# Data-driven decision making in circular economy SMEs

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**Abstract.**

This paper studies the data-driven decision-making and management mechanisms and practices in innovative SMEs operating in the evolving circular economy related industries. Being rather new area of business with strong development needs from the viewpoints of sustainable development, new consumer expectations and environmental targets, rapid changes in business environments and competition, as well as frequent changes in legislation cause not only challenges but also new business opportunities to circular economy SMEs. To prepare to the operational changes, optimize their operations, and to develop their competitive advantage, the circular economy SMEs need to continuously develop dynamic capabilities related to the utilization of the data collected from various sources to explore the future challenges and opportunities in their business environment.

In this paper, we present a comprehensive case study consisting of six industrial cases, all representing SMEs operating in the field of circular economy in Fin-land. In the case study, we investigate how the SMEs utilize data in supporting their decision-making on both strategic and operational level. The first interview round was conducted in Oct-Dec 2019. To understand the impact of COVID-19 pandemic to the data-driven decision making, we conducted the second interview round in Oct-Dec 2020. The results predict that descriptive analysis is the mainstream of data utilization in circular economy SMEs whereas there is still much room for improvement in the utilization of predictive analysis methods.

**Keywords:** data-driven decision-making; circular economy; SMEs.

## 1 Introduction

The exploratory utilization of data collected from the business processes, customers, competitors and other sources enables data-driven approaches for various decision-making functions in companies. This is particularly true for the firms that are operating in rapidly changing business environments, in which a firm may obtain significant competitive advantages by coming up with new innovations and customer solutions. Organizations adopting a data-driven approach may have opportunities to improve their business and outperform other organizations [1]. However, due to their relatively

small organizations, SMEs are often rather streamlined and limited with their financial resources and capabilities. For this reason, developing capabilities to utilize data in their business analytics and operations is particularly important for the SMEs.

Circular economy is based on closed-loop production systems and material flows. It aims to reuse materials and decrease the need of virgin materials that requires implementation of reverse supply chain and co-operation between actors [2]. The principal logic of the circular economy is to convert waste into resources by applying technical or biological conversion. The outcome of the conversion can be re-used in an industrial process or returned to the biosphere [3]. The business concepts related to the area of circular economy aim at addressing to sustainable development needs by minimizing resource input and waste, emissions, and energy leakage, without jeopardizing growth and prosperity [2]. The circular economy companies are showing increasing interest to invest in business intelligence and other practical data-based tools that enable them to make systematic planning for the future on both strategic and operational levels [5]. Business data also provides the companies basis for rapid and rational decision making concerning their key operations, including business and product development. However, for SMEs full utilization of data often causes challenges that may be related to e.g. lack of competences and capabilities or missing understanding of the business potential of the data utilization [6].

This paper studies the data-driven decision-making and management mechanisms and practices in innovative SMEs operating in the evolving circular economy related industries. The paper seeks to answer the following research question: *How the SMEs operating in the area of circular economy utilize data in supporting their decision-making?* We aim at finding answers to this question on both strategic and operational levels by means of a comprehensive case study consisting of seven industrial cases. In the case analysis, we approach the main research question from three separate viewpoints (sub-questions): *1) What data is utilized in strategic decision making? 2) How data is utilized in decision making? 3) How much Covid-19 is affected to data utilization in decision making?* The case data used in this paper has been collected during two interview rounds, which enables us to draw conclusions regarding the im-pact of COVID-19 pandemic to the data-driven decision-making and management in circular economy SMEs.

## 2 Data-driven decision making in SMEs

Increasing digitalization and massive volumes of data provide new sources of value for companies [7]. The impact of data on the economy has also been referred to as ‘the new oil’ [8]. Yet, many SMEs face challenges in making use of this ‘new oil’ [9]. Challenges in harnessing big data peculiar to SMEs include: low level of understanding of big data, classifying emerging developments such as big data analytics as hysteria and not as a viable business opportunity, lack of adequate infrastructure to analyze data, lack of in-house data-analytic experts, lack of representative case studies and success stories with respect to big data analytics in SMEs, lack of expertise and

selecting suitable solutions, effort needed in order to understand the available data, dirty data and other data quality issues, etc. [9–12]

### 2.1 Types of data

A good question is also what kind of data can be used in the data-analytics. Data at disposal of SMEs can be machine-generated (e.g. data that comes from machines, sensors, mobile phone applications, computer networks, etc.), human-generated (data collected by people e.g. name, address, telephone number etc.; and data generated in technology-mediated interactions via documents, emails and social media services), and business-generated such as transaction data from point of sales or enterprise resource planning systems [13, 14]. Furthermore, data can originate from internal sources or external sources. External data sources include, for instance, open data, acquired data, customer provided data and freely available data [15].

### 2.2 Data analytics in decision-making

Data can be used in decisions making in various ways and SMEs may lack understanding, what analytical methods are available in the first place, and which of these could be feasible in their context. Analytical methods that support in improved decision making are illustrated in Figure 1.

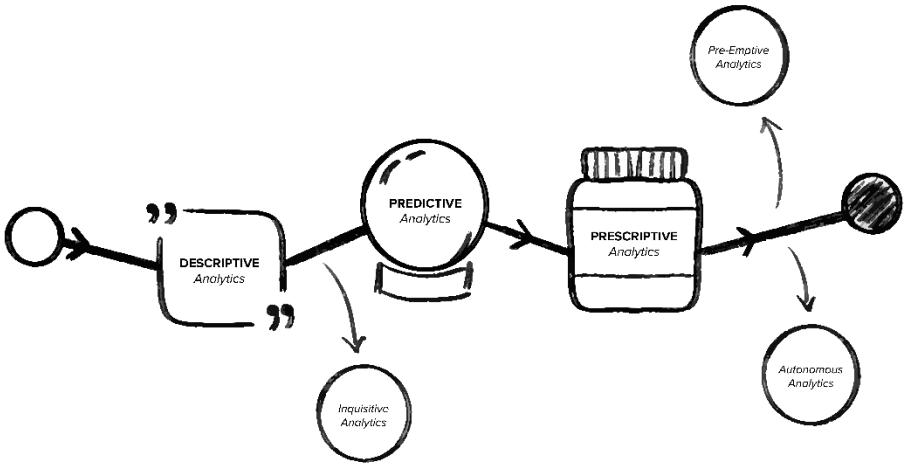


**Fig. 1.** Data analytics methods for improved decision making [16].

Each of the data analytics method can be used to answer various business questions. Next are outlined some typical business questions that can be addressed with these methods [16–18]:

- Descriptive analytics: Analytics that help in understanding, e.g. “What happened? How many, how often, where? What actions are needed?”
- Diagnostive or inquisitive analytics: Analytics that help in comprehending, e.g. “Why did something happen? Why is this happening?”
- Predictive analytics: Analytics that help in anticipating, e.g. “What if these trends continue? What will happen next? What is likely to happen in the future?”
- Prescriptive analytics: Analytics that help in responding to “Now what? What happens if we try this? What is the best that can happen? What actions should be taken?
- Pre-emptive analytics: Analytics that help in recommending “What is re-quired to do more?”
- Autonomous analytics: Analytics that help to understand the data with-out human hypotheses and minimal involvement of human analysts: “What can we learn from the data? What if we take action?”

For applying these analytic methods, several alternatives are available from relatively simple statistical and optimization tools in spreadsheet, traditional software packages, data visualization and analytics tools, descriptive, predictive and prescriptive analytics tools to open source programming environments [17]. While large corporations have specialist data scientists and the technology infrastructure in-house, SMEs may lack both the expertise and tools to benefit from data-analytics [10] or they may be unaware that they possess this capability.

### 2.3 Data analytics in circular economy SMEs

Kristoffersen et al. [19] have explored the relationship between data science and circular economy. Their focus is on how organizations can better structure their data understanding and preparation in order to align business objectives and circular economy related objectives. They propose that suitable utilization of data and analytics can have major efficiency improvements supporting sustainable and circular economy.

Supply chain requires information flows that enables sharing and optimizing material flows and can be supported by the key enabling technologies of Industry 4.0 [20]. The key challenge when reusing waste material, is material quality and the barrier is information exchange relating to the material flow supply and demand, transportation, and infrastructure [21]. SMEs face the requirements to provide information of the circular economy benefits to convince the customer and they find it challenging to get support from the supply and demand network [22]. Industrial networks provide opportunities to create value from waste by closing material loops among companies, but there are also various barriers, such as lack of information management systems, technological and financial resources, qualified professionals, and managerial commitment [23].

# 3 Methodology

In this paper, we conduct a comparative qualitative case study on seven SMEs operating in the area of circular economy. All the case companies are located in Finland. The case companies provide services related to waste management, biogas production, material recycling or the manufacturing of products based on waste materials. The empirical data used in this study was collected by interviewing company executives, mainly CEOs, in autumn 2019 and 2020. All the interviews were recorded and transcribed prior to analysis. The interview questions sought insight on how companies are utilizing data in strategic decision making, and what kinds of impacts the COVID-19 may have had on the data utilization. Table 1 displays a summary of the case companies.

**Table 1.** Case Descriptions.

| Case | Interviewed person | Number of employees | Industry | Core business area |
|---|---|---|---|---|
| Case A | COO | 50 | Combined facilities support activities | Waste management, recycling services and solutions for households and companies |
| Case B | Service Manager | 60 | The treatment and disposal of non-hazardous waste | Waste management and recycling services for households and companies |
| Case C | CEO | 80 | The treatment and disposal of non-hazardous waste | Waste management and recycling services for households and companies |
| Case D | Marketing and sales coordinator | 20 | Town and city planning | Environmental engineering design and delivering biowaste treatment solutions |
| Case E | CEO | 40 | The recovery of sorted materials | Recovering sorted materials |

| | | | | |
|---|---|---|---|---|
| Case F | CEO | 10 | The dismantling of wrecks | Recycling services for wrecks |
| Case G | CEO | 10 | The manufacture of other food products | Recycling and processing of oil-based material into fuel and animal feed |

# 4 Results

In this chapter, we summarize the results of the analysis made based on the case-specific interviews. This chapter is divided into three subchapters, each of which presenting the key results of the interviews from the viewpoint of our three sub-research questions. Some key results of the case data are also summarized in Table 2.

## 4.1 What types of data is utilized in strategic decision making?

Based on the interview data, most often companies mentioned business-generated data. Data that companies are utilizing relates to their own finances, efficiency of the production and collection-routes, material-specific and customer-specific volumes, customer experience and satisfaction. These were the most often used internal business-generated [15] data sources in the interviewed Circular Economy companies.

*We are utilizing data too little. Our financial data is somewhat in use. (Case D)*

*We utilize data of the number of our client companies and the amount of waste generated in them. (Case B)*

Companies mentioned that they use data describing competitors' development and financial condition, granted construction-permits and forthcoming initiatives, price trends of material fractions and country-specific data. These data sources rep-resent external data sources [15]. One case company mentioned partner company as an important data source to provide forecasts of forthcoming waste volumes.

*In a competitive situation, we utilize as external data, our competitors' financial data to monitor their situation. (Case D)*

*We utilize data on the price trends and seasonal variation of material fractions. (Case F)*

Strand & Syberfeldt [24] stated that external data may be the key asset for organizations, but most organizations primarily utilize internal data. They found that valua-

ble data for waste management companies can be found from the following external data sources: maps, orthophotos and road data; property and civil data; traffic & weather data. Compared to the companies we interviewed, none of them mentioned these external sources. Reason for this might be the fact that SME's may lack the expertise and tools to benefit from data analytics [10]. This requires more research in the future.

### 4.2 How data is utilized in decision making?

Based on the interview data, all seven interviewed companies conduct descriptive analytics and two of them conduct predictive analytics. These companies use data in production planning, process development, investment planning, competition, and internationalization. Data is utilized for example for making material-specific decision whether the company should process the material or to source processing as a service. Descriptive analytics shows the current states of a business, predictive analytics allows forecasting and shows future possibilities [16].

*The bottom line is that we have an adequate load, we can provide staff with work, we keep the work productive, and we make data-driven decisions about which direction to go. (Case A)*

*We've had to analyze more closely what we're doing, what works and what doesn't. Changes in the clients have required us to make operational changes. (Case A)*

*We are preparing to make investments and evaluate whether it is worth processing materials themselves or sourcing as a service. (Case B)*

*You always must quantify things that where we are, where we're going, and what road we're going to take. Data itself is the big value for us, through which we justify our decisions. (Case E)*

Predictive analytics allows forecasting and may indicate future opportunities [16]. This analysis type was mentioned as a data analysis method in two interviewed company cases. These companies utilize data to determine their stock size according to the price fluctuation or to predict forthcoming movements in the market.

*We collect external data on the financial situation of our customers and competitors to conclude, what kind of movements it is possible for them to make. Combining this information with a view of the market, we know who would be able to build the facility and, on the other hand, who could order it. (Case D)*

*In terms of the material fractions we sell, we aim to outline how large stocks we want or can hold, whether it's worth waiting for a price hike or whether the variation is unpredictable. (Case F)*

According to Strand and Syberfeldt [24], descriptive analytics in waste management company shows annual waste volumes and number of bins, while predictive analytics predicts required emptying fees for different bin types for the coming years, whereas prescriptive analytics optimize the number and configuration of vehicles as well as fuel consumption. Our interview results support these findings, for instance the interviewees indicated that descriptive analytics methods help them to keep the work productive. As predictive analytics they mentioned external data of the financial situation of their customers and competitors, to anticipate what is likely to happen in the market. Another example relates to the price fluctuation and defining the stock size.

### 4.3 How much COVID-19 is affected to data utilization in decision making?

Based on our interview data, COVID-19 pandemic has had only a minor impact on how data is utilized in our seven case companies Some companies found that data utilization should be further developed to allow forecasting and timely decision-making. During the COVID-19 pandemic, companies have had to analyze their own activities due to changes in their clients.

*We realized the need and had an opportunity to develop data utilization. We found that processing information must be more real-time to be able to make the right decisions in the right moment. (Case A)*

*We recognize that we need to develop data utilization in decision-making. We found during COVID-19 that if data utilization was better, we would be able to anticipate earlier. We learned the hard way that it should be done. (Case D)*

*Not affected exactly. As regards the export of material fractions, we monitor shipping routes, restrictions and in which locations the transport fleet accumu-lates. The location of transport equipment affects export costs. (Case F)*

For the time being, Finland has coped better with COVID-19 than many other industrialized countries. There have not been wide restrictions or lockdowns in society, which might give explanation to our interview results. The companies indicate that COVID-19 hasn’t had at all, or only a minor impact to data utilization in decision making. The companies we interviewed, highlighted increased consumer waste as well as infectious waste from hospitals due to COVID-19. Thus, our interview results sup-port the earlier findings of Ibn-Mohammed et al. [25] that reviewed the impacts of COVID-19 for global economy and observed that Circular Economy business relate to the increase of consumer waste caused by social distancing, online buying and takeaway food as well as increasing volumes of waste from the healthcare industry that can be infectious.

*If the COVID-19 situation gets bad, then preparedness planning will start in waste facilities: what kind of waste flows we should be prepared for, for example, for the treatment of contaminated hospital waste from which diseases can spread. (Case B)*

Ibn-Mohammed et al. [25] also expect that digitalization of supply chain enables companies to attain resilience towards global pandemic. Digitalization enables intelligent assets to share location, condition, and availability, as well as preventing failures across the supply chain. They stated that another view for digitalization must keep in mind: even the digital technologies can provide great benefits, they are affecting to the environment harmfully by increasing energy consumption and material consumption by device production.

The following Table 2 summarizes the findings presented in this chapter.

**Table 2.** Summary of utilized data types, data analytics, and the effect of COVID-19 in each case.

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1.What data is utilized in strategic decision making? | | | | | | | |
| machine-generated | x | x | x | x | | | |
| human-generated | x | | x | | x | | x |
| business-generated | x | | x | x | x | x | x |
| 2.How data is utilized in decision making? | | | | | | | |
| descriptive | x | x | x | x | x | x | x |
| predictive | | | | x | | x | |
| prescriptive | | | | | | | |
| 3. How much COVID-19 is affected to data utilization in decision making? | | | | | | | |
| not at all | | x | x | | x | x | x |
| only a little | x | | | x | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| to some extent | | | | | | | |
| rather much | | | | | | | |
| very much | | | | | | | |

As observable from Table 2 there were only little impacts of COVID-19 on utilization of data in decision making. Descriptive analysis was the main approach for the data utilization in all the companies. Most often used data source was business generated data, while some companies made use of also machine-generated data and human-generated data.

## 5 Discussion

In this paper, we have studied the data utilization in seven SMEs operating in the area of circular economy by means of a qualitative case study. The main goal of the study was to improve understanding on how these companies utilize data in supporting their decision making. In our analysis, we approached our main topic from three separate but interconnected viewpoints. The first viewpoint was related to the types of the utilized data. Our empirical data revealed that the business generated data that was most often coming from the companies' internal processes, was the most utilized data type. However, the external data related to competitors, material flows, and construction have growing value in the companies' operational management and planning.

The second viewpoint focused on the data analysis methods used by the case companies. The results revealed that descriptive analysis was the mainstream type for the data utilization in all the companies. This was not surprising, since the daily operational management in the SMEs obviously relies on the descriptive analysis that analyses the current state of the business. However, two of the case companies utilized also predictive analytics that allows forecasting and exploring of the future opportunities. The interview data showed that those companies that are utilizing predictive analytics have clearly understood the meaning and value of the data-driven decision making in strategic planning and management. However, our analysis also shows that there is significant room for improvement in the utilization of data in the circular economy SMEs, who would clearly benefit from efficient predictive analysis methods.

As the third viewpoint, we inspected the impacts of the current COVID-19 pandemic on the data utilization in the circular economy SMEs. Whereas the societal impacts in Finland have been quite low in general, also our conclusion is that the pandemic has had a minor impact on the SMEs studied. However, digitalization and the development of advanced data utilization in circular economy sector can clearly advance sustainable material usage, and also contribute to the building of resilient business in this area.

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## References

1. Watson, H.J.: Creating a Fact-Based Decision-Making Culture. Bus. Intell. J. 21, 5–9 (2016).
2. Urbinati, A., Chiaroni, D., Chiesa, V.: Towards a new taxonomy of circular economy business models. J. Clean. Prod. 168, 487–498 (2017). https://doi.org/10.1016/j.jclepro.2017.09.047.
3. McDonough, W., Braungart, M.: Cradle to Cradle: Remaking the Way We Make Things. North Point Press (2010).
4. Rizos, V., Behrens, A., Kafyeke, T., Hirschnitz-Garbera, M., Ioannou, A.: The Circular Economy: Barriers and Opportunities for SMEs. CEPS Working Documents No. 412/September 2015. (2015).
5. Järvenpää, A.-M., Kunttu, I., Mäntyneva, M.: Foresight to Shape Future Expectations in Circular Economy SMEs. Technol. Innov. Manag. Rev. 10, 41–50 (2020).
6. Ormazabal, M., Prieto-Sandoval, V., Puga-Leal, R., Jaca, C.: Circular Economy in Spanish SMEs: Challenges and opportunities. J. Clean. Prod. 185, 157–167 (2018). https://doi.org/10.1016/j.jclepro.2018.03.031.
7. Ruohomaa, H.: Ecosystem-based development in the transition of fourth industrial revolution, http://urn.fi/URN:ISBN:978-952-476-931-0, (2020).
8. Hilbert, M.: Big data for development: A review of promises and challenges. Dev. Policy Rev. 34, 135–174 (2016).
9. Iqbal, M., Kazmi, S.H.A., Manzoor, A., Soomrani, A.R., Butt, S.H., Shaikh, K.A.: A study of big data for business growth in SMEs: Opportunities & challenges. In: International Conference on Computing, Mathematics and Engineering Technologies (iCoMET). pp. 1–7. IEEE (2018).
10. Parra, X., Tort-Martorell Llabrés, X., Ruiz Viñals, C., Álvarez Gómez, F.: A maturity model for the information-driven SME. J. Ind. Eng. Manag. 12, 154–175 (2019).
11. Ransbotham, S., Kiron, D., Prentice, P.K.: Beyond the hype: the hard work behind analytics success. MIT Sloan Manag. Rev. 57, (2016).
12. Kim, W., Choi, B.J., Hong, E.K., Kim, S.K., Lee, D.: A taxonomy of dirty data. Data Min. Knowl. Discov. 7, 81–99 (2003).
13. Saggi, M.K., Jain, S.: A survey towards an integration of big data analytics to big insights for value-creation. Inf. Process. Manag. 54, 758–790 (2018).
14. Olshannikova, E., Olsson, T., Huhtamäki, J., Kärkkäinen, H.: Conceptualizing big social data. J. Big Data. 4, (2017). https://doi.org/10.1186/s40537-017-0063-x.
15. Hartmann, P.M., Zaki, M., Feldmann, N., Neely, A.: Capturing value from big data–a taxonomy of data-driven business models used by start-up firms. Int. J. Oper. Prod. Manag. 36, (2016).
16. Sivarajah, U., Kamal, M.M., Irani, Z., Weerakkody, V.: Critical analysis of Big Data challenges and analytical methods. J. Bus. Res. 70, 263-286. (2017).
17. Davenport, T., Harris, J.: Competing on analytics: Updated, with a new introduction: The new science of winning. Harvard Business Press (2017).

18. Husamaldin, L., Saeed, N.: Big data analytics correlation taxonomy. Information. 11, 17 (2020).
19. Kristoffersen, E., Aremu, O.O., Blomsma, F., Mikalef, P., Li, J.: Exploring the Relationship Between Data Science and Circular Economy: An Enhanced CRISP-DM Process Model. In: Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). pp. 177–189. Springer Verlag (2019). https://doi.org/10.1007/978-3-030-29374-1_15.
20. Centobelli, P., Cerchione, R., Chiaroni, D., Del Vecchio, P., Urbinati, A.: Designing business models in circular economy: A systematic literature review and research agenda. Bus. Strateg. Environ. 29, 1734–1749 (2020). https://doi.org/10.1002/bse.2466.
21. Winans, K., Kendall, A., Deng, H.: The history and current applications of the circular economy concept. Renew. Sustain. Energy Rev. 68, 825–833 (2017). https://doi.org/10.1016/j.rser.2016.09.123.
22. Rizos, V., Behrens, A., van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., Flamos, A., Rinaldi, R., Papadelis, S., Hirschnitz-Garbers, M., Topi, C.: Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers. Sustain. 8, (2016). https://doi.org/10.3390/su8111212.
23. Ormazabal, M., Prieto-Sandoval, V., Puga-Leal, R., Jaca, C.: Circular Economy in Spanish SMEs: Challenges and opportunities. J. Clean. Prod. 185, 157–167 (2018). https://doi.org/10.1016/j.jclepro.2018.03.031.
24. Strand, M., Syberfeldt, A.: Using external data in a BI solution to optimise waste management. J. Decis. Syst. 29, 53–68 (2020). https://doi.org/10.1080/12460125.2020.1732174.
25. Ibn-Mohammed, T., Mustapha, K.B., Godsell, J., Adamu, Z., Babatunde, K.A., Akintade, D.D., Acquaye, A., Fujii, H., Ndiaye, M.M., Yamoah, F.A., Koh, S.C.L.: A critical review of the impacts of COVID-19 on the global economy and ecosystems and opportunities for circular economy strategies. Resour. Conserv. Recycl. 164, (2021). https://doi.org/10.1016/j.resconrec.2020.105169.