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ORIGINAL ARTICLE

A reverse logistics diagnostic tool: the case of the consumer electronics industry

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Abstract The consumer electronics (CE) industry has high turnovers and a growing demand, such as on the home entertainment segment. At the same time, it generates e-waste of the order of a dozen million tons, about one quarter of the world's total. With the purpose of improving the environmental performance of businesses, the Waste Electrical and Electronic Equipment (WEEE) Directive was put in place in Europe. Given the high competitive environment of this industry, WEEE could be a clue for competitive edge. To create an environmental and economic win-win situation, however, companies have to master reverse logistics (RL). This is particularly challenging in fast clockspeed environments, as it is the case for the CE industry. In this paper, we develop a theoretically and empirically grounded diagnostic tool for assessing a CE company's RL practices and identifying potential for RL improvement, from a business perspective. To theoretically ground the tool, we combine specific CE literature with general theory on reverse logistics management and performance improvement. To empirically ground the tool, we collect field data by combining quantitative (a multiactor survey) with qualitative (interviews and company visits) methods. We demonstrate how our tool can be used to create awareness at senior management about the reverse logistics maturity state.

Keywords Consumer electronics · Reverse logistics management · Diagnostic tool · Maturity states

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1 Introduction

The consumer electronics (CE) industry has high turnovers and a rapidly growing demand. Electronic devices and gadgets are becoming “must-haves” for an ever growing number of consumers. CE is a fast clockspeed sector, i.e. new products are being introduced at a high rate [1], especially in the entertainment segment. Accompanying the frequent introduction of new products is the rise of e-waste. With the purpose of improving “environmental performance of businesses”, the European Commission issued the Waste Electrical and Electronic Equipment (WEEE) Directive.

To dump perfectly good products means throwing away value, which now WEEE gives the chance to manufacturers and importers to recover. This could be the clue to competitive edge in this highly competitive industry, with short lifecycles, steep price declines, and boiling pressure on profit margins. Original equipment manufacturers (OEMs) can strengthen their competitiveness by translating corporate strategy into a unique set of value drivers. To create an environmental and economic win-win situation, however, companies have to master reverse logistics (RL). In pursuing this challenge, companies have little practical

guidance at their disposal. To the best of our knowledge, there does not exist a helpful tool to assess an organisation's RL practices and to identify potential for improving RL performance from a business perspective.

To mend this shortcoming, we present in this paper a theoretically and empirically grounded diagnostic tool, to assess in which maturity state CE companies find themselves. Here, maturity with respect to a certain reverse logistics aspect denotes the extent to which the company is able to fulfil the specific requirements associated with it. Companies should strive for high maturity states, as there is evidence that high maturity is an enabler of high performance: for instance, Heinrich and Simchi-Levi [2] analysed data from 75 supply chains concluding that firms with mature business processes have lower inventory levels. In addition, McCormack et al. [3] provides empirical evidence between maturity level and supply chain performance, along four metric axes: overall plan, source, make, and deliver. We expect a similar relation between RL performance and maturity levels. Thus, in order to improve the RL performance of a company, it is crucial to first assess its maturity with respect to reverse logistics.

To construct our tool, we first put forward a reference model, and only then we elaborate on the diagnostic tool itself. A reference model, for a given supply chain management topic, embeds supply chain processes at an abstract level. Reference models can be put into action for a range of objectives (see [4]). Here, our reference model lays the basis for a managerial diagnostic tool as it can be used to bring transparency to the state of affairs (i.e. the maturity) of the company with respect to the various RL processes. While our reference model presents RL processes at a suitable abstraction level (so it applies to a variety of organisations), the diagnostic tool elaborates practices on management level (see also [5]). Our tool enables management to assess the organisation's current RL practices and identify potential for RL improvement. However, it does not indicate what should be the future direction. That is for management to decide on. Depending on viability and environmental concerns, some companies may go for a full RL programme, whereas others may e.g. confine themselves to some form of Design for X (DfX). To theoretically ground the tool, we carried out an extensive literature review on the industry, with respect to reverse logistics management. To empirically ground the tool, we combined company visits with a multiactor survey. To confront theory with practice, we organised a round table with experts from academia and industry (see Section 2 for details).

The research trajectory is a result of a joined project with PricewaterhouseCoopers (PwC), which is focused in constantly expanding its knowledge base in the area of reverse logistics management. Although the main objective of this research is to construct a well-founded diagnostic tool, useful to identify opportunities for improvement, there are two spin-offs: first, it brings knowledge on RL practices and RL trends in the European CE industry, and second, it provides insight in barriers and facilitators to excel in reverse chain management.

The composition of the paper is as follows. In Section 2, we present our methodology. Section 3 briefly summarises key literature. This is followed by a brief description of the CE industry and its supply chain management issues in Section 4. In Section 5, we describe the main barriers and facilitators in managing reverse logistics found in our study. Section 6 presents a generic reference model from a business reverse logistics perspective. In Section 7, we present a simplified version of the diagnostic tool for identifying reverse logistics maturity described in Section 7. Moreover, we show how the previously identified barriers and facilitators can serve as guides for the maturity states distinguished in our tool. Finally, Section 8 provides conclusions, recommendations, and directions for future research.

2 Methodology

With this research, we aim to develop a theoretically and empirically grounded diagnostic tool on reverse logistics management, from a business perspective. In order to ground the tool empirically, it is desirable to make use of a sector to which reverse logistics is of considerable importance. CE is a perfect candidate because (1) it has a high consumption volume worldwide and therefore, also high potential for reverse logistics, with large e-waste flows (as mentioned in Abstract); (2) it is one of the few sectors for which there is already in place take-back legislation e.g. in the European Union and several countries in Asia. In addition, after transportation and food consumption, CE appears to be the industry, with the third largest environmental footprint [6]. In Section 2.1, we discuss our research design. To get a clear picture of the origin of our empirical results, we describe our respondent groups in Section 2.2.

2.1 Research design

To theoretically ground the tool, besides specific literature of the sector, we look into reverse logistics management theory and performance improvement theory. We also make use of interviews with academic experts in the area of RL and interviews with PwC consultants in the area of performance improvement. To empirically ground the tool, we collect field data by combining quantitative (a multiactor survey) with qualitative (interviews and company visits) methods. With the first, we are able to identify the

key reverse logistics trends, facilitators, and barriers across several tiers of the chain, and with the second, we can go into details and explore business aspects in more depth, encapsulating them in a well-founded reference model. In addition, we organised a round table with experts both from academia and industry and PwC consultants, to discuss and bridge theory with input from practice. Figure 1 depicts the research design (see also Appendix I for more details on the research methods). We would like to highlight that the research was carefully designed according to the triangulation logic: i.e. "the collection of evidence via multiple sources" (see e.g. [7]) to diminish data and method biases.

Reverse logistics management as a young scientific field falls short of empirical research: only one third of the literature is empirically grounded, according to Rubio et al. [8], of which surveys make up only 5%. To complement surveys with more qualitative fieldwork data—though very useful [9, 10]—is exceptional.

Survey methodology proves to be a valuable research tool to approach several layers of the supply chain (see e.g. [11]). Our sector survey targeted four specific reverse logistics supply chain actors: producers, retailers, logistics service providers (LSPs), and service and repair (SR) companies. Yet, the main emphasis goes to producers, as they are the ones who have to primarily comply with the WEEE Directive. With a producer, we mean the entity that manufactures and sells under its own brand, resells under its own brand, or imports goods into EU member states (Directive 2002/96/EC). The sampling method was non-probabilistic. We used theoretical sampling [12]: this sampling approach has the purpose of developing a rich understanding of a concept (in this case, the practice of reverse logistics). Within this context, through PwC, we approached top international CE companies with global supply chains. We selected knowledgeable key informants [13]: all respondents held a management position and were directly involved in managing reverse logistics.

In order to obtain a more profound knowledge of the current state of reverse logistics management in the CE industry, we carried out in parallel five company visits [7]. The characteristic of the five organisations involved are labelled here as A–E and are described in more detail in the Appendix I. The whole study started in October 2007 and lasted 7 months.

In order to build the diagnostic tool, we first built up a reference model for reverse logistics (see Section 6). The basis of the first draft for the reference model was the literature review, which was subsequently triangulated with input from academic experts and our insights from the company visits. The reference model gives input on the aspects to be highlighted by the diagnostic model. In parallel, we carried out the survey investigating trends, potential barriers, and facilitators of reverse logistics.

In the next section, we discuss the response rates and characterise the respondent groups regarding sales volume, product life cycles, and geographic regions.

2.2 The respondent groups

In total, we sent surveys to reverse chain managers representing 112 producers, 18 retailers, 20 LSPs, and 10 SR companies. We received back surveys from 22

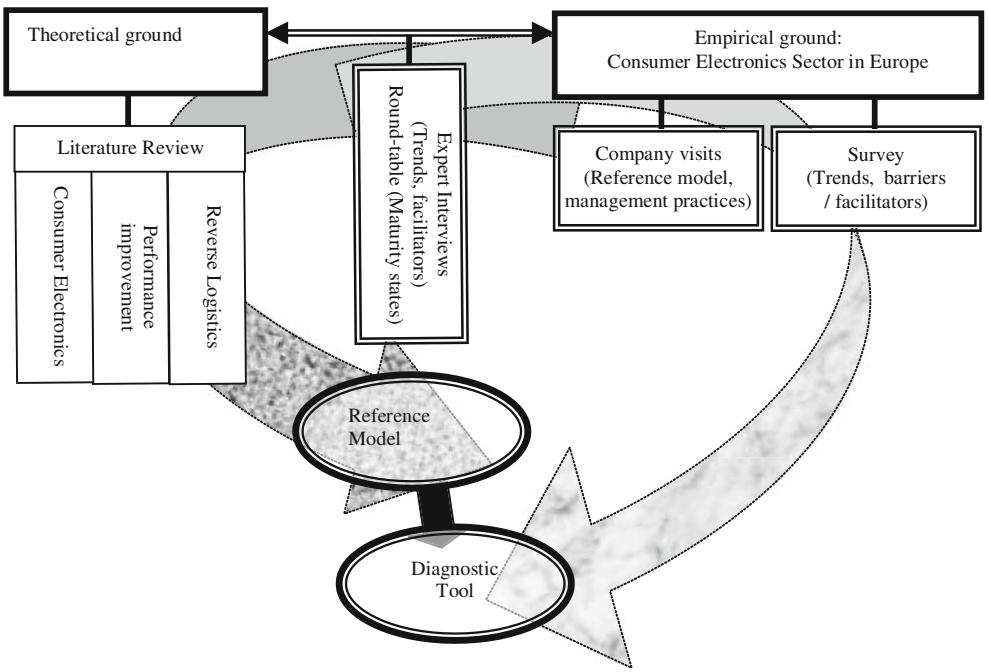

Fig. 1 The research design

producers, 5 retailers, 10 LSPs, and 5 SR companies. These numbers indicate response rates of, respectively, 19.6%, 27.7%, 50%, and 50%. Since each survey consisted of as many as 70 questions or more, we consider these rates high. Across respondents, the annual sales volume ranged from 3.3 million to 50 billion euros in the fiscal year 2007.

About 50% of producer respondents sold mainly products that fall in the category IT and telecommunication equipment, and 46% that mainly fall in the category consumer equipment. Our analysis is, thus, mainly based on perceptions of managers responsible for products in these categories. The remainder 4% of producer respondents sold mainly products that fall in the large household appliances category. This categorization is less relevant for the other survey groups, who offer services for products in all categories.

Though, across these categories, value and value depreciation of products vary, in general, the economic life cycles are short. The middle 50% of producer respondents indicated that their products have an average percentage of value depreciation between 3% and 10% per month.

Majority of the producer, LSP, and SR respondents indicated to fill in the survey for a Pan-European or EMEA (Europe, the Middle East, and Africa) region (respectively 91%, 80%, and 80%). The managers representing retailer chains had mainly responsibility for the national operations (80%). Countries represented are Belgium (20%), Germany (20%), Spain (20%), and The Netherlands (20%). The remainder 20% of respondents indicated to answer for Western European scope.

In addition to our survey research, we carried out company visits at CE producers and their service providers in UK, Germany, and The Netherlands. Those companies were multinationals operating in the European CE market, each with more than 1 billion euros annual turnover.

3 A synopsis of the literature

RL has become a recognised field with many contributions in the literature dealing with a variety of topics [14]. We refer to Dekker et al. [15] for a battery on quantitative methods; Guide and Van Wassenhove [16] for RL business aspects; Flapper et al. [17] and De Brito et al. [18] for case studies. For further insights on specific topics covered in the literature, we refer to the 10-year review by Rubio et al. [8].

Next, we give a snapshot of RL issues relevant for the consumer electronics sector, as dealt with in the literature. It is known that specific product characteristics affect the performance of end-of-life, especially product architecture [19]. For products with high modularity, remanufacturing is likely to be economically viable, whereas for integrated architectures, scrapping and recycling is probably the viable option [20].

An important issue in taking back electronic products is, therefore, information on the product state and past usage. A line of RL literature tackles precisely the value of information on product returns (see e.g. [21]). There are some models available to support the acquisition and the management of the data along the whole lifecycle of products. Yang et al. [22] propose a decision-making model to integrate lifecycle product information, testing it with consumer electronic data (refrigerators and consoles). Information gathering can be further supported by the use of information technologies, such as networked radio frequency identification (RFID) as illustrated by Parkilad and McFarlane [23].

OEMs are advised to develop their strategies in dealing with the WEEE Directive depending on the information available on the product returns [24]. Lately, there has been an increase of literature on extended producer responsibility in the CE sector. Khetriwal et al. [25] examine the case of Switzerland and conclude that to exploit the already-in-place retail network for reverse logistics is an efficient way of mitigating costs. Some of the studies investigate the impact of the WEEE Directive on specific sectors or countries, such as: the printer recycling sector in the UK [26]; the recovery sector in general in Germany [27]; or the general impact on developing countries such as Nigeria [28]. For an overview of electronic waste, legislation, and take-back practices, currently in place in the European Union, Japan, South Korea, Taiwan, and some states in the United States, please consult Kahhat et al. [29].

In sum, the literature offers the CE sector tools on: how to manage product returns information and which information to collect; how to match your take-back strategy with your product characteristics and information available; and how WEEE might impact your sector in your country. However, none of the studies takes into account the departing point of a particular CE company. CE companies are dealt with as being all alike, homogeneous in strengths and weaknesses.

We believe that in order to improve the RL performance of a specific company, it is crucial to first assess RL maturity. In this paper, we provide the means to do so by putting forward a diagnostic tool, to assess in which maturity state CE companies find themselves with respect to reverse logistics business aspects.

4 The European consumer electronics industry

Changes in the CE market are ongoing. We are aware that identifying all directions in which the market is moving is intractable. For that reason, we aim to highlight major

trends, as resulted from the field research, which show market implications relevant for OEM management and give our vision on the impact on complexity for managing the reverse supply chain.

Section 4.1 briefly indicates recent developments in the European CE industry. In Sections 4.2 and 4.3, we present the main reverse logistic trends found in our survey and company visits. First, from the expert interviews (both academic, industry, and consultancy), we identified trends in the consumer electronics industry and trends in RL management. Then in the survey, the respondents were asked to indicate the key trends. We also validated the relevance of them during the field study and the round table session.

4.1 Context and outlook

Leading principles in the European consumer electronics market have changed gradually over the last decades. The first wave started in the 70s and included a focus on the development of new technologies. The second wave in the 80s contained OEMs developing and marketing new products, enabled by technology, resulting in a product centric focus. Then, from the early 90s, business models became supply chain driven, and the leading principle changed from make-and-sell towards sense-and-respond. Nowadays, OEMs have to balance the concepts of product development, operational excellence, and customer intimacy.

Market reports estimate the consumer electronics market to generate a total European revenue of 45 billion euros in 2006, which represents a compound annual growth rate of 8.43% for the period 2004–2006. Large markets are United Kingdom, Germany, Italy, and France with a total European market share of 69%. According to Datamonitor [30], the global consumer electronics market is forecasted for an increase of 27.6% since 2006 with a compound annual growth rate of 5.9% in the period 2006–2011.

The European Directive 2002/96/EC defines four categories for consumer EEE: large household appliances, small household appliances, IT and telecommunication equipment, and consumer equipment (e.g. for home entertainment). This study primarily focuses on the latter two categories.

4.2 Main trends C market with impact on reverse logistics

In this section, we give an overview of the main trends impacting reverse logistics. The next section focuses on trends in managing reverse logistics in the CE market.

The following CE market trends were indicated to have high impact on reverse logistics management in our survey and company visits (compare with [31, 32]).

CE for entertainment The number and diversity of electronic equipment in households has increased dramatically in the last 10 years. According to data from the Consumer Electronics Association (www.cea.org), this is even more accentuated in households with teens: on average, such households own 11 more CE products than a household without teens (35 instead of 24). Not surprisingly, the top CE products owned by teens are for entertainment. These CE savvy teens will become more powerful consumers as adults for whom gadgets are must-haves. These then mature consumers will be extremely familiar with CE and technology and will turn to be more demanding consumers. The appetite for entertainment will leave them hungry of new technological stimulus in CE products, imposing a fast clockspeed tempo to the sector. Accompanying the frequent introduction of new products is the obsolescence of the old ones and therefore, the rise of e-waste.

Consumers become more powerful Transparency in the CE market is caused by almost unlimited access to product information. Consumers can easily switch between brands, and prices are easily compared. Consumer experience is, nowadays, the leading concept enhancing service levels (e.g. warranty liability) to secure brand loyalty. New service models such as swapping, household servicing, and remote servicing change success factors in the front end of the reverse supply chain. The impact of a recall can be dramatic if not carried out well. In addition, not only the consumer, but the public in general is putting pressure for corporate social responsibility, e.g. proper end-of-life disposal.

Shortening product development cycles Profit margins get squeezed, and together with the price erosion, this forces companies to launch new products as fast as possible. You have to be the first introducing new products if you want to make a profit. Economic life cycles of CE products may be even less than 6 months. Products are developed in little time shortening product development cycles. There is, therefore, only limited time for quality testing, and this increases the risk of quality problems or even a recall. In addition, it is not always clear how customers will make use of new product functionalities, and therefore, it is not possible to come up with a dedicated test programme. At the same time, the number of products in-warranty increases. Quick introduction of new products calls for extensive use of product information management, since quick feedback increases pressure for lean channels and requires complex forecasting and planning of service parts.

Supply and demand markets become more global Economic developments in new markets such as China and India

provide sales opportunities for new and recovered products. Global supply of products and services has increased. This comes along with a few challenges: global supply and demand for service parts puts pressure on global stock control and calls for skilled installed base management. Besides, supply of services (e.g. call centre, return merchandise authorization processing) in far away countries complicates exception management, and developing countries skip certain technology steps (e.g. no use of fax by developing countries).

More outsourcing and offshoring of production activities An increasing part of the production of CE products is outsourced to third parties. These vendors have moved their production locations to countries with lower labour costs. This type of work distributiveness puts pressure on the product quality and requires new information and communication systems. Large transportation distances increase risk of presale product damage, loss, or obsolescence. In addition, different companies bearing warranty liabilities increase the number of service contracts. There is also an increase of burden for remanufacturing due to loss of technical knowledge and skills. Furthermore, service parts are bought directly with the production batch, increasing the risk of service part stock out or overstock.

Because of the high level of innovation and the pressure on time to market, zero defects are unrealistic in consumer electronics. Actually, as a result of all the aforementioned trends, products with structural uncertainty are put on the market. Reverse logistics is, therefore, inevitable.

4.3 Main trends in managing reverse logistics in the CE market

Below are the main trends in managing reverse logistics in the CE market, as found in our empirical ground (compare with [33]).

More strategic focus on reverse logistics Throughout the CE market, senior managers are getting aware of strategic importance of product returns. Roughly speaking, out of our survey, we observe that managers in the IT and telecommunication sector have more strategic focus than managers in the consumer equipment sector. We found that reverse logistics is part of the corporate agenda of the majority of the companies in our field study. Our round table put forward that the consumer equipment industry has put effort to learn from practices used in IT and telecommunication equipment. Next, about two thirds of the producer respondents of the survey stated to have a functional unit dedicated to reverse logistics management.

Intensified collaboration between supply chain partners Chain partners intensify collaboration and strive to improve in win-win situations. In company visits A and B, we encountered some initiatives such as: joint rethinking of warranty processes between producers and retailers, approaching noncompetitors to share knowledge on reverse logistics and shared services, and enhance mutual trust between producer and vendor by sharing of information, both on performance as well as on cost. At all companies in our field study, a third party was involved in reverse logistics operations. Pan-European OEM of visit E used several vendors for its reverse logistics operations, to spread risk and mitigate vendor dependency. Our survey shows that OEM respondents already make broad use of third parties for reverse logistics and that within the coming 2 years, the following activities are to be further outsourced: disassembly (about one third), refurbishment (roughly 15%), remanufacturing, and recycling (above 40% of survey respondents). The round table confirmed that from a management perspective, this has led to a shift towards vendor management.

More use of swapping in the repair process Reliability and accuracy of repair turnaround times are achieved by more use of swapping of components and products. OEMs companies of visits A, D, and E held local swap stocks of finished products for the repair process. For instance, a company of visit D is able to meet the fixed repair turnaround time for 80% of the repairables. For the other 20%, it uses swap units. Our field study illustrates three practices along this trend: (1) Efficient use of swap stocks brings along an extra dimension for inventory management. General inventory rules are complicated by high uncertainty on timing and quantity of swap stock needed. (2) Updating swap guidelines is a necessity to gain from the swap benefits at low costs. With a high number of products in warranty, this is a challenging task. (3) Consigned swap stocks create local control over stocks, but limit central optimising.

Sustainability seen as competitive advantage Sustainability, seen as competitive advantage, is increasing. More than 80% of survey respondents do have a sustainability program in place, and it shows, moreover, that competitive advantage is the major driver of such programs. In addition, we found that 50% of the respondents has undertaken design initiatives to enhance reverse logistics, with design-for-repair and design-for-recycling principles. Nonetheless, survey respondents are sceptic towards global sustainability reporting and ranking systems. Results show that 50% of producer respondents rated such systems being of extremely low importance.

In Fig. 2, we visualise the main trends.

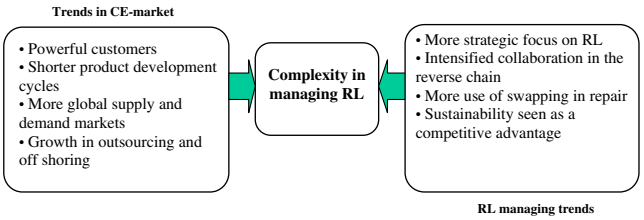

Fig. 2 CE sector: trends in the market and RL management

5 Barriers and facilitators in managing reverse logistics in the CE sector

Now that we have obtained insight in the various trends both in the CE market as well as in CE RL, let us explore which obstructions and which opportunities there are for managing RL. Section 5.1 summarises the main barriers and Section 5.2 the main facilitators, as perceived by our panel of respondents. In Section 5.3, we draw some conclusions.

5.1 Barriers in managing reverse logistics

According to the results of our survey, the main barriers in managing reverse logistics are the following:

B1 Lack of clear return policies. Sales departments are often not held responsible for commercial returns. This results in unclear warranty conditions, varying service levels, and take-back policies in commercial agreements with channel partners. We found that reducing the number of returns that are driven by commercial agreements is on the agenda of companies in visits B, D, and E. In these visits, service managers mentioned to struggle to make sales understand what are the consequences for customer service of commercial agreements and unclear warranty conditions.

B2 Little recognition of reverse logistics as a factor in creating competitive advantage. Companies are organised around the forward flow of goods. Returns are perceived as the appendix of the company and treated as such by several departments. Majority of survey respondents indicated to see a differentiating role for reverse logistics. Results show that importance of reverse logistics to the company is centred on high score. We observe a gap between the importance and the lower score for satisfaction of reverse logistics management. Our round table pointed out that improvements in reverse logistics are partly hold back by little recognition and available resources for reverse logistics.

B3 Lack of appropriate performance management system. Managers report that measuring and managing the true performance of reverse logistics is very hard. Internal and operational metrics are in place, but metrics for end-to-end process performance are seldom used or available. We refer to field study examples to illustrate this barrier. Managers of visit E indicated to measure the same metrics for the last 10 years, while processes and programmes had totally changed. In discussions, we found that metrics were measured in different units than objectives set for programmes. For example, work in progress was only reported in days, while the objectives were put on number of units. Next, managers of visit C indicated that their management systems were not able to integrate performance of different echelons in the reverse supply chain. When asked in our survey what management systems are in place for reverse logistics management, 60% or more of all respondents reported the existence of a key performance indicator (KPI) dashboard.

B4 Inadequate information technology support. For reverse logistics management, we found via our survey a gap between importance and satisfaction of current information technology support—96% of respondents rated importance high to extremely high, conversely 36% rate satisfaction high to very high. Companies make extensive use of systems that are run independently from their corporate enterprise resource planning (ERP) systems. Notable observations include:

- Product embedded information devices such as radio frequency identification are in the infancy stage of use for reverse logistics.
- Retailers show lower use of hardware technologies than other respondent groups.
- High use of serial number identification clears the path for installed base management.
- 68% of producers actually do have ERP technologies installed. The gap between importance and satisfaction shows however IT inadequacies.

B5 Limited forecasting and planning. Accurate return forecasts are hardly available. This is a direct barrier for both strategic and operational planning. In visits C and D, managers used midterm forecasts that are mainly based on basic return rate percentages and on historic data.

Overall, during the round table, IT managers indicated that differences between installed hardware can complicate end-to-end process approach. In addition, installation of customer relationship management (CRM) packages is on the agenda of the majority of survey respondents. Currently, only first movers have installed such packages for reverse logistics.

B6 Insufficient tax know-how. We found in visit B that tax managers were not at all involved in decisions made in the reverse supply chain. Main reasons indicated were differences in focal points, performance focus, "professional language", and paradigm. In the surveys, we asked the extent of collaboration between tax and supply chain departments on reverse logistics. Producer survey showed that collaboration was rated high by 32% of respondents, for LSP, 40% rated this high to very high, and for retailers, this percentage was 0%. Outcomes are rather worrying, considering the cost burden companies can face due to unawareness of customs procedures and planning, cash flow risks, and funding for value-added tax (VAT) payments.

5.2 Facilitators in managing reverse logistics

Main facilitators in managing reverse logistics—found in our survey study and validated in more detail during the company visits and the round table—are the following:

F1 Top management awareness. Senior management is aware of complexity and risk for commercial, repairable, end-of-use, and end-of-life returns. In company visit D, managers reported directly to senior management, and they perceived this as an important factor for their success. This is in line with analysis of Aberdeen group [34] that 92% of best-in-class had a senior director or executive overseeing reverse logistics.

F2 Strategic partnerships with supply chain partners. Collaboration with suppliers, sales channel partners, and third party service providers on strategic level.

F3 Detailed insight in cost and performance. Insight in internal failure and external failure costs, both clear and hidden. Measuring the right indicators and understanding what indicator implies what performance. All producer respondents (100%) managed reverse logistics as a cost centre. Nevertheless, only 36.7% has availability of real-time insight in costs related to reverse logistics management.

F4 Strategy focus on avoiding returns. Attention and focus at strategic level to prevent channel partners and end-users to return products. Avoidance is part of a clear reverse logistics strategy. When asking producer respondents to indicate if they have a specific reverse logistics strategy, we found that 45% actually did have a specific strategy, 18% was not aware, and 37% said there was no such.

In practice, some returned products are in fact in working condition when they enter the reverse stream. We found that the nonfault found rate is used in practice as performance indicator. Fourteen percent of respondents indicated to answer exactly. We understand that the rate is very much related to—amongst others—type of products sold, return policy, and effort in avoidance and gate keeping.

F5 Reclaiming value from returned products. Part of cost of goods sold can be reclaimed by collection of returns and asset recovery from them. Literature described that product characteristics heavily influence applicability of asset recovery [35, 36]. Our round table confirmed that senior level awareness of benefits, both economical as ecological, for asset recovery was a determining factor. Operations managers in visits A and E experienced burdens to convince higher level management that, in their perception, more recovery could be explored. Survey participants indicated to find it difficult to answer the percentage of value reclaimed due to not taking a value perspective towards returns. We found specific programmes that were actually managed as profit centres, and for us, this substantiates the argument that managers should see returns as valuable assets (similar to [37]).

F6 Capability to put products rapidly back into the market. Mainly for products in the early phase of the economic life cycle can value depreciation be an issue. With products losing value several percent a month the return cycle time can be a key indicator for management of returns operations. We found that cycle times in practice depend on stage in product life cycle, type of rework required, company policies on reselling, and—to a large extent—availability of spare parts. In addition, survey respondents indicated that product value diminishes between 3% and 10% per month. Needless to say that a reduction of multiple days can increase expected market value.

We observed in our company visits that managers dealt with products under warranty by various service models and approaches towards customer service. Managers indicated to design service models highly customised per country and especially in Western Europe, with high standards compared to service levels in other continents. A manager in visit E indicated that he was currently reassessing the customer cycle times, to get to know if they were actually not over delivering customer expectations.

5.3 Conclusion

Leading consumer electronics companies in Europe put limited strategic attention to reverse logistics, despite the fact that regulation is getting more stringent, and many stakeholders demand for sustainable e-waste solutions with respect to economical, ecological, and social aspects. In

Sections 4 and 5, we identified what management practices multinational OEMs apply. Senior managers gave their perception on main trends, barriers, and facilitators in reverse logistics management. Main RL barriers and facilitators are displayed in Fig. 3. For a full chain picture, we integrated also perceptions of managers representing multinational retailers, LSPs, and service and repair companies. Our analysis shows that operational management is maturing and that complexity throughout the chain increases. But from a corporate perspective, only few companies see reverse logistics as a value driver and support operations with a clear reverse logistics strategy and vision. It results in lack of resources to fully explore the true value potential that reverse logistics comprises.

6 The reference model

In this section, we first isolate those RL aspects—encountered in our study—that are essential from a business perspective. Next, we use them as building blocks for our reference model.

To our knowledge, no specific reference model is present in current day literature that captures the practices and business models that we studied on OEM abstraction level. Our examination of available reference models brought forward that the Supply Chain Operation Reference (SCOR) model and the Global Supply Chain management Forum (GSCF) model are the most relevant (see Appendix II for more information on these reference models). Both include process descriptions for reverse logistics only marginally [38]. The SCOR model mainly focuses on the functions of purchasing, manufacturing, and logistics.

In our opinion, a number of business aspects important in the CE industry have been undervalued in these reference models (SCOR and GSCF) to exploit the full area of RL improvement potential in reverse logistics management. In comparing the two models, however, GSCF is more encompassing because it covers the additional functional areas of: (1) research and development, (2) marketing, (3) finance, and (4) service [39].

In line with the responsibility of corporate management for performance of all business functions, we, therefore, favour to use the GSCF frame as departing point. Similarly to Rogers et al. [40], we define the following strategic subprocesses:

Returns management strategy and goals A recovery strategy should be part of a reverse chain strategy [41]. Yet, only 45% of producer respondents had a reverse logistics strategy, indicating that firms will have different maturity levels regarding return management strategy.

Acquisition and gate keeping Acquisition is one of the critical steps in defining the reverse logistics chain. Guide and Van Wassenhove [42, 43] argue that acquisition of used products is the control lever for the management and profitability of reuse activities. Out of our survey, 23% of producers have taken initiatives to increase the volume of returns in the last 2 years, hinting this as a discriminating maturity factor.

Outsourcing and relationship management Here, decisions on what to outsource are made. CRM is a focal point for managers in the CE market. Identifying and fulfilling customer service requirements is essential [44]. We found that, in practice, improving data quality for forecasting was occasionally related to monitoring customer's base. ERP suppliers indicated to see increasing use of installed base management for strategic decision support at their customers. Lambert et al. [39] argue that CRM and supplier relationship management (SRM) form the critical links in the supply chain. Indeed, the notion of producers is not confined to OEMs or original design manufacturers, but also comprises suppliers, such as service and repair companies, logistics service providers, and spare parts vendors. Several papers discuss strategic decisions concerning collaboration with third parties in product recovery, e.g. contracting, joint ventures, or vertical integration [45, 46]. Our survey illustrates a high rate of respondents using third party services for reverse logistics, which underlines the importance of SRM. It is key in the realm of supply chain management that business processes are cross-functional [39], and that supply chain managers align strategies and implementations with strategies in the areas of finance, operations, marketing, new product development, and sales [47]. Managers contemplating

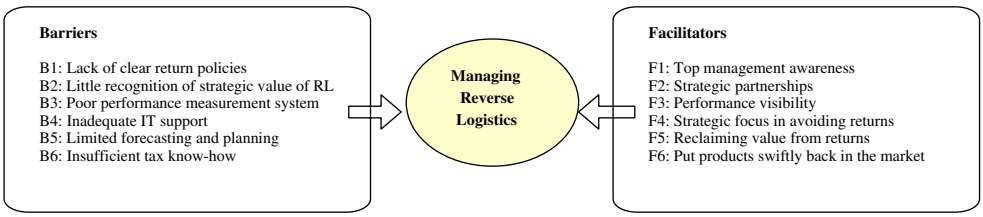

Fig. 3 Main barriers and facilitators of reverse logistics management

product recovery strategies should consider which of these drivers currently apply to their company and industry. This will likely require discussions with managers from a variety of functions, since knowledge about production costs, brand reputations, customer expectations, and legislative agendas is typically diffused across an organisation [45].

Return material authorisation Additionally, decisions have to be made concerning crediting returns, and senior management bears tax compliance risk, thus, we add these factors to our model. Two examples illustrating strategic decisions: invoicing cycle time of return merchandise authorisations directly influences the cash position of a company; structure and focus of VAT and customs in order to have a close relation with local authorities will prevent nonrecoverable VAT and support a smooth customs process.

Remarketing Strategic decisions of interviewees in visits A and D involved for example colocality of recovery activities with home base of brokers for recovered assets. Additionally, we observed that creating demand or generating higher sales prices can be fuelled by the use of remarketing at strategic level, capitalising on going green strategies. Hence, we add remarketing to our model.

Performance management Noquantified cost came forward as a main barrier for successfully managing reverse logistics, and 28% of producer respondents did not even have a KPI dashboard in place. This stresses the importance of performance measurement. Another reason for incorporating performance management is that business is not only about measuring the right things, but also on measuring things right.

In our case, we envision the role of sender/giver (see [48]) to be either the consumer or business customer at the supply side, where an active role as exchange of information or capital takes place. At the demand side, future customer includes original sender/giver, new customer (inside, intergroup, or outside the company) or disposer.

Based on the input of the field study and the literature, our vision on OEM's strategic decisions contains also the following aspects:

Product life cycle management (PLM) was explicitly used—in visits B and D—as starting point in strategy formation for the company business model including returns. For our reference model, we use a reverse logistics perspective to PLM with aim to incorporate, quoting De Brito and Dekker [48], the "encircling aspect of the process as a whole".

Corresponding to the trend of demand and supply markets becoming more global, we believe that facilitators in strategic decisions differ between loops in the alternative and the original supply chain. We found that a loop into an alternative chain can imply strategic decisions on forwarding assets to non-European markets or changing from business-to-business to business-to-consumer market.

Strategic use of swapping and exceeding customer expectations in high demanding Western European markets are examples of aspects related to a loop into the original supply chain. Additionally, for both the alternative and original chains, we found strategic aspects used in practice for closed loop management: products design, network design, and facility locations [49].

Strategic decisions to use swap solutions bring along a whole new dimension in inventory and spare part management. To our knowledge, literature that incorporates a swap management perspective to reverse logistics is scarce. Minner [50] recommends future research for use of returns at several processes, implying swap units, for the use of strategic safety stocks in the reverse logistics supply chain. Strategic aspects of related strategies, forecasting [51, 52], and network planning [53] have had more attention in literature.

Tax planning Additionally, optimal tax structuring can provide significant cost benefits, and our field study revealed that reverse supply chain managers are not aware of this. Tax is in many cases part of the finance departments, but deserves specific attention in regard of the gap in tax awareness and know-how in reverse logistics We, thus, add tax planning to our reference model, more specifically: value-added tax and customs, as these are most relevant in respect of reverse logistics [54].

OEMs treat products requiring easy service before they could be fed into the market separately from returns demanding more work, e.g. a form of reprocessing. For that reason, we use the distinction of De Brito [55] of direct and process recovery. Distinction seems even more relevant regarding difference in hold-up risks, sharing proprietary information, and high environmental uncertainty [45].

Our model includes all strategic factors described by Dowlatshahi [44], but extends strategic costs with management costs for avoidance, gate keeping costs, and tax costs. We capture overall quality in product life cycle management and related strategies, customer service in customer relationship management and related strategies, as well as environmental and legislative concerns in voice of stakeholders. This illustrates the comprehensive character of our reference model.

Figure 4 reproduces our vision on the most important diagnostic aspects, from a business perspective, in a

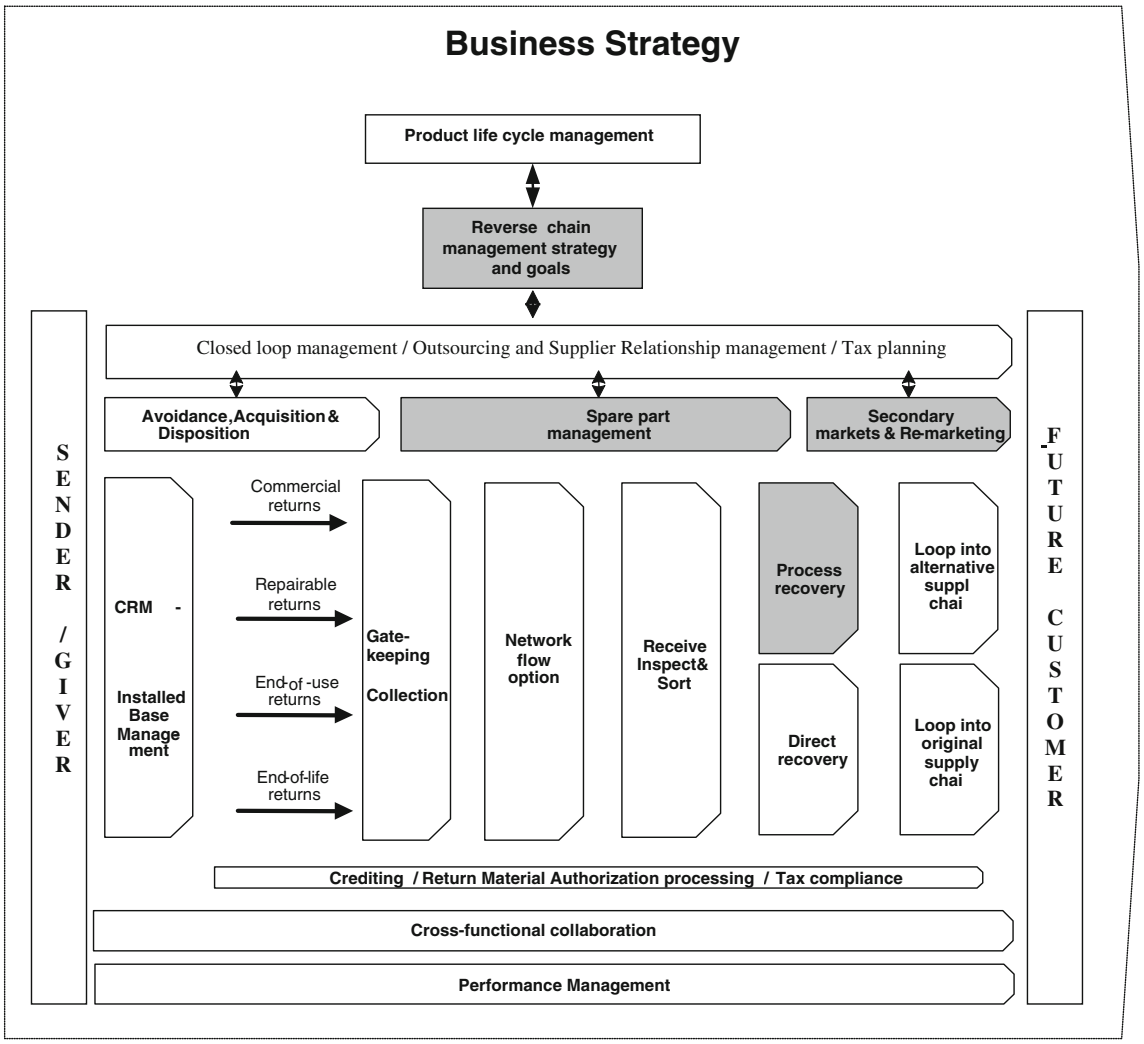

Fig. 4 The reference model. The *grey boxes* are used in Section 7.1 in a simplified version of our diagnostic tool in order to illustrate the functionality of the tool

comprehensive reference model, that forms the framework for our maturity diagnostic tool, as explained next.

7 A diagnostic model

Based on the conceptual reference model of the previous section, we have developed a diagnostic tool. In the present section, we present a simplified version of our tool focusing on (1) business strategy, as well as on the grey-highlighted aspects in Fig. 4, i.e., (2) RL strategy and goals, (3) spare part management, (4) secondary markets and remarketing, and (5) process recovery.

In Section 7.1, we present our diagnostic tool. Section 7.2 shows how the barriers and facilitators discussed in Section 5 may serve as guides in identifying maturity. As mentioned earlier on, by maturity with respect to a certain reverse logistics aspect, we mean the extent to which the company is able to fulfil the specific requirements associated with it.

7.1 Illustrating the diagnostic model

The aspects that form the building blocks of our reference model re-emerge in our diagnostic tool, on a management abstraction level.

The structure of our diagnostic tool is as follows: Per aspect of the reference model, the tool distinguishes one or more dimensions along which maturity can be diagnosed. Throughout, the tool distinguishes four states of maturity. A model can trace several states of progression of a business function (in this case, reverse chain management), starting from a largely negative role in state 1 to a key competitive element in state 4 [56].

For each dimension, we indicate per maturity state the profiles that an OEM recognises as description of current

practice in that state. Basis for these dimensions and descriptions was an iterative process with OEM managers, practitioners, and consultants.

The reverse logistics tool developed in this way is intended to be exhaustive for the CE industry in the sense that it fully covers all states in the CE product life cycle.

To exemplify our tool within the limits of this paper, Table 1 shows the dimensions and maturity requirements of five of the 27 aspects in the tool. These five aspects were selected on the basis of their relevance in the survey results.

For the dimensions from Table 1, we provide a fictitious example (the retail chain QuackTronics) in Fig. 5 below.

7.2 Barriers and facilitators as maturity guides

The fact that—in our diagnostic model—a CE company finds itself in a specific maturity state regarding a certain dimension is strongly related to the existence of barriers and facilitators (see Section 5) pertaining to that particular dimension. Clearly, the existence of barriers is an indication of a low maturity, whereas to have some facilitators in place is a hint of a higher maturity state.

In this section, we illustrate how barriers/facilitators can be used to disclose the maturity state of associated dimensions.

Table 1 Illustration of the RL diagnostic tool: five aspects and their dimensions

		Business maturity			
Business aspect (reference model)	Dimension	State 1: immature	State 2: naïve mature	State 3: semimature	State 4: mature
Business strategy	Integration of reverse chain management in supply chain strategy	Reverse chain management is an appendix of the supply chain strategy	Reverse chain management is secondary part of the supply chain strategy	Reverse chain management is semi-integrated in supply chain strategy	Returns chain management is an integral part of the supply chain strategy
Reverse supply chain management strategy and goals	Managing reverse logistics as core business process	Product returns are perceived as irrelevant and managed as purely cost driver	Importance of product returns is recognised but no awareness about how to handle	Strategic focus on product returns and manage both as cost and value driver	The reverse supply chain is a strategic, profit generating core business process
	Holistic supply chain approach	Isolated approach to manage returns in each part of the reverse chain	Cross-functional approach to manage product returns	An integral approach of the supply chain is taken to manage returns	A comprehensive supply chain approach is adopted to manage product returns
	Clear reverse logistics goals for end-to-end process	Reverse Logistics management goals are not in place	Reverse logistics management goals are in place for parts of returns processes	Reverse logistics management goals are in place for all processes	Reverse logistics management goals are in place for all end-to-end processes
	Alignment with business objectives	Reverse chain operations are not adapted to business objectives	Reverse chain processes are adapted to business objectives	Reverse chain processes and operations are aligned with business objectives	Reverse processes and operations are aligned with business objectives and market developments
Spare part management	Synchronisation	Spare part planning and forecasts do not incorporate product returns	Short term return forecasts are used in spare part planning and forecasts	Return forecasting is integral part of spare part planning	Synchronised planning of spare part demand and return forecasting
Secondary markets and remarketing	Knowledge of secondary markets	Knowledge about secondary markets for recovered assets is considered as irrelevant	Knowledge about secondary markets for recovered products is available	Knowledge about demand markets for recovered asset is used during the returns processes	Advanced knowledge of demand markets for recovered assets is integrated in management decisions for reverse flows
	Remarketing	Non-fault found and excess products are written-off as faulty products	Non-fault found and excess products are used to retrieve spare parts	Secondary markets are identified for nonfault found and excess returns	Primary markets are identified for nonfault found and excess products
Process recovery	Aligned asset recovery strategy	No clear asset recovery strategy exists	Clearly stated recovery strategy exists based on economic and technical viability of recovery options	Clearly stated asset recovery strategy is aligned with reverse chain strategy and business strategy	Fully aligned recovery strategy exists based on economic, technical, and environmental viability of recovery options

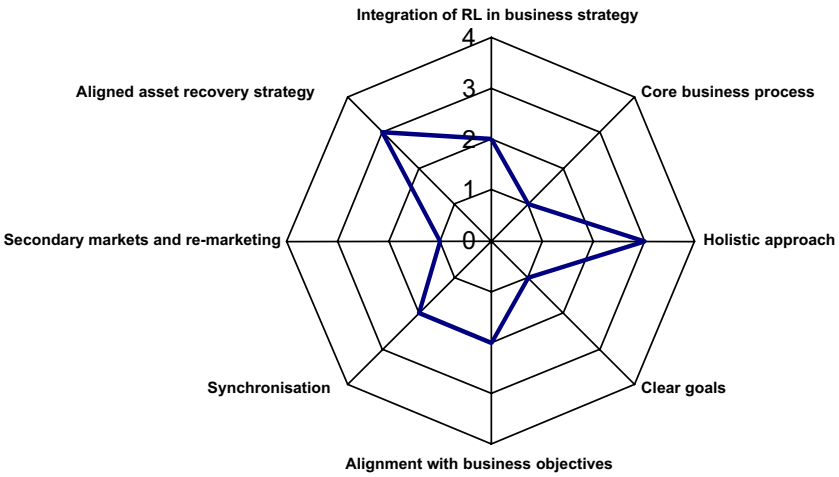

Fig. 5 Visualisation of the results of diagnostic tool for QuackTronics

Suppose the company QuackTronics (see Fig. 5) experiences barrier B2: Little recognition of reverse logistics as a factor in creating competitive advantage. The influence of this barrier is rather pervasive. It affects integration of RL into SC Strategy (business strategy), giving it a low maturity. It also causes a low maturity for the first dimension of reverse SCM and goals (managing RL as core business process). Furthermore, it speaks out a low maturity verdict for the first dimension of process recovery (aligned asset recovery strategy).

As an illustration of a less pervasive barrier, consider B5: Limited forecasting and planning. Clearly, this barrier frustrates spare part planning, thus entailing a low maturity for the dimension synchronisation associated with the aspect spare part management.

Let us now look at the bright side. The company QuackTronics recently entered in an alliance with a group of suppliers. Hence, facilitator F2 is valid: Strategic partnerships with supply chain partners. This facilitator indicates high maturity for several dimensions, such as: (1) business strategy and the integration of RL into SC strategy, (2) the second dimension of reverse SCM and goals (holistic SC approach), and (3) the first dimension of process recovery (aligned asset recovery strategy), see Fig. 5.

Finally, as an illustration of a less pervasive facilitator, consider F6: Capability to put products rapidly back into the market. This facilitator indicates high maturity for the dimension remarketing associated with the aspect secondary markets and remarketing. Currently, QuackTronics does not have this facilitator in place, which explains its low maturity on remarketing.

7.3 Applying the tool (for self-assessment)

The tool is designed for self-assessment facilitating OEMs in the process of gaining insight in their baseline of RL management. Added value of the tool is that it enables management to assess the company's full area of RL management in a time-efficient way. Next, it can help supply chain managers to get reverse logistics management on the corporate agenda.

Before we exemplify how the tool can be used in practice, we would like to stress that business models and (reverse) supply chain structures can vary strongly between OEMs. This means that a similar problem at different companies does not necessarily result in a similar assessment's outcome.

Let us reconsider our fictitious example (the retail chain QuackTronics) of which we present a spider diagram in Fig. 5. QuackTronics handles returns on an ad hoc basis. Ed, the financial controller, finds out that, in the most recent fiscal year, the company bears a huge cost burden due to obsolete stock. He issues his worries to Tom, the supply chain manager. Tom recently got acquainted with our diagnostic tool and decides to use it to assess maturity of the reverse logistics management.

After doing self-assessment through our diagnostic tool, Tom arrives at the spider diagram of Fig. 5. This diagram displays three dimensions with low maturity. Tom decides to go for a depth-first approach: first attack one problem exhaustively, then go to the next. Since he is especially triggered by the immature state for the dimension secondary markets and remarketing, he starts with that. Tom initiates a series of interviews and finds out that, generally, nonfault products are written off as faulty products. In addition, secondary markets have not been fully explored by the company.

Tom succeeds in alarming top management. Triggered by the immature state of the above marketing dimension top management, decides to start up a high-level business case on improving marketing potential. It does so by identifying primary markets for nonfault found products and secondary markets for recovered assets.

Thus, the value of the tool lies in facilitating awareness of the overall RL as is situation of QuackTronics. Decision making on improvement actions is up to management.

8 Conclusions, recommendations, and further research

8.1 Conclusions

In this paper, we develop a theoretically and empirically grounded diagnostic tool for determining the reverse logistics maturity state of a CE company, from a business perspective.

Theoretically, our tool is based on the combination of specific CE literature with general theory on reverse logistics management and performance improvement. Empirically, the tool is based on collecting field data by combining quantitative (a multiactor survey) with qualitative (interviews and company visits) methods.

Employing our field study, we identify the main reverse logistic trends in the CE market. We capture our vision on the most important diagnostic aspects, from a business perspective, in a comprehensive reference model. This forms the framework for our diagnostic tool for identifying reverse logistics maturity. The main barriers and facilitators in managing reverse logistics found in our field study serve as guides for the maturity states distinguished in our tool. Our tool is an important means to create awareness at senior management about the reverse logistics maturity state.

Though we focused on the consumer electronics sector, our reference model is likely to be transferable to other sectors as well. The reason for this is that CE is a sector that has been confronted with return flows for a long time so that a broad range of general RL problems has been experienced. Issues that we capture in our reference model are therefore not esoteric, but also play a role in other industries. Another reason is that we also used input from general RL literature and from academic experts.

In literature, little, if any, is published on self assessment for reverse logistics management. However, before starting any improvement program for RL performance of any company, it is of vital importance to first make an RL blueprint through self-assessment. In this paper, we provide the means to do so by putting forward a diagnostic tool, to assess in which maturity state CE companies find themselves with respect to reverse logistics business aspects.

8.2 Recommendations to OEMs

Let us give a number of general recommendations to producers to improve managing their reverse logistics, using the lessons learned during the company visits including the round table discussions with academic and industry experts:

- Critical in the start is to define the current internal situation. Identify the improvement areas and quantify the increase in stakeholder value thereof. The diagnostic model presented in this paper can be used to create awareness of the “as-is” state at senior management.
- Managing reverse logistics is not the activity of just one department or actor in a supply chain. In order to optimise the end-to-end chain, collaboration of all relevant departments (from research and development to finance/tax) and channel partners is fundamental in realising improvements.
- Proactively managing the entry points of the reverse supply chain. Preventing avoidable returns is a main focus area. Clear warranty conditions and harmonised and standardised return policies are basics. Measuring and rewarding avoidance initiatives can increase the predictability and manageability of products being returned.
- Reveal true costs, revenues, and end-to-end performance. Visibility in “clear” costs such as costs of rework, processing customer complaints, warranty claims, and product recalls is a first step. Extending the profit and loss account with “hidden” cost, e.g. opportunity tied up in returns, cost of tax compliance, and control, advances the insight in expenditures.
- Active take-back products management. In four company visits, we observed that programs had been introduced for getting back sold products. However, survey results show that, in the last 2 years, only a minority of respondents have undertaken take-back initiatives. We observe that 45% of producer respondents is not aware of return acquisition initiatives. Recalls, low quality (repair) products, or little proof of environmental consciousness have increasing impact on corporate image. End users blame the brand owner for a good or bad warranty process. Front-end parties delaying or underperforming repair activities damage brand image. Nonrepairable products can be made dysfunctional, but unauthorised companies acquire used products from the market. In the consumer market, it is very hard to get control over the product once it is sold.

8.3 Further research

Our field results revealed a number of interesting topics that, to our knowledge, had limited attention in current literature. It was, however, not possible to cover all the adjacent topics, which certainly would enrich this study. Below, we present several contiguous issues that had to be

scoped out in the present paper, but which can feed future research:

- Risk analysis as well as a cost–benefit analysis to the areas under study in the diagnostic tool and the relation between maturity state and RL performance. Insight in costs and benefits of improving a particular area provides valuable information for determining future improvement directions. Another option is to add marginal values, which point out which action has highest marginal cost or risk.
- Expanding research scope. By for instance including carriers and packaging materials, or to perform similar research in other continents.
- Replication of the study in other industries. This research has purely focused on consumer electronics. Interesting would be to investigate how our findings relate to developments and practices in other industries. The research process leading to the diagnostic tool can be replicated as follows: firstly collect the different barriers and facilitators (then design the reference model) and finally use the reference model to define maturity states. Yet, as mentioned before, the reference model is likely to be transferable to other sectors as well. Thus, only minor adjustments on that step are likely to be necessary.
- Replication with multiactor perspectives: e.g. to use the end-customer as research focus. Insights in and understanding of customer needs are important aspects for producers to determine reverse supply chain strategies. A study on their perceptions and experiences would be very valuable. Directly executable can be the rating of the relative importance of identified facilitators by these end-customers.
- In this paper, we put forward a tool to enable management to assess the organisation's current RL practices and to identify potential for RL improvement. However, the tool does not indicate explicitly what should be the future direction.

Some suggestions for future research in this respect include:

- Very little literature, if any, is available on optimising reverse logistics jointly from tax and operation perspective. We can imagine that compliance and control risk for value-added tax and customs can be variables in network design studies. Transfer pricing between multigroup companies and transfer of legal ownership can be variables to incorporate in inventory optimisation and studies on effectiveness of reverse logistics programmes.
- Producers make extensive use of third parties for reverse logistics activities, and many papers are present on outsourcing practices. However, in some cases, we found that producers perceive reverse logistics activities as core business, and managers indicated that activities actually had been in-sourced. In literature, we did not find many publications or case studies that investigated in-sourcing of reverse logistics activities.
- Our facilitators fully correspond with enablers that are part of the performance management approach suggested by the European Foundation for Quality Management (EFQM). This calls for further research on applicability of the EFQM excellence model [57]. Further development of key performance indicators is part of this suggestion.
- Maturity in supply chains is generally a poorly understood subject as most of the supply chains never reach high maturity states [58]. In this paper, we used barriers and facilitators as a means to shed light into the maturity state. Nonetheless, we recognise the need for a more rigorous study on the concept of maturity.
- The extension of the tool with a future strategy orientation. This calls for additional research on under which conditions should the decision maker develop a full RL programme or when should simply implement a single RL-related action. This particular research would support decision making in supporting a long-term strategy and is ought to balance the opportunities with the viability for the specific firm, taking into account its context and the confinement of its operations.

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Appendix I: research methods in more detail

Field visits

In total, five multinational producers were visited. For anonymity, we refer to these visits by naming them visit A, B, C, D, and E. We give a very brief description of the studies.

Visit A

In this visit, we interviewed managers of an asset recovery plant. By means of long-term partnership, a LSP is providing the forward logistics, customs formalities, and also the reverse logistics. Part of the recovery strategy of company A is the refurbishment of internal returns (dead on arrival), end-of-lease returns, and general customer returns. It has chosen to form a closed loop with reverse logistics,

refurbishment, and remarketing into the consumer market. Tenders are sold to controlled brokers in Western Europe.

Visit B

We conducted interviews with spare parts, customer care, and LSP managers. In this visit, we interviewed European management of after-sales operations. They manage all after-sales activities, dealing mainly with returns under warranty. A central warehouse provides spare parts for all service engineers and workshops throughout Europe and received items being returned back. The warehouse serves as a hub between front end and back end of the repair network. Company B manages the operation (e.g. stock levels), and the LSP is executing the tasks.

Visit C

We interviewed operations managers of company C and European managers of the LSP. Company C receives high volume of returns due to a "accept everything" return policy. It collects commercial, repairables, and end-of-use returns centrally for the whole EMEA region. Particular products are economically viable to remanufacture and recycle. However, majority of products is sent into the waste stream. Products with a reasonable quality are resold as is via internet tenders. A LSP takes care of the external logistics, and another LSP is managing and operating internal testing, sorting, recovery, and disposal.

Visit D

We interviewed managers of company D and the LSP responsible for European returns management. Mainly leasing products in the B2B market, managers of company D are responsible to deliver service levels of sales agreements. Reverse logistics brings used service parts and end-of-lease products back to the European consolidation centre. Disassembly services and retrieving service parts from products is provided by a LSP, while company D is managing and operating in-house service part stocks and flows.

Visit E

We interviewed the hub manager and a global service part manager. In this study, we visited a UK logistics hub. The hub is operated by a LSP that provides testing, grading, and sorting for commercial and warranty returns. Next, the hub receives also repaired or refurbished products back, retests them again and takes care of redistribution. Company E's policy of guaranteed repair turnaround time requires quick repair or use of swap units.

Analysing the studies, we see already the diversity in solutions and models that supply chain managers are responsible for.

Outline of the survey questions

Balancing between insights in the survey and not entangling in details, we herewith give an outline of the survey questions.

The survey questions have been clustered around:

- RL strategy (e.g. type, the link to corporate strategy)
- structure (e.g. reverse chain, outsourcing)
- process (e.g. recovery options, continuous improvement)
- organisation (e.g. human resources, learning, and development)
- technology dimensions (e.g. track and trace, IT functionalities).

Each dimension contained a range of seven to 12 questions. First part of the questions is dealing with factors affecting reverse logistics, i.e. trends.

Type of questions included open questions (e.g. what are main trends in CE market), single select (e.g. importance of IT on a scale from 1 to 7), multiselect (e.g. which type of returns does your company manages), and closed questions (e.g. separate RL function: yes or no).

Face-to-face interviews

Considering the explorative character of the expert interviews we used a majority of:

- open questions (no finite number of answers)
- spontaneous (respond can be given in own words)
- open-ended (answer is recorded verbatim).

One can state that this type of questions worse the biases effects of interview surveys, but we believe that the expertise of the respondents compensate these drawbacks for a large degree.

Round table

The participants from industry included managers of service providers, (e.g. IT, repair, and logistics) and of a logistics platform.

Via direct contacts of PwC, we invited the participants 1 month in advance, sending them the objectives and agenda for the session upfront. In total, 14 attendants participated in a 4.5-hour session, held in Amsterdam. Facilitated by one of the authors and a PwC consultant (tax background), it was split into two major parts: (1) validation of the research findings and (2) breakout sessions on maturity states.

Outcome of the session is integrated in our research findings, and attendants received a copy of the PwC report [54] shortly after publication.

Appendix II: reference models

A reference model is a tool to capture and model the supply chain structure, a means to understand a supply chain. From the perspective of Fettke et al. [59], a reference model represents the business processes and the dynamic aspects of an organisation. In our study, we examined reference

models that would be general enough so that they incorporate different business approaches. Lambert et al. [39] identify five models, of which two specifically provide process descriptions claiming to achieve supply chain optimisation. Moreover, these two models are rich enough to incorporate, to some degree, reverse logistics explicitly: SCOR model [60] and GSCF framework [61].

Supply chain operations reference model

The SCOR is a product of the Supply Chain Council and captures the council's consensus view of supply chain management. Five key steps can be distinguished, as follows:

- plan: the development and establishment of courses of action over specified time periods that represent a projected appropriation of supply chain resources to meet supply chain requirements.
- source: the procurement, delivery, receipt and transfer of raw material items, subassemblies, product, and/or services.
- make: (1) make-to-stock, (2) make-to-order, and (3) engineer-to-order processes.
- deliver: (1) the process of delivering a product that is maintained in a finished goods state prior to the receipt of a firm customer order, (2) the process of delivering a product that is manufactured, assembled, or configured from standard parts or subassemblies, (3) the process of delivering a product that is designed, manufactured, and assembled from a bill of materials that includes one or more custom parts.
- return: return is documented in two locations—source and deliver. Those return processes that connect an organisation with its supplier (i.e. the return of raw material) are documented as source return activities. Those processes that connect an organisation with its customer (i.e. the receipt of returned finished goods) are documented as deliver return activities. Hence, source return implies the process, initiated by the customer, of returning material deemed defective by the last known holder or designated return centre. And deliver return implies the processes of the last known holder or designated return centre authorising and scheduling the defective product return and the physical receipt of the item by the last known holder or known return centre and their transfer of the item for final disposition determination.

These key steps aim to structure process, metrics, best practices, and technology features to provide a basis for supply chain improvement [60].

Reverse logistics is explicitly referred to in three parts of the SCOR model, namely: plan return, deliver return and source return. For the processes, deliver return and source return the SCOR model distinguishes between:

- Return of defective products
- Return of maintenance, repair, and overhaul products
- Return of excess products

For plan return, deliver return, and source return, the model provides standard process definitions, best practices, performance metrics, and related inputs and outputs both at the level of process and at the configuration levels. For more information, please, have a look at SCOR [60].

Global supply chain forum model

The framework defines supply chain management as the "integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders" [62]. Implementation is carried out through the interactions of three primary elements, namely:

– the supply chain network structure,
– the supply chain business processes, and
– the management components.

GSCF considers eight supply chain management processes, as follows: customer relationship management, supplier relationship management, customer service management, demand management, order fulfilment, manufacturing flow management, product development and commercialization, and returns management. For each process, strategic subprocesses are provided which relate to the structure for managing the process, as well as operational subprocesses which provide the details for execution.

Returns management includes all activities related to returns, reverse logistics, gate keeping, and avoidance. Customer relationship management and supplier relationship management form the critical links in the supply chain and returns management is coordinated by them. To employ this model, it is critical that one has information from all functional areas (including finance/tax). This breadth is exactly, in our opinion, what makes this model useful for reverse logistics management. For more information, please have a look at GSFC [63].

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