Knowledge as a Circular Resource

Integrating Information Exchange and Circular Business Models for Product-life Extension

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Abstract
The change from a linear to a circular business model requires the development of new services integrating information exchange and product usage to prolong product life through maintenance and repair. Information exchange has been identified as important for promoting circular economy, and this study draws on empirical data from a two case studies to demonstrate which kind of information supports maintenance and repair, and how the information exchange can be facilitated. Case company A offered maintenance of white goods (e.g., washing machine) as a subscription service where reminders and maintenance guides were emailed monthly to customers. Company B offered virtually guided repairs of white goods. The study finds that sharing information on what and when to do something facilitates end-users to participate in maintenance and learn about maintenance; more than half of the company A questioned customers reported that they learnt from guides and were involved in maintenance due to guides and reminders. For repair the problem description and possible solutions is information that must be exchanged, and a simple voice and video call can facilitate repairs that prolong product life with a minimum cost for the end-user. Both types of information exchange are facilitated by simple-tech solutions relying on known and cheap technology (e.g., email service, video call, and text-messaging). The findings of the study suggest that the development of circular business models does not always require expensive high-tech solutions to integrate information flow with product flow and usage, and companies are recommended to experiment with designing solutions based on known technology.

Keywords – Circular business models, Knowledge management, Information exchange, Case study

Paper type – Academic Research Paper

1 Introduction

Circular economy aims at reducing energy and material leakage from systems to disconnect goods manufacturing from raw material usage (Bocken et al., 2016; The Ellen MacArthur Foundation, 2013). To promote circular economy within businesses legislators are developing new policies e.g. European Circular Economy Action Plan, with the intent of increasing business focus on product life-time. Focus on product life-time is also promoted by changes in customer awareness and behaviours towards after-sales services to ensure better economic and environmental performance of products (Shokohyar et al., 2014). A circular buusiness model contrasts with a linear business model by prolonging the useful life of product, part, and material through continuous cycles of maintenance, repair, reuse, refurbishing, remanufacturing, and recycling (Geissdoerfer et al., 2020). From a resource perspective maintenance is generally prioritized over recycling because the functional value of the product is retained through maintenance instead of the product being shredded down to its constitutive material through recycling (The Ellen MacArthur Foundation, 2013). Thus, policy and customer requirements change market conditions making the product life-prolonging activities *maintenance* and *repair* impending for companies to develop in the transition from linear to a circular business model.

The efficiency and effectiveness of circular economy is dependent on information exchange spanning intra- and extra-organizationally (Bhatia et al., 2020; Bressanelli et al., 2022; Guldmann & Huulgaard, 2020; Škapa, 2019). However, there is scarce empirical evidence of integration between information management and circular business models (Atiku, 2020; Klapalová, 2019), and the link between information management and the principles of circular economy (Jäger-Roschko & Petersen, 2022). In particular there is limited research on after sales services and product life extension (Islam & Huda, 2018).

This paper addresses the lack of empirical evidence through a multiple case study of two companies; company A sold a service that assisted consumers in maintaining their white goods (e.g., washing machine and dishwasher), and the case is analysed to inform how information exchange supports maintenance. Company B refurbished and sold pre-owned white goods and it is analysed to inform how information exchange supports repair. Collectively, the cases inform an analysis of how information exchange prolongs product life-time and how information exchange is integrated with a circular business model. The aim of the paper is to develop recommendations for operationalization of information

exchange supporting circular economy principles. At this aim, the following two research questions are directive:

1. What information exchanged between a company and end-user can facilitate maintenance and repair?
2. How can the information exchange be facilitated?

2 Theoretical background

Circular business models are an important enabler for companies adopting circular economy practices. A circular business model prolongs product and part life-time through successive cycles of maintenance, reuse, repair, remanufacturing, and closing material loops (Geissdoerfer et al., 2020). To capitalise on circular economy a business must facilitate prolonged usage and capture of product embedded value, and facilitate information management in relation to products (Nußholz, 2018).

Since it is a recent issue, there are limited studies highlighting the interplay between information management and circular economy (Atiku, 2020). Extant studies underline the positive implications for integrating information flows and knowledge management with the circular economy (De Marchi & Di Maria, 2020). However, current information flow practices focus on supporting production and sales of new goods, whereas the information flow in the circular processes dealing with used products is often overlooked (Jäger-Roschko & Petersen, 2022). To increase circularity by addressing barriers of information flow three initiatives are necessary (Jäger-Roschko & Petersen, 2022): i) interorganizational information sharing between business areas like manufacturing and recycling must be improved (often smaller companies lack technology and knowledge to engage in information sharing (Burger et al., 2018)); ii) access to information for all circular economy actors must be facilitated (manufacturers often restrict third party recyclers or maintenance companies access to information (Burger et al., 2018)); iii) incentives for circular economy information sharing must be created. Reducing barriers for integration of information flow enables end-users to become more proactive actors within the life-cycle of a product and engage in life-prolonging maintenance and repair (Emmanouilidis et al., 2018). User engagement towards acting on the data provided by products is essential for the information flow to have an impact (Mulcahy et al., 2019). The lack of engagement has several sources e.g. engagement of end-users in monitoring power consumption of their refrigerator is inhibited by several barriers; smart plug cannot be installed, instruction guide

is missing, and monitoring tools introduce more complexity (Fensel et al., 2017). To increase user engagement, companies must address both the perceived impact in terms of privacy and the ease of use (Kim et al., 2017). Therefore, in the design of after-sales services, like repair and maintenance, user interaction needs and methods for inducing behavioural change must be considered in order to increase engagement (Geelen et al., 2013).

Maintenance and repair keep a product in good working condition and capable of delivering functional value to the end-user, thus increasing the functional value realized over time (Morseletto, 2020). Maintenance of equipment is, in general, a crucial element of keeping a process relying on technical equipment running stable and without unwanted stops. The functional value is maintained by keeping the function available for an end user, e.g. keeping a car running by changing oil, but maintenance can also retain the visual value of a product and thus retain the functional value. Extending the life-time of product is not always a straightforward decision (Boldoczki et al., 2020) and requires assessment of "*environmental benefits/drawbacks of extending the operating time of products that can be achieved due to specific design and maintenance actions, in comparison to their replacement with newer ones"* (Ardente et al., 2018).

3 Research design and methodology

Given the study's exploratory aim a case study approach is adopted (Yin, 2009), analysing information exchange practices of two Danish companies operating in the white goods sector. The case companies were established as circular business models that incorporate information exchange, and were selected by purposeful sampling (Suri, 2011); Company A informed the study of information exchange for maintenance and company B informed the study of information exchange for repair. Access to data were facilitated by the lead author that co-founded both companies.

Case company A was a start-up born circular offering life-prolonging preventive maintenance for white goods and was called FIXRS. The company operated for 3 years (from 2020 to 2022) and assisted the end-user through a virtual DIY (Do-It-Yourself) solution comprising emails, monthly reminders (Figure 1) and video-guides (Figure 2). The reminders and guides were sent monthly and divided in a wheel lay-out, and the guides were accessible via the website and paying customers were emailed the reminders. The reminders were developed as short stories with video, pictures, and text, and the picture in

Figure 2 show step 3 in the guide on how to clean the filter of a washing machine. The customers were sent emails and text messages as reminders and containing links to maintenance video guides e.g. on how to remove calcium or clean filters. The company had approximately 70 paying customers at the time it was closed, and the customers were both private and public (e.g. offices with small kitchens). The company closed because the business model was not financially viable.

Figure 1 – Overview of maintenance tasks for a year

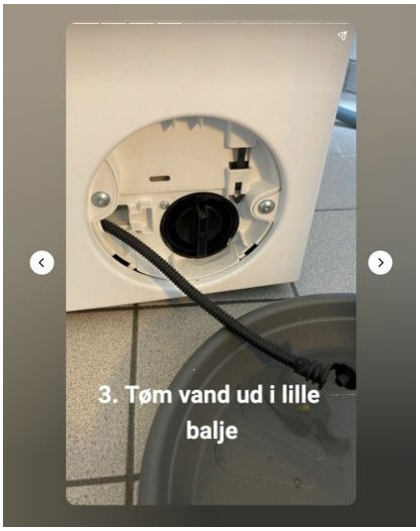

Figure 2 – A still from a video guide in story format

Case company B existed from 2019-2022 and was called SimpleVerySimple (SVS). SVS was a privately owned company established with the purpose of creating a profit by reusing and refurbishing whitegoods and selling them to B2C and B2B. The company had a combined workshop and store near greater Copenhagen, where units were refurbished and sold as pre-owned (see Figure 3). SVS incorporated information exchange between technicians and customers to remotely diagnose problems and complete repairs through virtual guidance of the customer by the technician. Information exchange on repairs was an effort to reduce the cost of repairs by avoiding transport and to reduce the downtime of the unit. During the 3 years, approximately 3300 machines were processed of which 1100 machines were either reused or refurbished and sold, and the remaining 2200 were recycled at a professional recycling facility. SVS main supplier of raw material (used whitegoods) was the largest Danish retailer of whitegoods, which was supplemented with used

whitegoods from various sources. The company was closed as it was not possible to find investors.

Figure 3 – Pictures from the workshop and sales room

3.1 Data collection and analysis

Data was collected and analysed with different methods for company A and B, respectively. Company A had a large uniform customer base that received a comparable service from the company thus a questionnaire approach was chosen to infer general conclusions about the impact of information exchange for maintenance. Company B had limited cases (Situations with information exchange to repair a unit) and each case was considered unique in terms of the situation (Problem and repair) and the customer. The characteristics suited a case approach studying the particularities, contextual factors, and common traits to inform general insight on information exchange for repair.

Data for Company A was collected and analysed as follows:

1. A questionnaire was developed by the lead author. The questions were validated with three independent informants to improve and qualify questions and answers.
2. After the company was closed, the questionnaire was emailed to previous customers asking 3 questions regarding usage and impact of reminders and guide and included an open ended text field with room for comments. The data informed an analysis of how information exchange impacted end-users to perform maintenance, and analysis of how the guides on conveyed knowledge to the customers. The text field had no stated purpose, and the data was expected to inform a qualitative analysis of the responses.

The questionnaire was emailed with an explanatory text and no reminders were sent.

3. Additional supporting data was extracted from the newsletter service used to send and track email reminders to further analyse the impact of reminders and guides using data on how many customers opened the email and clicked a link to a guide. Data from the text message service could not be extracted.
4. The questionnaire data was analysed and corroborated with quotes from the text field.

Data from Company B was collected and analysed as follows:

1. Two paradigmatic examples where a technician solved a problem and completed a repair over the phone were identified.
2. Semi-structured interviews with the technician were performed by the lead author to inform a qualitative based analysis of the successful.
3. Examples to derive findings of general validity were analysed.

4 Results

In the following pages, the results of study are briefly illustrated.

4.1 Company A: maintenance

The questionnaire was sent to 70 previous customers and 31 responded, yielding a response rate of 43% (see Figure 4), and 14 respondents left comments and one respondent choose not to answer question 2. In the text field 9 respondents left positive comments regarding the service in general and two comments that raised the issue about maintenance being difficult to judge the impact of thus reducing the motivation.

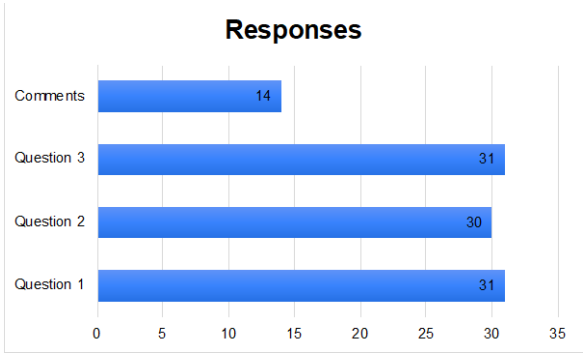

Figure 4 – Response rate

The majority of the respondents (60.3%) affirmed that they to a large extent or complete extent learned something new about maintenance through the guides (See Figure 5). One comment was positive towards the content of the guides e.g. "*For a non-handyman the guides were great*". However, two other comments raised an issue: The character of maintenance and how it fits the end-user's capabilities appear to have an impact, as two respondents left comments on maintenance tasks they were unable to perform, such as moving a washing machine or refrigerator. Exemplified by this quote from a respondent: "*It was demotivating to be reminded of tasks that I could not do for example pulling out the washing machine*".

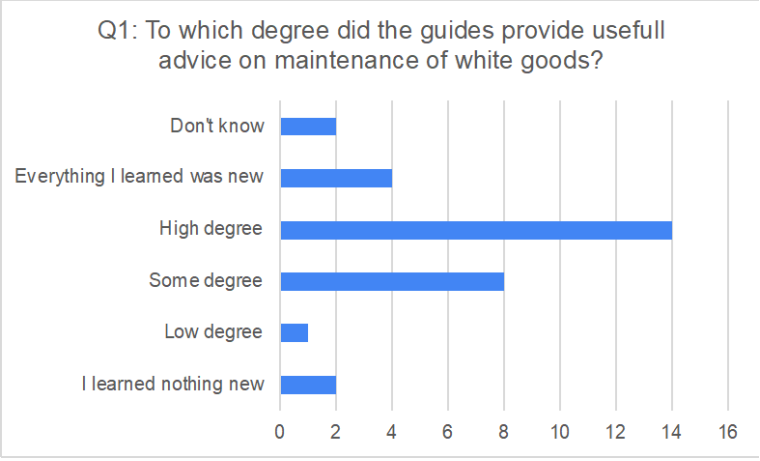

Figure 5 – Responses to question 1

More than half (56.7%) of the respondents considered the reminders to have a high or decisive degree on their behaviour for getting the maintenance done (see Figure 6). This finding is supported by the open text field where 10 of the respondents indicated that reminders were important to get maintenance done, as exemplified by this quote: "*I think the product was great, particularly because I was reminded of maintenance*". One respondent stated that they already did some maintenance, and no negative comments were stated regarding the reminders.

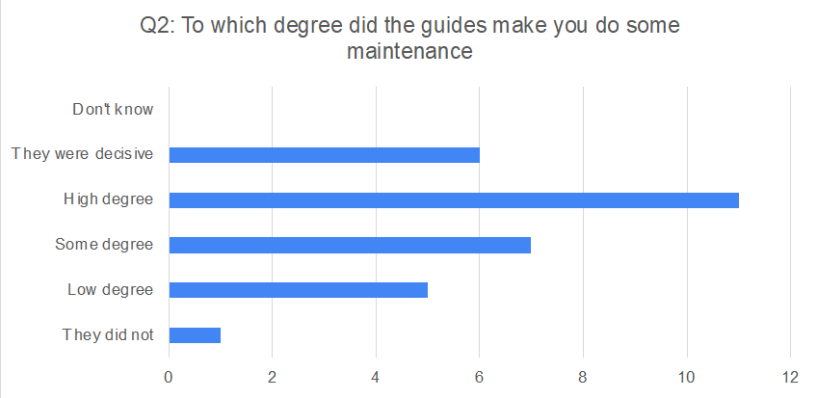

Figure 6 – Responses to question 2

The data from the email service shows a downward trend in terms of reminders being opened and clicked (See Figure 7). When an email was opened it was registered as "open" and a subsequent click on a link to a guide is registered as "click". Data for text messages is not included. Data were tracked for an 8-month period during which few customers were added, and few cancelled their subscription.

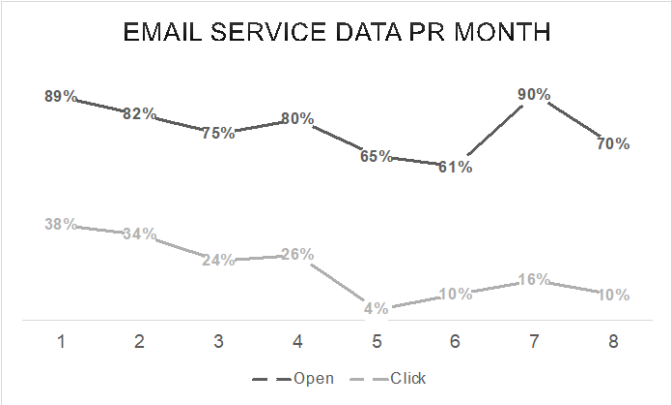

Figure 7 – Data from email service pr. month

4.2 Company B: Repair

Two cases of repair assisted by information exchange were identified with company B. These are examples of small problems that could be handled over the phone and potentially avoid a technician driving out to the customer or the customer scrapping the machine.

4.2.1 Case A: A piece of glass in dishwasher pump

An end-user (customer of the company) contacted the company with a complain regarding a noise coming from the dishwasher when it was running. A call was scheduled between the end-user and the technician. During the first call the technician asked the customer to notice if there was a specific time during the wash cycle that the machine made the noise. A second call was scheduled where the customer informed the technician that the noise came when the machine was pumping water out, and the technician explained the end-user that there probably was something stuck in the pump (e.g. a small piece of glass or porcelain) and instructed the customer to vacuum the pump to remove the foreign object. The customer did as instructed and confirmed over mail that solution worked and solve the problem.

4.2.2 Case B: Lack of cleaning

An end-user complained that the washing machine did not pump water out or was very slow to pump water out. A call was scheduled between the end-user and the technician, and the technician gave instructions on how to clean the pump-filter inside the machine. The filter catches large objects (e.g. coins and hairpins) that enter the machine with the clothes,

and if the filter is clogged, that pump takes longer to remove water from inside the machine. The end-user completed the instruction and confirmed that the solution had solved the problem.

In both cases A and B the problem was identified and solved using a simple technical solution that facilitated the conversation between technician and end-user.

5 Discussion

In the following pages, what emerges from the investigated cases is discussed.

The study confirms that information exchange supports circular economy (De Marchi & Di Maria, 2020), and hence that the information flows between actors must be facilitated, with the case companies acting as facilitators of information. Neither company studied end-user perceptions of the solutions and still managed to support end-users, which provides a different perspective on the necessity of studying user perception before building service (Geelen et al., 2013). One reason could be that the companies relied on proven and known technology.

5.1 End-user information need

The study finds that the information needs of end-users are different for maintenance and repair, respectively. For maintenance, end-users require knowledge about when to do something and what to do, which can be integrated to one information flow where a monthly reminder comprises when and what to do. The information needed can be identified and comprised using existing and available knowledge on maintenance. The findings of the study highlight that end-users have limited knowledge about maintenance indicating the existence of a potential for operationalization of circular economy through reminders of maintenance. For repair the information need is instantaneous, i.e., when a machine stops working, and the needed information exchange cannot be prepared but resides *in situ* with the end-user that must describe the problem, and the technician that must identify and communicate a remedy.

The study finds that the user engagement in maintenance reminders declines over time, demonstrated by the downward trend of emails being opened and clicked. This could indicate that end-users learn and thus are less prone to use the guides which is supported by the 60.3% of the respondents that learned something new through the guides. However, the decline could also indicate a need for feedback on the impact of maintenance to

continuously engage end-user (Geelen et al., 2013), something which company A did not provide to their customers. Future studies could explore the user engagement by adopting a longitudinal approach to study barriers and enablers of long-term engagement.

5.2 Simple tech solution

The study finds that simple-tech solutions (i.e., solutions relying on proven and available technology, e.g., email subscription services and text messages) can facilitate information exchange supporting life-prolonging maintenance and repair. Communication from a company to end-users concerning maintenance can be facilitated by a standard e-mail and text message service, and video guides can be developed using free software. For repair, the solution is more rudimentary; a simple video and voice call service was used. The technologies used by the companies are simple and available at a very low cost, which is in contrast with previous findings, where a low diffusion rate of technology is a barrier for information exchange with high investment costs being a reason for the barrier (Jäger-Roschko & Petersen, 2022). This study places a new perspective on this barrier; there might be a low diffusion rate of technology, but cost is not necessarily a barrier. Instead, a reason for the low diffusion rate could be that companies have yet to develop the services that rely on the technology or perhaps have too grand technological perspectives and thus overlook simple and easily accessible solutions.

The technical solutions identified in this study do not rely on monitoring end-users through sensors; thus, the barrier of privacy is not present (Kim et al., 2017). However, not having sensors makes the advice on maintenance simpler by relying on pre-determined timing on when to do something instead of analyzing data and providing specific advice. This could potentially reduce the impact of maintenance. The findings suggest a potential trade-off between a simple-tech, low-cost, and non-intrusive solution and a high-tech, high-cost, and high-intrusive solution and future studies could address the trade-off and how the different solutions engage end-users.

4 Conclusions: contributions and limitations

Circular business models are important enablers of the shift towards a circular economy, and integration of information flow with the physical product improves efficiency and effectiveness of the business model. There is, however, a lack of empirical evidence for the link between information flow and the life-prolonging activities

maintenance and repair (Jäger-Roschko & Petersen, 2022). This study contributes with empirical evidence through a multiple case study aiming at answering the research questions "What information exchanged between a company and end-user can facilitate maintenance and repair?" and "How can the information exchange be facilitated?".

From the academic point of view, the study contributes to the scarce research about the interplay between information and knowledge management and circular economy. The study indicates that the kind of information that has to be exchanged to support circular economy depends on to the specific nature of the activity involved. The study provides emprical insight on how sharing information on what and when to do something facilitates that end-users engage in maintenance, however, the long-term engagement remains unclear. For repair the problem description and possible solutions is information that must be exchanged when the problem emerges, and a simple voice and video call can facilitate repairs that prolong product life with a minimum cost for the end-user.

For practitioners, the study provides suggestion about the tools that can facilitate information flow and what kind of information to share with end-user to engage them in extending product life.

The study is not without limitations. In particular it is affected by the usual limitations of a case study methodology, and especially the difficult generalization of the results. This paves the way for future research devoted to confirming what emerged from the present analysis, for example, by means of surveys.

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