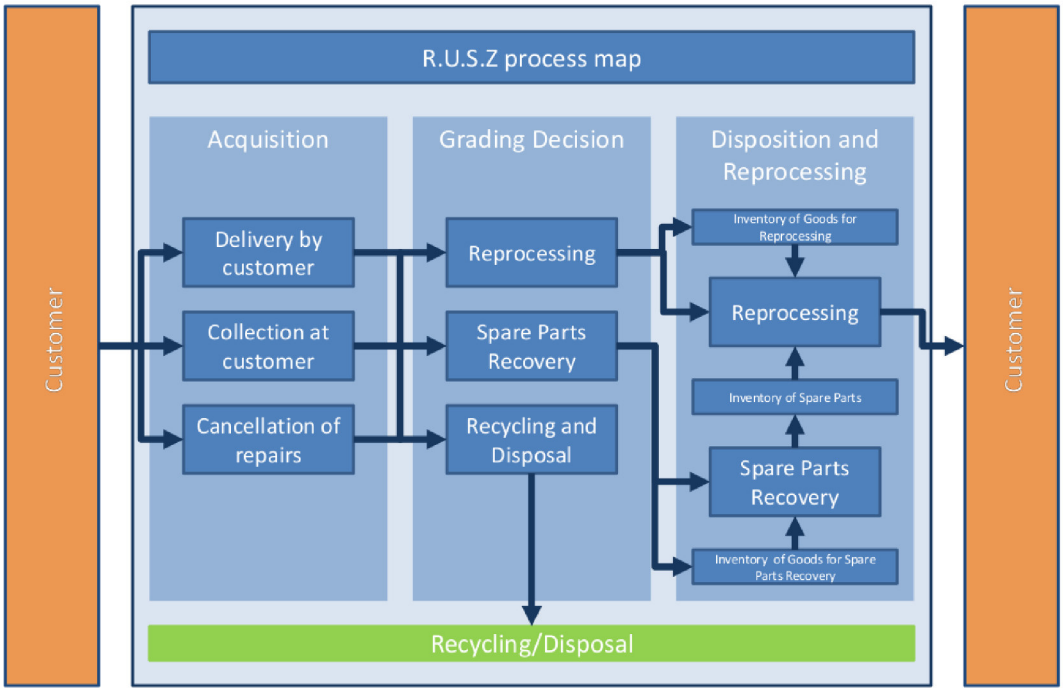



Figure 1: Process map of reverse logistics at R.U.S.Z.

Some specific characteristics of R.U.S.Z raised our interest, and some guiding research questions were formulated:

- What are the main characteristics and decisions of the processes at R.U.S.Z and how do they interact?
- What are the main drivers of business at R.U.S.Z? Which factors affect the decision-making at R.U.S.Z, and how does the company cope with these influences?
- What are the unique properties of a non-profit organization dealing with reverse logistics, if there are any? How are the reverse processes organized at an NPO/SCC? How does such a firm differ from conventional profit-oriented business?

## 2.1 Methodology

The first contact with the head of R.U.S.Z, Mr. Eisenriegler, was in the course of an invited talk and a subsequent discussion at the University of Graz. This was the stimulus for a cooperation and led to this scientific exploration of the reverse logistics at R.U.S.Z.

Regarding the methodology, we decided to use case study research due to several factors. Case study research has played an important role for the development of research in the area of reverse

logistics and closed-loop supply chains (RL/CLSC). Well-known examples for case studies giving impulses for scientific work are about IBM [19] and ReCellular Inc. [22]. Furthermore, a review of case studies in the area of reverse logistics is presented in [9].

Yin considers a case study as 'an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context' [53]. Due to several reasons given below, an in-depth, explorative case study is an adequate methodology to deal with the investigation of R.U.S.Z. First of all, using explorative case study research is supported by the fact that NPOs with entire reverse logistics processes from acquisition of used products to remarketing can rarely be found. Next, the case study allows to get a holistic view on processes and decision-making of R.U.S.Z. Both the holistic view and the type of questions ('what?', 'how?') favor the case study method. Additionally, R.U.S.Z can not be studied without considering its case-specific context; for example, the complex acquisition of used products and the sale of reprocessed products instead of new ones with consequential questions regarding warranty or pricing have to be included and studied in the case study to guarantee an overall understanding. Finally, the case of R.U.S.Z is an investigation of a contemporary phenomenon. All of these arguments are in line with literature related to case study research (see, e.g., [53], [31], and [50]).

The R.U.S.Z - case study is mainly based upon a company visit on April 24th, 2013, including interviews with the head of R.U.S.Z and an employee. Questions asked during the interviews are based upon an intense literature review to identify characteristics already known in the scientific community. Furthermore, the guideline of questioning prepared for the interviews followed the generic reverse logistics flow established in research literature (e.g., the processes acquisition, grading, and disposition of used products [18]). This procedure allows and supports us to find differences compared to standard process models used in scientific literature. We conducted a semi-structured interview with the head of R.U.S.Z (duration: 150 minutes), consisting of open-ended questions; with this approach we were trying to get a holistic view on R.U.S.Z' business and decisions. The main focus was on the logistics processes, decision-making, and challenges for R.U.S.Z, both on a strategic and an operational level of business. Furthermore, a company tour tracking the processed items helped to clarify and make sure the logistics processes and flow of material at R.U.S.Z. In the course of this company tour, another interview with a duration of 15 minutes was conducted with an employee responsible for receiving and classifying of acquired used products. The interviews were conducted in German, and the information was documented directly by detailed handwritten notes.

Next to interviews, some additional data sources were available. R.U.S.Z publishes yearly reports concerning their business development. These reports include data from operations and descriptions of the strategic concepts. Furthermore, data could be gathered at presentations given by Mr. Eisenriegler, the head of R.U.S.Z. Finally, R.U.S.Z provided us with the entire business database of the day-to-day business, including datasets for the years 2011, 2012, and 2013. This database contains detailed information regarding operations, e.g., delivery dates, quality of returned used products, decision-making, and completion dates.

Two additional phone calls helped to clarify ambiguous information: on the one hand, the scope of the case study was extended to include information concerning customer preferences and the consequences on pricing of reprocessed goods. On the other hand, in the course of the analysis of the business database a further clarification regarding datasets was required. Due to validity reasons, the case study was given to R.U.S.Z to recheck all the information.

# 3 Discussion and evaluation

In this section, some observations and key figures regarding R.U.S.Z are presented, including organizational, logistical and ecological topics. As described above, the information is based upon R.U.S.Z' yearly reports, several discussions with employees and the head of R.U.S.Z, and the business database of the day-to-day business.

## 3.1 Goals of R.U.S.Z

Contrary to many companies engaged in the reprocessing business, R.U.S.Z is not profit-oriented but organized as a non-profit organization (NPO). As it is postulated in the common definition of social economy, ecological and social goals play a major role for decision-making at R.U.S.Z, next to economic objectives [5].

Although R.U.S.Z does not actively pursue the objective to maximize profits, decision - making and the company strategies must ensure financial sustainability to keep business running in the future. This is related to the fact that R.U.S.Z is self-feeding; public support is solely granted under strict conditions for the reintegration of long-term unemployed people. Therefore, the main economical objective is to earn sufficient to cover all types of costs (investments, staff, etc.). Due to the fact that R.U.S.Z is a comparatively small company, it is limited in terms of budget and investment capital. Naturally, these limitations cause that the capacities are restricted. However, from R.U.S.Z' point of view, limited reprocessing capacities are also part of the business strategy to avoid the risk of overwhelming (and subsequently, costly) resources. According to R.U.S.Z, this is one of the key factors for a sustainable business, as it helps to cope with the risk of potential supply or demand shortages due to low fixed costs.

R.U.S.Z also considers ecological and social objectives. Remanufacturing and refurbishing of used items and the subsequent reuse result in extended product usage phases. Consequently, less virgin resources are consumed, and at the same time, waste is reduced. Additionally, an optional upgrading process significantly reduces the energy consumption of washing machines. Therefore, as an ecological goal, R.U.S.Z wants to provide consumers as many reprocessed used products as possible to minimize environmental impact. Another aspect concerns consumer education: next to convincing people to repair broken products instead of throwing them away, buying of high-quality durable goods is promoted.

Regarding the social responsibility, R.U.S.Z wants to provide socially disadvantaged people with energy-efficient durable goods at reasonable prices; offering these energy-efficient second-life products should substitute sales of throwaway products. Therefore, the socially disadvantaged people get a discount of 20 % on all services and products offered by R.U.S.Z. Besides this goal, the main related social objective is to solely employ long-term unemployed people: R.U.S.Z provides regular work to reintegrate them in the working world. Consequently, the unemployed people get practical experience. The goal is to place all of these people in open-ended jobs, both at R.U.S.Z and other companies. All in all, 400 long-term unemployed people were employed and trained, whereof 300 people were placed in open-ended jobs. An economic side-effect of the offered services is the local value creation: contrary to producing new goods, which is mainly outsourced abroad, the added value remains inland.

To give a résumé, economical objectives make sure the financial continuation of the company by covering costs but not by maximizing profits, while ecological (maximize the ecological surplus,

maximize the sales of reprocessed products under certain restrictions like budget, capacities, human resources) and social goals (reintegrate long-term unemployed people, on-the-job training to convey a maximum amount of knowledge) are pursued actively, too.

## 3.2 Organizational Structure of R.U.S.Z

Since the foundation of R.U.S.Z in 1998, the focus is on employment of long-term unemployed people. Currently, 21 people work for the company, whereof two persons focus on strategic activities like long-term projects and calculations. Fifteen workers are assigned to three departments: nine workers are responsible for white goods, five persons focus on consumer electronics/brown goods, and one cares about reconditioning of computers. All of these workers are responsible for any of the activities which occur within a department, e.g., remanufacturing, spare parts recovery, and disposal of used products. Besides the workers, two apprentices are trained, and one person is solely responsible for the used-goods receiving. Another two part-time employees as well as Sepp Eisenriegler, the general manager of R.U.S.Z, are assigned to an overhead cost center.

From 1998 to 2007 hundreds of long-term unemployed people were reintegrated, they did a 12-month on-the-job training funded by the Public Employment Service Austria. Since the beginning of 2008, R.U.S.Z has turned to be a private non-profit company. However, still long-term unemployed people are trained. As the costs for this are not covered by public authorities in terms of subsidies, R.U.S.Z has developed a specific Corporate Social Responsibility-concept: private profit-oriented companies take over the sponsorship for the on-the-job trainings. The productive efficiency of a new worker is estimated at 50-70 %, and the sponsorship covers the costs to cope with this reduced efficiency. On average, the worker achieves the full potential after a half year on-the-job training.

## 3.3 Integrated Reverse Logistics and Decision-Making at R.U.S.Z

Reverse logistics consists of different aspects, in detail, acquisition of used products (supply), grading, subsequent disposition decisions and reprocessing, and finally, remarketing of reprocessed products. Clearly, the individual processes at R.U.S.Z can not be considered as isolated activities, as there exist interdependencies between the processes. First of all, the acquired quantity of used products determines the maximum amount of reprocessed products. Next to the used products which are prepared for reuse, some additional products have to be acquired to ensure a sufficient supply with spare parts needed for reprocessing activities. However, the more products R.U.S.Z acquires, the higher is the total effort which has to be spent to determine the qualitative condition of the used products. Besides the fact that the cost for reprocessing correlates negatively with the quality of the acquired and classified product, the result of the classification restricts the possible reprocessing options. All the reverse logistics activities - acquisition, grading, as well as disposition and reprocessing - use resources and are subject to capacity restrictions.

These activities have to be balanced and allocated carefully to the available reprocessing capacity. For example, there is a trade-off between grading and reprocessing which has to be considered. Exorbitant classification of used products is not effective, as these graded goods could not be reprocessed due to limited capacity. Therefore, the excessive grading results in wasted resources, which could be used for acquisition or reprocessing instead of (futile) grading. Contrary to that, it may be useful to overproduce and store reusable products or spare parts in a period to avoid

capacity bottlenecks in subsequent periods.

The decision-making at R.U.S.Z is not based upon decision support systems or optimization approaches but on experience. The actual decisions depend on the present situation concerning workload and capacities. Regarding the acquisition process, R.U.S.Z acquires all available white goods, without any limit. After the acquisition, the used products are promptly classified in a grading process. The grading of products by using defined criteria (condition, brand, age) results in items being either used for reprocessing/spare parts recovery or - after classification as non-reuseable - directly recycled. Used products classified as reprocessable are reprocessed, while the remaining reusable goods are used for spare parts recovery.

Thereafter, the decision on further treatment of classified products selected for reprocessing is mainly based on the current workload: if capacity in terms of staff is available, the items are immediately treated in their determined way. Otherwise, the products are stored. Additionally, R.U.S.Z has experience concerning the items which are in demand; naturally, this also influences the reprocessing decision.

In the course of reprocessing activities, efforts are made to reprocess the item in the designated way. However, due to grading errors the used item may not be brought to the intended quality level (see Sections 3.5 and 3.6 for details regarding the grading and disposition).

The quality of the reprocessed product is quantified by visual and safety inspections and functional tests. At the final stage of reprocessing, remanufactured products classified as class 1 can be assumed to be in quasi-mint condition, while class 2/3-items can be considered as refurbished, as they meet the specified minimum criteria. The decreasing quality levels of the different product classifications correlate with declining sales prices.

Concerning spare parts, there is no superior strategy which spare parts to collect. The recovery process is executed by acting as one thinks best, so workers dismantle parts considered as being suitable. Due to the absence of a warehouse management system, neither the quantity nor the quality of available spare parts can be determined exactly. Nevertheless, acquisition of used products, grading, disposition, and spare parts management are interrelated, what is illustrated by the following two examples: for instance, without sufficient supply with used products both reprocessing and spare parts recovery are disrupted. Furthermore, an inefficient grading process may lead to a huge bulk of reprocessable items, but simultaneously also to a lack of spare parts needed for reprocessing those products. Actually, these characteristics lead to stockout events at R.U.S.Z. From time to time, the company faces situations when certain spare parts are out of stock, what entails the interruption of reprocessing activities and a search for appropriate spare parts.

Available used products differ in brands, age, and condition. Clearly, these differences affect the further reprocessing possibilities of the items. Nevertheless, spare parts often can be used for multiple brands.

The reprocessing activities have to be considered over time, as the supply with used products and the demand for reprocessed goods vary throughout the year, but inventory and reprocessing capacities remain more or less static. For example, manual work power is restricted: therefore, the products processed using these capacities have to be balanced over time. Consequently, tasks like spare parts extraction or reprocessing may be done in previous periods without effective demand to ensure the supply with reusable products and spare parts in future periods.

Finally, the reprocessed products are sold as second-life products in the on-site showroom. For

all of the resold items, a warranty of one year is provided.

### 3.4 Supply with Used Products

R.U.S.Z receives used products from different sources of supply for reprocessing activities. In Table 1, the supply sources for reprocessed products in 2011, 2012, 2013 and total supply (2011 & 2012 & 2013) are listed: next to customers who delivered their used products, the collection service at the customer's home was the main source of supply. Acquisition quantities coming from both of those sources of supply can be actively influenced by taking costly measures, for example by a fee for the pick-up service or by effort for advertisement and information. This also explains the fact that the amount of acquired used products declined in 2013 by about 40% compared with 2012. The enormous decrease was caused by the reduction of effort spent for public relation to acquire used products due to the prioritization and growth of the business segment 'repair services' in 2013.

There are two additional sources of supply for reprocessing items. On the one hand, R.U.S.Z has pre-sorted white goods on stock, as the acquisition and reprocessing of white goods started before 2011. All used goods which are classified as reprocessable but not reprocessed immediately after their arrival at R.U.S.Z are stored. Therefore, these products are an additional supply source for reprocessing. On the other hand, as R.U.S.Z offers a repairing service, people sometimes cancel the planned repair and donate the white goods instead of spending money for a costly repair. Interestingly, the amount of reprocessed items coming from inventory declined significantly in 2012 and 2013 compared with 2011. Despite this fact, the absolute number of products from the remaining three sources remained at a comparable level or increased in 2012. In 2013, the percentage values of the three sources of supply were similarly distributed. The reason for the decrease of reprocessed stocked items is the rising business concerning the repairing services. The used products coming from stock are solely reprocessed in situations when there is not enough work (in terms of repair services or reprocessing of recently acquired used products) to keep the staff busy. Thus, these stocked items are used for balancing the workload.

Table 1: Sources of supply in 2011, 2012, 2013.

| | 2011 | 2012 | 2013 | Total |
|---|---|---|---|---|
| Delivery by customer | 631 (46.5%) | 639 (49.3%) | 416 (53.3%) | 1,686 (49.1%) |
| Collection at customer | 374 (27.6%) | 405 (31.2%) | 191 (24.4%) | 970 (28.2%) |
| Products on stock | 107 (7.9%) | 26 (2.0%) | 0 (0.00%) | 133 (3.9%) |
| Cancellation of repairs | 245 (18.0%) | 227 (17.5%) | 174 (22.3%) | 646 (18.8%) |
| Sum | 1,357 | 1,297 | 781 | 3,435 |

Since 2012, R.U.S.Z has demanded a fee of €9 for the pick-up service, compared with €24 in the year 2011. This price reductions was possible as the municipality of Vienna sponsors the pick-up service. The amount of collections at customers' homes increased in the year 2012 compared with 2011 by about 8%, but dropped by about 53% in 2013 due to the decreased effort. Naturally,

in these circumstances it is impossible to analyze these results in detail; however, according to R.U.S.Z, the reduction of the collection fee has a positive effect on the amount of items received. This assumption of a positive effect is supported by some indirect indicators: for instance, the number of complaints regarding the collection fee decreased significantly. An additional example is that refusals of donations due to the fee were reduced to almost zero. Nevertheless, the main intention of demanding a collection fee is to act as an inhibition, as it should prevent the misusage of R.U.S.Z' services as free waste collection.

However, the question remains if a decreased pick-up fee results in an increased total number of available used items: collections at the customers may simply substitute deliveries by customers due to lower cost. Consequently, instead of increasing the total number of acquired goods, only the fraction of used products delivered by customers would decline.

The acquired/returned quantity fluctuated throughout the year, although the pick-up fee and similar efforts to control the return flow remained the same in the course of the year (see Table 2 for data on a monthly base). The hypothesis that the monthly aggregated quantities may be uniformly distributed is not supported (tested with $\chi^2$-test), neither for 2011 or 2012 nor for 2013. Therefore, non-uniformly distributed, stochastic supply patterns can be assumed.

Interesting results can be observed regarding the correlation coefficients of the monthly acquired used goods in the individual years: while 2011 and 2012 correlate positively with respect to the monthly values (correlation coefficient of 0.44373), the remaining comparisons show negative correlation coefficients (2011 vs. 2013: -0.28523, 2012 vs. 2013: -0.61885). This can be interpreted as similarities of supply patterns or seasonal effects in 2011 and 2012, but an inverse supply pattern in 2013.

Table 2: Absolute receivings per supply source and month.

| | Delivery by customer | | | Collection at customer | | | Products on stock | | | Cancellation of repairs | | | Sum | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 |
| Jan | 45 | 51 | 42 | 33 | 4 | 40 | 6 | 0 | 0 | 32 | 9 | 11 | 116 | 64 | 93 |
| Feb | 24 | 82 | 48 | 81 | 1 | 22 | 1 | 0 | 0 | 22 | 17 | 18 | 128 | 100 | 88 |
| Mar | 19 | 67 | 12 | 58 | 9 | 14 | 3 | 0 | 0 | 22 | 11 | 9 | 102 | 87 | 35 |
| Apr | 41 | 43 | 39 | 32 | 42 | 44 | 26 | 0 | 0 | 13 | 19 | 10 | 112 | 104 | 93 |
| May | 31 | 51 | 31 | 45 | 83 | 19 | 19 | 0 | 0 | 15 | 18 | 4 | 110 | 152 | 54 |
| Jun | 43 | 58 | 7 | 33 | 52 | 0 | 12 | 26 | 0 | 18 | 22 | 4 | 106 | 158 | 11 |
| Jul | 23 | 36 | 76 | 40 | 55 | 1 | 2 | 0 | 0 | 15 | 28 | 1 | 80 | 119 | 78 |
| Aug | 48 | 36 | 55 | 20 | 24 | 6 | 0 | 0 | 0 | 19 | 18 | 15 | 87 | 78 | 76 |
| Sep | 76 | 71 | 26 | 18 | 35 | 22 | 28 | 0 | 0 | 16 | 32 | 23 | 138 | 138 | 71 |
| Oct | 112 | 66 | 20 | 10 | 45 | 15 | 0 | 0 | 0 | 36 | 24 | 12 | 158 | 135 | 47 |
| Nov | 125 | 54 | 23 | 4 | 39 | 2 | 0 | 0 | 0 | 21 | 19 | 17 | 150 | 112 | 42 |
| Dec | 44 | 24 | 37 | 0 | 16 | 6 | 10 | 0 | 0 | 16 | 10 | 50 | 70 | 50 | 93 |
| Sum | 631 | 639 | 416 | 374 | 405 | 191 | 107 | 26 | 0 | 245 | 227 | 174 | 1,357 | 1,297 | 781 |

A graphical representation of the supply variability throughout the year regarding acquired quantities in 2011, 2012, 2013, and in total can be found in Figure 2. In 2011, the relative amount/month ranges from 5.16% to 11.64%. Similarly, the relative acquired quantity/month ranges from 3.86% to 12.18% in 2012 and from 1.41% to 11.91% in 2013, respectively.

As indicated by the correlation coefficient, the years 2011 and 2012 - and following from those years, the combined view on data considering all years - indicate seasonal effects. Besides the obvious effect of holidays in July and August, which results in a low of acquired products, peaks can be found in February, May/June, and September - November. In December/January as well as in March the acquisition quantities are significantly lower. Nevertheless, some stochastics is still included in these fluctuations. The distribution of supply in 2013 differs from those in the preceding years: while still a peak can be found at the beginning of the year, the remaining months show a reverted development. For instance, contrary to 2011 and 2012 the amount of acquired used products reaches the maximum at the end of the year.

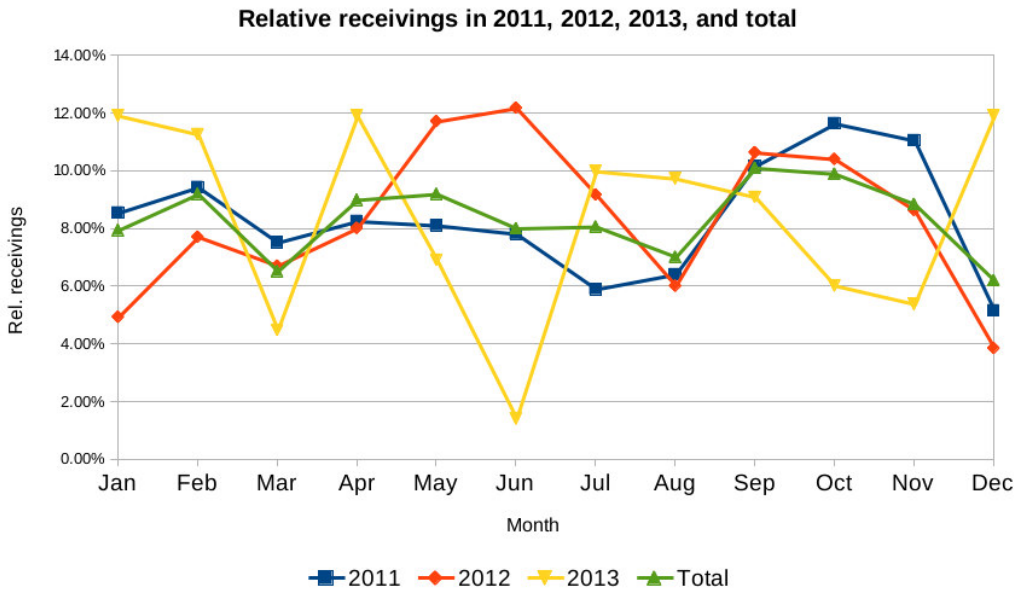



Figure 2: Relative receivings in 2011, 2012, 2013, and total.

Based upon an estimation before the project started, R.U.S.Z expected a higher acquisition amount than the actual one. Next to the fee for the collection service, there are several reasons for the low acquisition quantity.

First of all, in 2010 customers got a government-funded bonus if they traded in their used product for a new, energy-efficient one. In order to get the money, the used products had to be returned to a retailer or a designated collection center. As R.U.S.Z was not considered as an appropriate collection center, all reprocessable and reusable used products exchanged in the course of this measure could not be acquired. Additionally, the bonus stimulated the replacement of used goods. This led to early purchases and a reduced amount of used items available in subsequent years. Another reason is that potential donators often prefer the concurrent collection and removal free of charge offered by chain of stores in case new consumer electronics/white goods are bought and delivered. Finally, chain of stores deny a cooperation with R.U.S.Z in terms of allocation of used products due to potential cannibalization of their share in the market caused by reprocessed items. According to Austria's market leader in the area of electrical and electronic products, all of the used products acquired by chain of stores are disposed of professionally [42]. Consequently, this also reduces R.U.S.Z' supply with used and potentially reprocessable goods.

The potential number of white goods for acquisition in Vienna can be estimated based upon

the annual sales volume. In Austria, around 1,350,000 new white goods are sold per year [15]. This includes about 250,000 used washing machines which are exchanged with new ones [41]. Although R.U.S.Z is located in Vienna and focusing their business on this region, a considerable amount of used white goods would be available, supplied by different sources. The amount of these yearly exchanged used white goods can be estimated roughly by comparing the number of households in Vienna (without surrounding area: 0.863 m) with the number of households in Austria (3.678 m) [46]: consequentially, around 317,000 white goods (including about 58,700 washing machines) can potentially be acquired per year. Furthermore, assuming that each household owns a washing machine, the average usage phase until a washing machine is replaced is about seven years (number of households/exchanged used washing machines)

## 3.5 Grading Process/Quality of Used Products

Acquired used white goods are graded in the course of two different activities. On the one hand, products picked up at the customer's home are preselected and roughly graded as reusable or non-reusable, depending on their condition; for instance, a rough visual inspection of the condition of the casing is performed, or indications of malfunction are documented. On the other hand, a manual grading, sorting, and classifying process is performed for all products right after arriving at R.U.S.Z. This classification is mainly based upon a visual inspection, which is conducted by skilled and experienced staff. In the course of this grading process, all reusable used products are classified in three categories (class 1/2/3), depending on brand, condition, and age. Branded goods in a good shape up to specified ages are graded as class 1 (high quality, so-called 'raisins', e.g.: Miele, max. 20 years, passed visual inspection) or class 2 (medium quality, also referred to as 'potential', e.g.: Eudora, any age, no oxidation, passed visual inspection), while the remaining reprocessable products belong to class 3 (low quality, named 'social', e.g.: various branded goods, easy to repair, passed visual inspection). Nevertheless, reusable products classified as class 1, 2, 3 can also be used for spare parts recovery. The non-reusable items are classified as products for spare parts recovery or recycling/disposal. Afterwards, the classified used products are either placed into stock, reprocessed, cannibalized, or collected for material recycling. However, since October 2012 R.U.S.Z has stopped preparing class 3-items for reuse almost totally, as refurbishing these products is not cost-covering due to the low sales prices. Additionally, the limits for reprocessing class 2-items have been tightened.

One main issue is the error-proneness of the grading process: due to the fact that a detailed check including testing all parts is not conducted at the grading stage, the classification does not always match the possible reprocessing options. Thus, as the grading process and the reprocessing step are separated, differences between the planned and the actual disposition decision occur (refer to Section 3.6.2 for a detailed analysis concerning grading errors).

Figure 3 presents the proportion of the respective classification results. In both 2011 and 2012, the main part of the acquired items was classified as reusable, whereby class 3-products were observed most. About 25% of the goods were collected and directly recycled. In 2013, most of the parts were recycled due to the strategy change with related focus on high-quality items, while the relative amount of class 1-items remained at about the same level. In 2012 and 2013, the amount of items chosen for spare parts recovery increased significantly compared with 2011. This can be explained by the modified business strategy: as mentioned above, reprocessing class 2-products and class 3-items is not cost-covering in the majority of cases. Instead of reprocessing these goods

R.U.S.Z focuses on the strictly selected class 1 and uses class 2/3-items mainly for spare parts collection. Thus, the amount of products for spare parts recovery raised and the quantity classified as class 3 decreased compared with before.

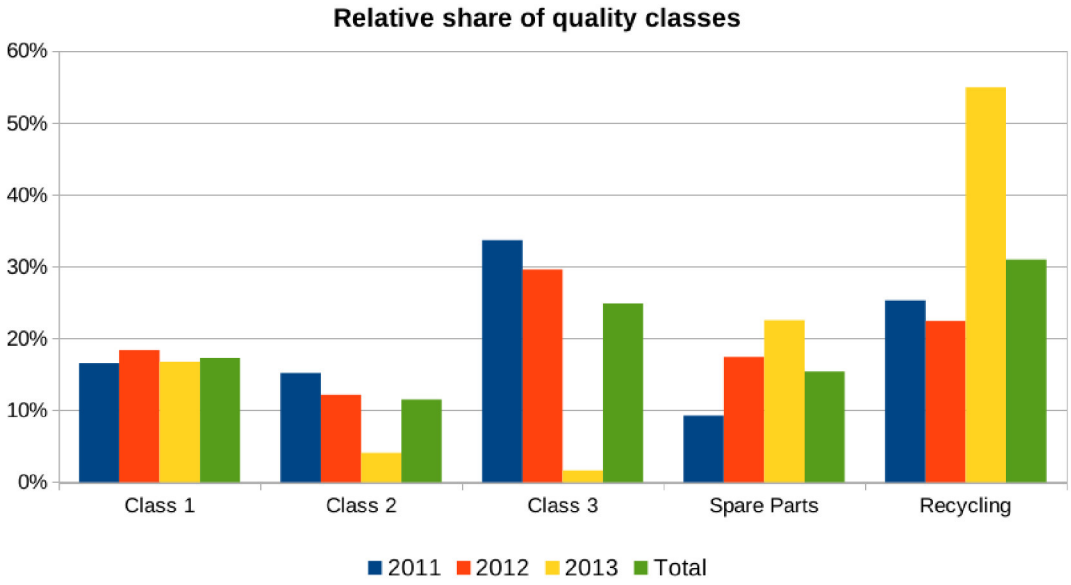



Figure 3: Relative quality distribution in 2011, 2012, 2013, and total.

In Table 3, the distribution of the product qualities throughout the years 2011, 2012, and 2013 is shown. The amount of acquired products of a quality category greatly differs from month to month: for example, in 2011, the quantity of acquired and classified class 1-products ranges from 3 to 34, resulting in a sum of 225 items. An interesting increase of recycled items can be observed in Aug. - Dec. 2011: due to excessive stocking up with reprocessable items, the storage capacity exhausted. Thus, R.U.S.Z sorted out stocked used products in a comparably poor quality to create space for new acquired products in a better condition. Interestingly, although the total number of items, the units recycled and the class 2-/class 3-products decreased in 2012 compared with 2011, the amount of class 1-products increased. This may be explained by the increased consumer awareness to return only high-quality items, as this is promoted by R.U.S.Z. As mentioned above, the total supply with used white goods declined in 2013. Contrary to that, the quantity of recycled items is - in absolute values - the largest in that year. Simultaneously, the number of items classified as class 2 or class 3 dropped. Both effects are results of the strict selection strategy concerning the two quality classes. Naturally, also the amount of needed spare parts reduces with a decreasing number of reprocessed items.

## 3.6 Disposition Process and Reprocessing Activities

In this section, the reprocessing activities are described in detail. Acquired used products can be remanufactured and - optionally - upgraded, refurbished, cannibalized to extract spare parts, or recycled. According to R.U.S.Z, the main cost driver for all types of reprocessing and spare parts recovery is the manual workload, as automation fails due to the variety of error types and the resulting complexity. The second-ranked cost driver is the material cost in terms of recovered - or

Table 3: Quality grading of receivings in 2011, 2012, and 2013.

| | Class 1 | | | Class 2 | | | Class 3 | | | Spare Parts | | | Recycling | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 |
| Jan | 20 | 10 | 23 | 25 | 17 | 5 | 43 | 27 | 1 | 11 | 3 | 45 | 17 | 7 | 19 |
| Feb | 23 | 17 | 26 | 25 | 16 | 4 | 45 | 41 | 3 | 25 | 22 | 34 | 10 | 4 | 21 |
| Mar | 19 | 17 | 6 | 22 | 8 | 0 | 40 | 34 | 0 | 12 | 12 | 1 | 9 | 16 | 28 |
| Apr | 21 | 17 | 16 | 19 | 14 | 3 | 39 | 48 | 0 | 13 | 14 | 20 | 20 | 11 | 54 |
| May | 33 | 27 | 10 | 21 | 25 | 1 | 37 | 50 | 1 | 11 | 16 | 22 | 8 | 34 | 20 |
| Jun | 17 | 19 | 3 | 21 | 10 | 0 | 37 | 54 | 2 | 26 | 40 | 3 | 5 | 35 | 3 |
| Jul | 5 | 24 | 26 | 19 | 17 | 6 | 47 | 37 | 2 | 6 | 20 | 0 | 3 | 21 | 44 |
| Aug | 9 | 17 | 7 | 3 | 10 | 3 | 17 | 23 | 0 | 1 | 7 | 31 | 57 | 21 | 35 |
| Sep | 8 | 21 | 8 | 7 | 21 | 4 | 29 | 42 | 3 | 0 | 17 | 5 | 94 | 37 | 51 |
| Oct | 33 | 33 | 6 | 22 | 9 | 2 | 37 | 10 | 1 | 9 | 18 | 7 | 57 | 65 | 31 |
| Nov | 34 | 25 | 0 | 14 | 8 | 0 | 61 | 12 | 0 | 4 | 35 | 4 | 37 | 32 | 38 |
| Dec | 3 | 11 | 0 | 8 | 3 | 4 | 25 | 6 | 0 | 8 | 22 | 4 | 26 | 8 | 85 |
| Sum | 225 | 238 | 131 | 206 | 158 | 32 | 457 | 384 | 13 | 126 | 226 | 176 | 343 | 291 | 429 |

even new - spare parts. Another aspect concerning costs is that a high-quality product causes less reprocessing cost than a used item in a bad condition; thus, reprocessing cost correlates negatively with the quality of a product. R.U.S.Z traces this back to several reasons: products classified as reusable are typically manufactured by brands which design durable and robust products. Usually the design of those products allows a faster replacement of broken parts compared with non-branded goods due to an eased accessibility. Consequently, reprocessing causes less labor cost. Furthermore, the brands are often market-dominating and have big shares in the market. Thus, a large proportion of the acquired products are branded goods, and consequently, appropriate spare parts can be recovered cost-efficiently.

### 3.6.1 Reprocessing Procedures

A product as good as new can be obtained by applying a remanufacturing process to a used product. In the case of R.U.S.Z, the average additional usage phase of a reprocessed and, in particular, remanufactured item is about 10 years. As the remanufacturing process is expensive and time-consuming due to the complexity of the process and the resulting large proportion of required manual work, only the used products classified as class 1 - which indicates an excellent condition of the returned item and consequently low remanufacturing cost - are chosen for this process. While the average time needed to remanufacture an item is one hour, the effort varies between 30 minutes to 3 hours, depending on the condition of the product.

Refurbishing a product means to improve the quality condition of a used item so that specified minimum quality requirements are fulfilled. Different from the items undergoing a remanufacturing process, a refurbished product is observably a used product. However, in case of R.U.S.Z, refurbishing a used item needs similar resources as remanufacturing with required manual work time of 30 minutes to 3 hours and an average reprocessing time of about one hour. Potentially, most of the refurbished goods could be remanufactured by spending a much higher effort, which would result in an excessive cost-intensive reprocessing. Although the refurbished products can be sold only at a lower price than remanufactured ones, the refurbishment is profitable and does pay

off.

The upgrading/tuning process can be applied to reprocessed class 1/2 - products within one hour of working time and results in an upgraded product with an increased performance compared with the original. Thus, upgrading is an innovative process, which improves the product compared with the original product and provides some additional benefit, e.g., in terms of saving energy (see Section 3.8 for details concerning R.U.S.Z' energy efficiency activities). Spare parts can be extracted from all white goods, independent from their classification. However, the best sources for spare parts are acquired items in a bad but still usable condition. Products with better qualities are preferably prepared for reuse due to their superior profitability. According to R.U.S.Z, several spare parts can be recovered from one item, e.g., in the case of washing machines, program selector switches, pumps, motors and so forth. Interestingly, the parts oftentimes are standardized, thus they can be used for several product types of a brand or even for reprocessing products of different brands. The cannibalization of designated used products needs an amount of work of about 20 minutes.

Figure 4: White goods and spare parts inventory (Source: R.U.S.Z).

Besides the reprocessing of entire products, a special case is the recovery of washing machine motors: because of the large quantities of precious copper used for the production of these motors, investing 15 minutes of worktime in disassembling the motor pays of in any case, as the value of these recovered resources exceeds the spent effort. Thus, even broken washing machine motors are dismantled.

Figure 5: Repair shop and recycling container (Source: R.U.S.Z).

Next to the usage for reprocessing, spare parts are sold to do-it-yourselfers in rare cases. A

further aspect concerns the repair service offered by R.U.S.Z: as customers prefer new spare parts, spare parts gathered from used items are hardly used for customer repairs. All remaining white goods are recycled in cooperation with a waste collection service provider.

### 3.6.2 Error-proneness of the Grading Process

Although the used products are classified in a grading process, it often turns out that the actual quality of a product was determined imprecisely. This is caused by the type of sorting process: as R.U.S.Z performs a visual inspection, the quality of the acquired used product can only be estimated. The actual quality is observed in the course of reprocessing, when the product is (partially) disassembled. Thus, the disposition decisions on reprocessing the items are made based on an erroneous grading process. This interesting observation is explored in Table 4, which presents a comparison of the grading decisions and the actual disposition decisions. Due to restricted capacity and resultant lags of time before processing, not for all of the received used products reprocessing is finalized. These items - for instance, items received shortly before end of year 2013 - are stocked and marked as 'No Final Decision'.

About 48% of used products classified as class 1 were sold, 18.5% were used for spare parts recovery, and around 6% were collected for recycling. Concerning the remaining items, no final disposition decision has been made. The proportion of products used for spare parts recovery or being recycled increases in the case of class 2/3-products, in particular since October 2012 when the classification strategy has changed. Although those used products were intended to be sold, large amounts of products were treated differently than the previous grading result suggested. Vice versa, caused by data inconsistencies, used items classified for spare parts recovery or - in exceptional cases - recycling were sold, and some products intended to be recycled functioned as spare part suppliers. Summing up, the actual quality of an item is not determined at the grading process but at its reprocessing. The grading process delivers an estimation of the product condition. However, the question why to conduct the grading process in consideration of the error-proneness of the grading process remains. Although this question can not be answered exhaustively in the course of this case study, an indication for a potential answer can be identified in the next Section 3.6.3.

Table 4: Grading decision vs. actual disposition decision (2011, 2012, 2013).

| **Classification Decision** | | **Actual Disposition Decision** | | | | |
|---|---|---|---|---|---|---|
| Selection for Reuse | Classification | Sales | Spare Parts | Recycling | No Final Decision | Total |
| YES | Class 1 | 287 | 110 | 35 | 162 | 594 |
| | Class 2 | 131 | 108 | 63 | 94 | 396 |
| | Class 3 | 267 | 247 | 209 | 131 | 854 |
| NO | Spare Parts | 2 | 432 | 94 | 0 | 528 |
| | Recycling | 2 | 18 | 1,043 | 0 | 1,063 |
| Total | | 689 | 915 | 1,444 | 387 | 3,435 |

### 3.6.3 Lead time analysis of reprocessing

R.U.S.Z is limited in terms of acquisition, testing/sorting, and reprocessing capacities, what may

lead to consequences like the aforementioned process time lags or excessive inventories of used products/spare parts. The implications of limited capacity in the reverse logistics processes are explored with a lead time analysis. In this case study, the lead time is defined as the time between the arrival of a used product at R.U.S.Z' site until the completion of activities (reprocessing, spare parts recovery, collection for recycling), whereby a lead time of 0 means a completion at the same day.

In the years 2011, 2012, and 2013, 3,435 items were recorded in the business database. Out of this dataset, 48 records could not be used due to data inconsistency, and 387 items were not completed (no final decision). The items were split according to their actual use. Therefore, the analysis consists of lead times related to reprocessed items, used products for spare parts recovery, and items collected for recycling.

Table 5 shows some statistics concerning the data records used for the analysis of lead times at R.U.S.Z. The 3,000 data records show that many used products were collected for recycling, while around 21.93 % were reprocessed. Both the median and the mean indicate that reprocessing was performed at the same time or faster than gathering spare parts. This can be explained by the superior prioritization of reprocessing with subsequent sales compared with spare parts recovery. Interestingly, the median of used products which were destined for recycling is zero, so a good portion of used white goods was sorted out immediately after the arrival at the R.U.S.Z-site. This fact implies a potential answer to the question regarding the value of an error-prone grading process (see Section 3.6.2). Used products which are apparently not reprocessable are eliminated before the actual reprocessing. Consequently, this saves costly space in the capacity-restricted goods inventory.

Exceptional, long-lasting cases may bias the analysis. Therefore, an analysis including all data records with lead times of less than 90 days (or around 3 months) is shown in the lower part of Table 5. It turns out that - in contrast to the result above - in this setting the median of lead time for reprocessing is significantly greater than the one for spare parts recovery, while the mean only slightly differs.

Table 5: Statistics concerning lead times.

| **Number of Data Records** | **Reprocessing** | **Spare Parts** | **Recycling** |
|---:|---:|---:|---:|
| Total | 658 | 907 | 1435 |
| $<$ 90 days | 585 | 763 | 1255 |
| **Lead Time** | **Total Dataset** | | |
| Minimum [days] | 0 | 0 | 0 |
| Median [days] | 8 | 8 | 0 |
| Mean [days] | 32.98 | 49.64 | 32.84 |
| Maximum [days] | 596 | 737 | 652 |
| **Lead Time** | **$<$ 90 days** | | |
| Minimum [days] | 0 | 0 | 0 |
| Median [days] | 7 | 5 | 0 |
| Mean [days] | 14.56 | 14.33 | 6.54 |
| Maximum [days] | 89 | 89 | 89 |

We provide more analyses regarding the distribution of the lead times in Figure 6. On the left,

the analyses contain lead time data over the whole period. According to the statistics in Table 5, a bigger part of used products is treated within a lead time less than 90 days. Thus, the figures on the right are limited to this period.

Independent from the actual reprocessing decision, a great portion of used products was reprocessed within 29 days. Concerning the data including lead times with less than 90 days, the analyses are related reprocessing, spare parts recovery, and recycling. While the decision for recycling was made instantaneously in the course of the grading process in nearly 80% of all cases, both reprocessing of items (12.82% reprocessed within one day) and spare parts recovery (27.52% finished within one day) were subject to varying lead times.

In the following Table 6, the lead time analysis depending on the completion year of reprocessing is presented. Particularly interesting is the impact of the decision concerning the strategy change in 2012/2013 to apply a stricter classification procedure. Nevertheless, the lead time may also be influenced by the lower total acquisition quantity. However, the impact of this reduction of acquired goods can not be explored in detail with the available data.

Overall, the lead times with respect to reprocessing, spare parts recovery, and recycling decreased significantly in 2013. This is true for the scenarios including all available data as well as for the data where the lead time is less than 90 days and concerns both mean and median values. The lead time without exceptional cases (lead time $< 90$ days), which is more appropriate for determining lead times of day-to-day business, shows that for spare parts recovery and recycling the mean is less than the half. Interestingly, the decreased lead time concerning recycling is contrary to the fact that the recycled quantity increased. Additionally, also the average reprocessing lead time is considerably reduced by about 32%, and the related median shows an improvement of even 50%.

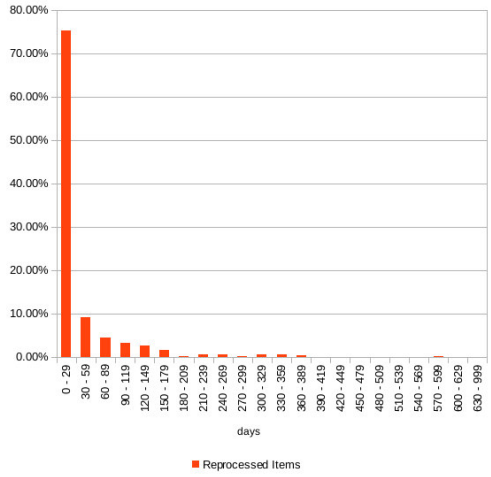
The key factors of the lead time reduction are the reduction of the total amount of acquired used goods and the focus on high-quality products. Naturally, the former directly reduces the total needed capacity for quality grading and reprocessing. Secondly, high-quality products in a good condition impact the needed reprocessing capacity: both the comparably good quality of the used products and easily accessible components (as described in Section 3.6) reduce the reprocessing effort and consequently, the lead time.

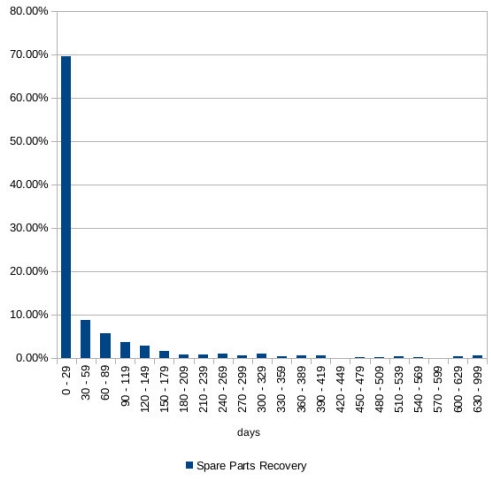
## 3.7 Markets & Demand

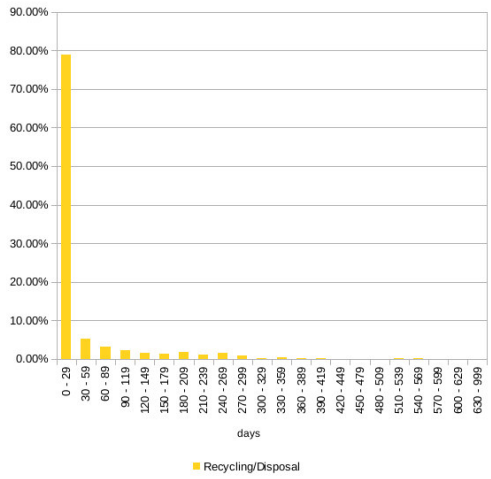
According to R.U.S.Z, all of the remanufactured/refurbished products can be sold easily, as on average demand is greater than the number of finished items. Finished reprocessed goods are not always sold instantaneously but with time delays between the end of reprocessing and the actual sale, so the time when a product is finished may not necessarily coincide with the demand for a product. Besides the unknown demand time, also the demand size can not be determined exactly. The potential demand is great but not unconstrained: in detail, the number of socially disadvantaged households in Vienna with the need to exchange washing machines is projected at around 12,000 per year (about 50,000 in total Austria). Any potential conventional customers are added to this number. As stated above, the supply with used products and the available production capacities of R.U.S.Z are limited. Consequently, the output of reprocessed white goods is restricted by the supply. Thus, the quantity demanded is far beyond R.U.S.Z capacities.

Since October 2012, the business strategy of R.U.S.Z has been adapted. Instead of focusing primarily on socially disadvantaged households, R.U.S.Z wants to change its image from a pure

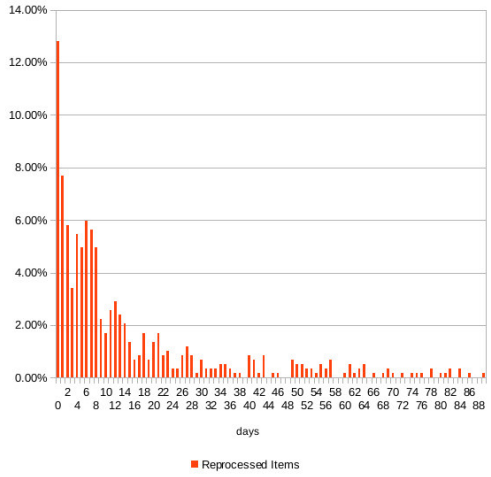
All data

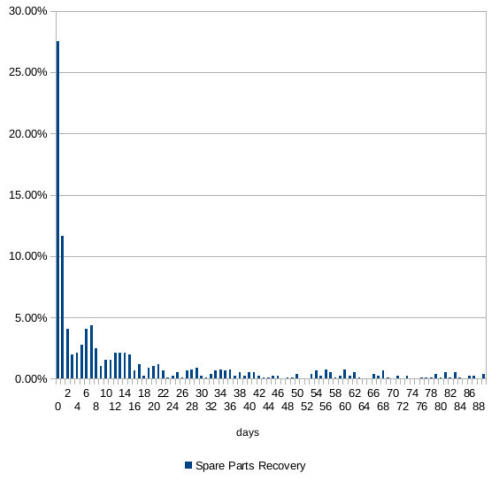



Lead times $< 90$ days



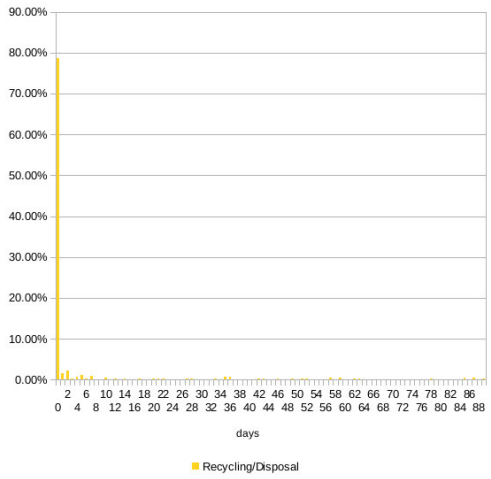




Figure 6: Lead times: reprocessing, spare parts, recycling [days].

Table 6: Statistics concerning lead times per year.

| | All Data | | | Lead time < 90 days | | |
|---|---|---|---|---|---|---|
| Reprocessing | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 |
| Quantity | 266 | 329 | 63 | 249 | 274 | 62 |
| Min [days] | 0 | 0 | 0 | 0 | 0 | 0 |
| Median [days] | 7.50 | 12 | 4 | 7 | 8 | 4 |
| Mean [days] | 22.24 | 45.63 | 12.29 | 13.92 | 15.99 | 10.81 |
| Max [days] | 241 | 596 | 104 | 82 | 89 | 69 |
| Spare Parts | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 |
| Quantity | 281 | 443 | 183 | 260 | 350 | 153 |
| Min [days] | 0 | 0 | 0 | 0 | 0 | 0 |
| Median [days] | 8 | 15 | 1 | 7 | 7 | 0 |
| Mean [days] | 24.62 | 64.13 | 52.99 | 14.61 | 18.40 | 4.51 |
| Max [days] | 313 | 663 | 737 | 87 | 89 | 84 |
| Recycling | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 |
| Quantity | 470 | 478 | 487 | 403 | 382 | 470 |
| Min [days] | 0 | 0 | 0 | 0 | 0 | 0 |
| Median [days] | 0 | 0 | 0 | 0 | 0 | 0 |
| Mean [days] | 33.69 | 53.19 | 12.05 | 7.70 | 9.19 | 3.40 |
| Max [days] | 338 | 652 | 490 | 85 | 87 | 89 |

socially-concerned company toward an image which attracts additional target groups, e.g., ecologically and/or socially concerned higher income earners or students living in apartment-sharing communities. One of the main drivers of the business diversification was the overbalanced consideration of products classified as class 3 for social purposes. This resulted in small margin of profit or was - in single cases - even loss-generating due to the low sales price combined with a rather high reprocessing effort.

Regarding the sales prices of the reprocessed goods, the rule of thumb is to charge 1/3 of the new product's price for a reprocessed item. In case of remanufactured products in an as-new shape and with a prestigious brand image, the sales price can be up to 1/2 of the price of a new product. In detail, the minimum sales price for a reprocessed washing machine must exceed €280, as otherwise reprocessing is not economically viable. The maximum price demanded for a remanufactured washing machine is about €500 for recent premium-quality branded goods. However, the final decision on the sales price is a matter of experience on the part of the R.U.S.Z sales team. According to R.U.S.Z, the popularity of reprocessed products does not solely depend on price: in the case that two technically similar products with differing ages and brands but identical expected durability are available, customers do not insist on the product with the favorable price. Customers also consider, e.g., brand awareness and age with respect to their buying decisions, so relatively new products of well-established brands are top sellers.

Following and extending legal requirements, R.U.S.Z offers a guarantee of one year for reprocessed and sold used products. The distinguishing feature of R.U.S.Z' guarantee compared to the implied warranty for sold second-life products is the voluntary waiver regarding the reversal of evidence while the duration of guarantee. In the case of a legitimate claim, R.U.S.Z primarily tries to repair the broken part. However, in case the repair is not possible (e.g., due to overwhelming

Figure 7: Sales area of R.U.S.Z (Source: R.U.S.Z).

cost), the broken reprocessed product is exchanged with a comparable product free of charge. Interestingly, the guarantee was an additional driver for the change of strategy in autumn 2012: the original production materials used for items graded as class 2 or class 3 are of poor quality. This resulted in increased exchanges of products and repairs. So even in case the sales of items may have been profitable, the free after sales service for those broken refurbished products caused losses due to excessive expenditures of work and on material.

## 3.8 Energy Efficiency and Environmental Impact of R.U.S.Z' activities

The energy-saving method 'Tuning of Washing Machines' developed by R.U.S.Z used for upgrading products increases the energy efficiency category of washing machines and improves the energy efficiency category from, e.g., C to A. This can be achieved by a reduction of water consumption resulting in energy demand of around 20%. In detail, in case of washing machines the energy-intensive water heating can be optimized by reducing the total water consumption. Consequently, the total energy consumption for heating the water is decreased, while the quality of the washing process remains at the same level. However, as the supply with washing machines with an energy efficiency category of C declines due to the fact that nearly all of these have been returned and replaced by better ones, upgrading washing machines will vanish in near future.

As a side effect of reprocessing used products, environment is impacted by the extension of the product usage phase of a reprocessed product by about ten years. Selling remanufactured/refurbished products induces a postponement of the resource consumption for producing new products. Additionally, the second life of reprocessed products including a related extended usage phase potentially reduces the overall consumption of resources. For an overview of the ongoing scientific discussion concerning the economical impact of refurbishment of white goods we refer to [8], [12], [13], [34], and [40]. Contrary to these resource savings from an extended life cycle, potential environmentally friendly innovations must be considered to get a holistic view on the environmental impact. These innovations may decrease the resource consumption of new products in the usage phase and reduce or even (over)compensate benefits from an extended usage phase.

# 4 Conclusions

In this section, we discuss the results of the presented case study. Furthermore, based upon the information provided above, we identify research fields that may be explored. We gain deep insights into R.U.S.Z, including detailed data of operational business. Overall, a comparison of the activities concerning reverse logistics at R.U.S.Z with the existing literature shows that they are similar - and partially equivalent - to approaches known from and used in research (see, e.g., [22], [14], [24]).

## 4.1 Operative Planning

In the case of R.U.S.Z, reusable and non-reusable used products are classified and sorted right after the acquisition, while the actual reprocessing activities are executed at future dates. This is caused by the following facts: first of all, acquisition, grading, and disposition/reprocessing are separated processes. Furthermore, the reprocessing activities per se are uncoupled from the acquisition. Additionally, they are subject to limitations of reprocessing capacity. For instance, one capacity bottleneck is the availability of trained staff, what results in a postponement of potential - economically reasonable - reprocessing related to the handing over of used products. Next to this reason, availability of used products as well as storage capacity limit the reverse logistics activities. Finally, the necessity to store graded used products and spare parts must be taken into account. Concerning the grading process, we observed discrepancies between the classification result of acquired used items and the actual reprocessing of these products; this is in line with both analytical and empirical scientific work (see, e.g., [45] or [47]). Two main reasons were identified why the continuation of an error-prone grading process may be beneficial: first, the identification of obvious defects, which definitely prevent a profitable reprocessing, allows to recycle these goods instead of wasting storage capacity by storing. The second argument concerns the trade-off between grading and reprocessing: although the reprocessability of a graded used item is not ensured, the pre-selection increases the chance of not throwing away reprocessing capacity by trying to reprocess a non-reprocessable good. One of the cases described by the authors in [14] concerns CompCo, a non-profit company dealing with reprocessing computers. Interestingly, similar results regarding the reverse logistics processes can be found, which indicate the accuracy of this work in terms of external validity. For instance, both companies prevent a misusage as disposal company by charging a fee. While this is the case at CompCo when the donated computer can not be reprocessed, R.U.S.Z charges for the collection of used products. Another example concerns decision-making, which is in both companies based upon a visual inspection of the product's condition, the brand of the used product, and age.

An interesting aspect of R.U.S.Z' operations management is the interaction between reprocessing, supply with spare parts, and warranty. As mentioned above, warranty involves the requirement to provide after sales service in terms of the correct operation of the sold product. According to R.U.S.Z, guaranteeing a minimum additional utilization phase is necessary for customer confidence concerning reprocessed goods.

All of these activities are interrelated: the supply with spare parts is inevitable for maintenance of reprocessing operation. Nevertheless, an increased reprocessing rate cuts the availability of spare parts and vice versa. This is caused by both the limited capacity, which is used either for reprocessing or spare parts recovery, and the restricted number of available used products, which

can be assigned to the options. Additionally, there are two opposing effects influencing future financial planning: on the one hand, short-term profit can be increased by rising reprocessing rates, involving greater risk to run out of spare parts in the future. On the other hand, reduced reprocessing results in lower short-term profit, but makes possible sustainable business by increased spare parts availability. Obviously, this trade-off has great impact on the financial continuation of the company.

Some further goal conflicts appear concerning the relationship between reprocessing, spare parts recovery, and warranty: both reprocessing and after sales service - related to repairing of warranty claims - need spare parts. Consequently, spare parts recovery has to be balanced with respect to those both demands. Additionally, in some cases a sold product has to be replaced by another reprocessed item due to a warranty claim beyond repair. Finally, a relation between the classification of the acquired product and the chance of a warranty claim exists: for sold low quality reprocessed items (e.g., class 2 or class 3), the probability that an item requires repairing or replacement is increased. As explained above, this can be traced back to the worse material quality used for low-cost items by the OEM compared with products classified as class 1.

All in all, the case study gives rise to some questions concerning the operative planning at R.U.S.Z which can be modeled and explored:

- Assuming that a relation between acquisition effort and acquired quantity or quality of the products exists: Which acquisition effort should be taken? How can the stochastic returns be handled? Does an increased acquisition effort result in a raised return rate, or are there only substitutional effects between the offered collection service and used products returned by customers?
- Reprocessing of used products deviates from classification/grading, so grading errors may exist. How much effort should be spent for grading? How should the trade-off between increased effort for grading/less grading errors (and vice versa) be resolved?
- Which disposition options should be considered, especially in due consideration of different sales prices, reprocessing efforts, and capacity limitations?
- What is the optimal strategy for disposition of used products under given (uncertain) quality?
- How can the interrelations between reprocessing, spare parts recovery, and warranty be modeled, particularly over time? How can the optimal strategy including these three components be determined?
- How does the option of possible downward substitution affect the reverse processes (e.g., class 1-product used for spare parts recovery although demand may appear)?

## 4.2 Business Objectives: The Effect of Being an Ecological, Economical, or Social Company

Another aspect concerning R.U.S.Z is the specific case of non-profit business. To the best of our knowledge, only a few articles of scientific work in the field of RL/CLSC consider NPOs. General aspects concerning, e.g., the development and design of a closed-loop supply chain or how to establish a framework to acquire used products are discussed by the authors in [28]. They study a

collaboration between Nike and Throwplace.com; by means of this example, the authors show that a cooperation between an original equipment manufacturer and an NPO can be advantageous for both companies. As stated above, due to the fact that R.U.S.Z is a non-profit organization, the objectives partially differ from many profit-maximizing companies in the remanufacturing sector. However, to give consideration to the goals of R.U.S.Z, either a multi-objective-approach or an approach with maximizing ecological benefit under profitability/social constraints can be used.

The guiding research questions presented in Section 2 emphasize that the focus is on exploring R.U.S.Z under consideration of the fact that it acts as sustainable - and not solely profit-driven - company. Some aspects which differ from a profit-maximizing company were identified.

First of all, the focus of R.U.S.Z on environmental, economical, and social objectives results in suboptimal economic profitability. The reduced economic efficiency is caused by accepting additional risks (e.g., risk concerning potential reintegration by employing long-term unemployed people) or by preferring ecological/social rather than economical objectives (e.g., enabling of customer repairs by sales of spare parts despite cost for spare parts recovery exceeds the sales price).

The impact of the fact that products are sold with discount to socially disadvantaged people is twofold: obviously, the social benefit is that these people are provided with high-quality white goods instead of new low-quality products with short life cycles. Additionally, the high-quality products are more eco-friendly and efficient than the throwaway products, what results in an ecological benefit. However, this social responsibility involves not to insist on highest profitability of the sold products due to lower sales prices than possible.

Furthermore, the acquisition of used products depends on goodwill of potential donators, particularly in view of the additional effort/cost related to the pick-up service of R.U.S.Z or deliveries by customers.

An additional aspect concerns the staff: as mentioned above, R.U.S.Z employs long-term unemployed people what allows them to reintegrate in working life. The challenges of the employer-employee relationship in the case of R.U.S.Z exceed those of conventional employment, as the reintegration process often concerns both working life and social life. Therefore, support and assistance do not only concern working environment but also private life.

Two additional aspects concerning the ecological, economical, and social goals were identified:

- Under which conditions does the reprocessing strategy with ecological-economical-social goals differ from a profit-maximizing objective?
- How can the environmental impact of the different strategies be determined (new sales vs. sales of reprocessed products)?

## 4.3 The Relation between Reprocessing and Pricing in the Market

R.U.S.Z currently determines the sales prices of reprocessed products based upon a rule of thumb (1/3 to max. 1/2 of price of a new product). Assuming different qualities of the used products, one can ask how the optimal pricing strategy should look like, and furthermore, how the reprocessing activities interact with the market.

- How does the potential market structure influence the reprocessing decisions?
- How should R.U.S.Z price the reprocessed products?

## 4.4 Competition vs. Cooperation: Why do Big Retailers not Support the Principle of Providing Returned Used Products for Reprocessing/Reuse?

The case study also indicates that there is a lack of collaboration between manufacturers, retailers, and the reuse sector, although legislation aims at the preparation of returned items for reuse. Big retailers take back customers' used white goods when selling a new one. These retailers are not willing to cooperate with R.U.S.Z by providing the collected items, as they fear that the reprocessed white goods could cannibalize their own sales. According to R.U.S.Z, the superior market position and the resulting power in collecting used items is one of the main reasons for R.U.S.Z' low supply with used products.

Some examples dealing with competition in a manufacturing/remanufacturing context exist in scientific literature. An interesting approach is presented in [16]. Potential competition caused by a third-party remanufacturer threatens a manufacturer's profit. The authors analyze the conditions under which remanufacturing is profitable, and based upon the results entry-deterrent strategies are developed. Although the work aims at ensuring the manufacturer's monopolistic selling position, the presented framework is appropriate to cope with analytical modeling of holistic research questions involving all components of the triple bottom line. Overall, motivated by information of the R.U.S.Z-case, some questions are formulated:

- How does potential cooperation/competition influence the strategies of manufacturers/remanufacturers, big retailers, commercial collectors, and third-party reprocessing companies?
- Which consequences can be observed regarding ecological/social objectives, from a societal view or the view of ecologically or socially concerned reprocessors?
- How can policy-makers support desired development in the context of ecological/economical/social objectives? For example, in the case of either ambitious reuse rates or an integrative network of commercial collectors, waste collection service, recyclers, reprocessing companies: how do certain policies affect the stakeholders, and which consequences arise from that?

## Competing interests

The authors declare that they have no competing interests.

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