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Designing Configurator for Take-Back for a Circular Economy - A Conceptual Framework

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Abstract

Closing the material loop is fundamental to circular economy (CE). However, significant quantities of resources are currently landfilled. Today, companies realise the importance of take-back for CE but face several barriers in implementing it, lack of knowledge, being one such barrier. To address this, a proposal is presented for the design of a configurator to support companies evaluate different approaches, as well as opportunities and challenges for designing and implementing take-back. The paper presents a conceptual framework for the configurator, based on a systematic literature review.

Keywords: conceptual design, circular economy, take-back, configurator, sustainability

1. Introduction

The current predominantly linear production- and consumption-based economy has resulted in serious environmental problems. Increasingly shorter product life cycles coupled with the linear (take-make-dispose) economy has resulted in scarcity of natural resources and a significant surge in waste generation (Bhatia et al., 2020; Gupt and Sahay, 2015). Globally, only 30% of the waste material collected involves resource recovery (material recovery 11%, energy recovery 19%) (Singh and Ordoñez, 2016). In this scenario, implementing a closed-loop supply chain and take-back systems has become necessary for organisations. “Take back” includes the activities involved in transferring the used product from customers’ possession to the recovery site (Ghoreishi et al., 2011). It is a multifaceted process needing special attention for managing it, including additional capabilities that are different from those required in forward or traditional logistics (Bhatia et al., 2020; Ghoreishi et al., 2011). Though companies today realise the importance of take-back systems, they often face challenges in designing and implementing them (Vaz et al., 2013) for many reasons, not least due to a lack of knowledge, and experience in take-back practices and lack of skilled professionals in this field (Waqas et al., 2018). These challenges spell the motivation for the design of a configurator, outlined in this paper, that can help companies to design take-back for their products. The overarching question this paper seeks to address is how to design a configurator that can help establish take-back systems?

The rest of the paper, following this introduction, is organised as follows: firstly, in section 2, the research methodology is described. Section 3 elaborates key findings from the systematic literature review. In section 4, the authors present a conceptual framework of the configurator. In section 5, the authors present their conclusion. Further work areas are also elaborated in this section.

2. Methodology

A systematic literature review (SLR) was carried out related to the various activities in a take-back system, including the factors that influence, motivate, drive, or constrains take-back design, plus the decision criteria for a take-back, and metrics to measure performance or success of take-back.
The first step in the SLR was to identify relevant keywords and search strings, which was achieved via a preliminary literature review, to scope the field. It was revealed that existing literature covers the subject of take-back under "reverse logistics" or "closed-loop supply chain" or "reverse supply chain." The search string chosen for this work therefore comprised the following: ("take back" OR "reverse logistics" OR "reverse supply chain" OR "clos* loop supply chain") AND (step* OR stage* OR process* OR activity OR driver* OR factor* OR challenge* OR constraint*) AND (waste OR "end of life" OR "post consumer waste"). Scopus was chosen as the scholarly database for the SLR, due to its coverage of both technical and socio-technical subject matter. Further, exclusion criteria were applied to the screening process, namely that English-language journal papers published in the past ten years (between 2010 and March 2021) were in scope. The search yielded 658 articles. These articles were subject to a screening of titles and abstracts. Articles were excluded if they focused on the development of quantitative or algorithmic models for optimising logistics, route planning, number of collection or recycling centres, collection volumes and/or costs, and carbon footprint - as these elements were not in the main interest for such a configurator design. The resulting literature pool counted 108 articles (as shown in figure 1).

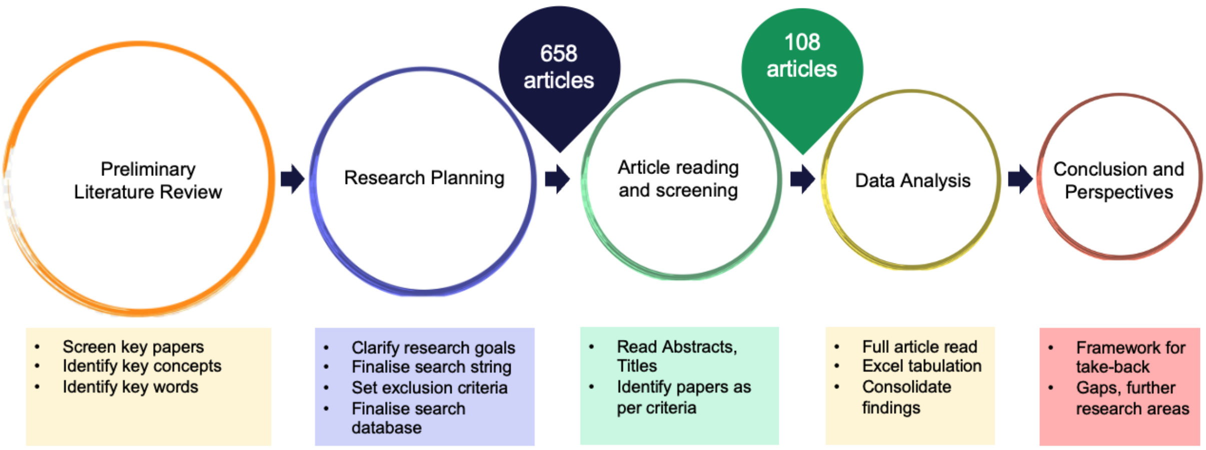

Figure 1. Methodology for systematic literature review

The 108 articles were analysed initially by full article reading and summarising the content based on the main objectives of their work. The study is carried out using the research framework provided by DeBrito (De Brito and Dekker, 2002), who analyse the topic from three main viewpoints: (1) why (the drivers for initiating take-back); (2) how (the actors and the processes in take-back); and (3) what (the product and its characteristics). Additional information was added to the categorisation of all articles, including: the product in focus for take-back; the geography; and the year of publication. A spreadsheet was used to capture and filter the data on the chosen and reviewed articles. Finally, the key concepts and subject areas identified in the SLR formed the basis of the development of conceptual framework for take-back configurator.

3. Findings

The selected papers reviewed in detail in the SLR covered a wide variety of products (18 in total), though a vast majority of the papers focused on waste from electrical and electronic equipment (WEEE) followed by unused medicines, Municipal Solid Waste (MSW) and plastics (as shown in figure 2). The geographical spread of the articles was also interesting, covering a broad range of countries and a particularly significant amount from Brazil.

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From a content perspective, the papers covered a varied set of subjects, as can be seen by figure 3. A few papers covered multiple areas. Key performance indicators (KPI's), behavioural aspects and reverse logistics were the top subjects covered, followed by descriptions of take-back and collection models.

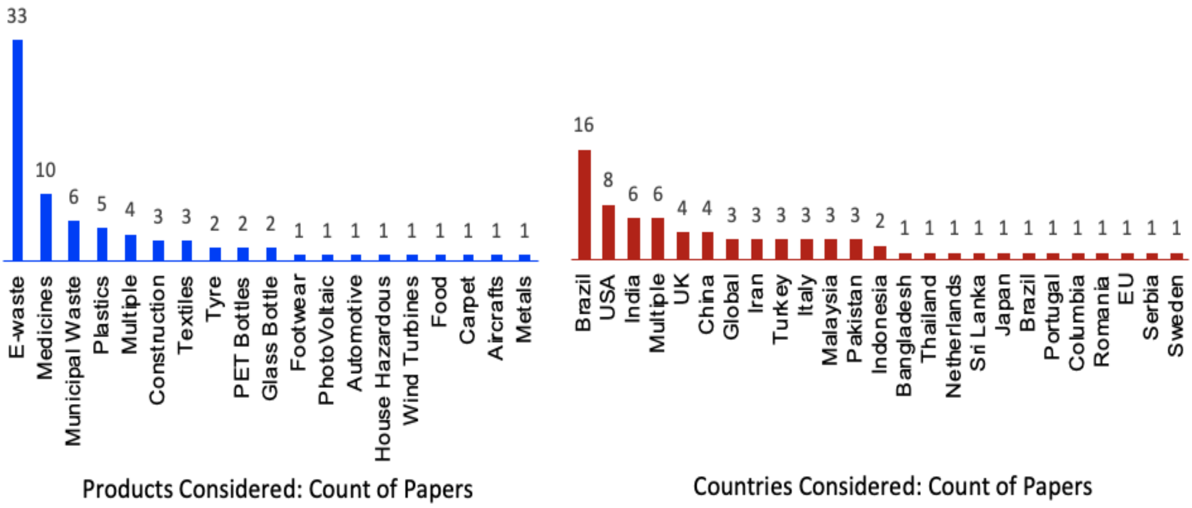

Figure 2. Count of papers covering products and countries

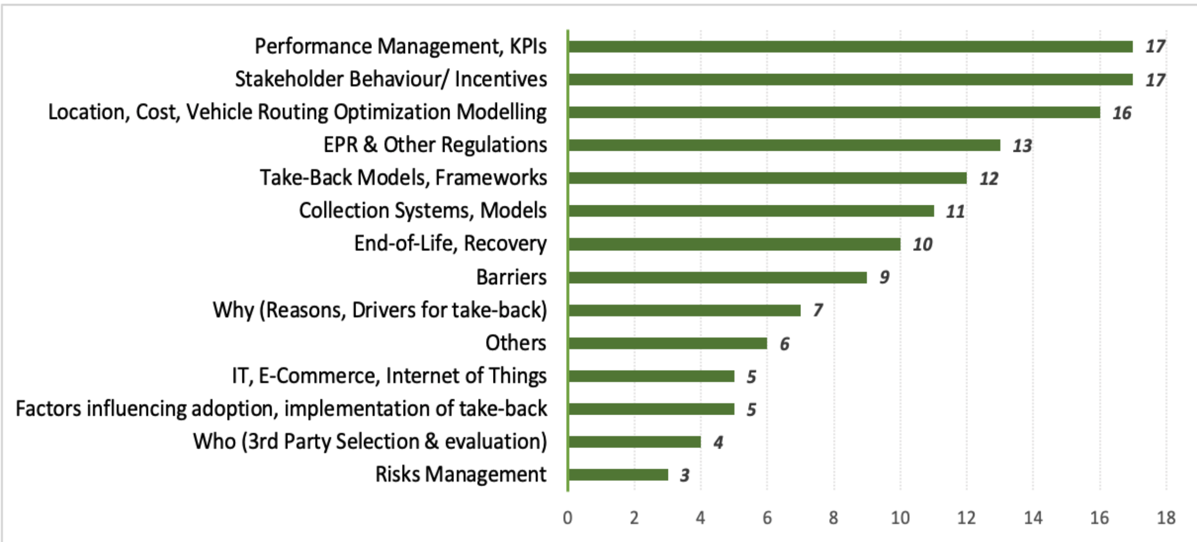

Figure 3. Aspects of take-back covered in systematic literature review

Following this high-level view of the data analysed, the subsequent sub-sections focus on some of the key aspects identified in the SLR structured according to the framework from DeBrito and Dekker.

3.1. Why: the drivers for take-back

Various authors have studied the reasons for companies to take back their products at different stages of product life cycle for e.g., manufacturing returns, commercial and warranty returns, products at their end-of-use or end-of-life (EoL). While exploring the level of adoption among manufacturing companies in Malaysia, Abdullah and Yaakub, (2014) grouped the driving forces into four categories: (i) regulation; (ii) customer expectation; (iii) financial and competitive reasons; and (iv) corporate citizenship (Abdullah and Yaakub, 2014). They found that regulations have the most significant influence, while customer expectations have a moderate influence. Regulations mandate producers to take back their products. The directives on EoL vehicles, electronic waste (WEEE), and

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packaging in Europe, for example, mandate companies to recover their products (van der Wiel *et al.*, 2012). Market forces, in terms of the economic and strategic drivers can also significantly influence companies' decisions to initiate take-back as evidenced in the Dutch metal industry in the Netherlands (van der Wiel et al., 2012). Decrease in production and initial purchasing costs or reduced energy consumption associated with reuse, remanufacturing, or recycling of products are ways of harnessing the economic benefits. Krikke et al. (2013) completed a comprehensive global survey to understand drivers of returns; they distinguish between early returns (commercial, warranty returns) and returns in the life cycle (EoL, end of use (EoU)) and conclude that the drivers for commercial and warranty returns are market-driven (Krikke et al., 2013). With regards to EoL returns, they note that Extended Producer Responsibility (EPR) legislation is growing across the world as governments adopt recycling schemes. Vaz et al. (2013) argue that enhancing the corporate image is a priority goal in most reverse logistics programmes, since it helps differentiate a company's products from its competitors (Vaz et al., 2013). Corporate image, in turn, is an outcome of corporate behaviour in terms of corporate citizenship and adherence to regulations.

3.2. What: the product and its characteristics

The papers in this SLR covered 18 product categories, as detailed in figure 2. DeBrito mentions that it is not just the product but also its characteristics that need to be considered for designing take-back systems. The essential aspects of product characteristics are: their composition; the use pattern; deterioration; dimensional size; and packaging solution (De Brito and Dekker, 2002; Xie and Breen, 2014). The product composition can be assessed in terms of ease of disassembly, the homogeneity of the product constituents, presence of hazardous materials, and ease of transportation. The product use pattern can vary based on location and duration of use, influencing collection system design. The deterioration aspect determines the residual value and or the functionality of the product after use. Product dimension can also influence the ease of collection, e.g., large electronic appliances vs. batteries or medicines. Wind Turbines, for instance are very large products, the take-back-channel structure therefore needs to start with disassembly on-site at wind farms (Ortegon *et al.*, 2013).

3.3. How: the actors and the processes

De Brito describes the 'how' in terms of the actors and the processes involved in recovering value. While the actors can be returners, receivers, and collectors/processors, the processes can be categorised as the collection (acquisition of products from customers up to a recovery point), selection and sorting, recycling, or reprocessing, and finally redistribution (i.e., bringing the recovered goods to new users).

3.3.1. Collection system

The OECD defines waste collection as the collection and transport of waste to the place of treatment or discharge (Han and Cueto, 2015). The collection could be for a specific type of product or cover multiple kinds of waste simultaneously. The collection system is often one of the most critical elements in a take-back system, it could be very challenging to collect products from millions of residents or users of products and aggregate them for further processing (Esposito et al., 2018). Collection systems can also depend on consumers properly segregating, storing, and transferring waste to the drop-off/collection point, making convenience an essential factor (Wagner et al., 2013). This may, however, conflict with the cost or profitability of recycling (Tong *et al.*, 2018). Studies have investigated various aspects of collection systems, e.g. the collection models, key characteristics of collection channels (Alkahtani *et al.*, 2021), criteria for selecting collection models (Shumon *et al.*, 2016) etc. The collection models vary widely across product categories. Table 1 elaborates some of the models found in the literature.

These collection models may be summarised as falling into one or more of the following categories: consumers drop-off at collection points (situated at convenient locations e.g., retail stores, pharmacies, etc), door to door collection, mail-back solutions, informal sector-based collections, e-commerce-based systems, or hybrid solutions. Choice of collection model for take-back is often linked to design of business models for a circular economy in the literature (Centobelli et al., 2020).

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Table 1. Collection systems for various products

Product	Collection Models	Reference
Textiles	1. Donation partnership with charity organisations 2. In-store take-back schemes in collaboration with third-party 3. In-store voucher-based take-back schemes by brands 4. Direct leasing agreements with customers (e.g., carpets)	(Hvass, 2014)
WEEE	1. Retailers under legal obligation or voluntary basis	(Salhofer *et al.*, 2016)
	2. Municipal Collection Centres	(Isernia *et al.*, 2019)
	3. Voluntary Collection Events	(Alves *et al.*, 2021)
	4. Reverse Vending Machines (RVMs) at various places	(Tong *et al.*, 2018)
Used Batteries	Battery retailers, outdoor recycling banks	(Xie and Breen, 2014)
Medicines	Pharmacies, GP surgeries	(Xie and Breen, 2014)
Beverage containers	Deposit-Refund Systems	(Ahlers *et al.*, 2021)
Household Hazardous (HH) Waste	1. Designated HH hazardous waste facilities 2. Special collection events 3. Voluntary retail take-back 4. Mail-Back	(Wagner *et al.*, 2013)
Internet (ICT) models	1. Barcodes on waste. A scan by collector generates coupons 2. Reverse Vending Machines (bottle, mobiles, batteries) 3. E-commerce platform bridge consumer & recycler	(Tong *et al.*, 2018)
Postal Services	1. Pre-paid shipping labels to consumers (small appliances) 2. Post Office as collection points: e.g., ink cartridges in Japan	(Esposito *et al.*, 2018)
Informal sector based	1. Material Recovery Facilities (MRFs) - e.g., in Brazil 2. Waste Pickers' Cooperatives	(Ferri *et al.*, 2015)
Hybrid Models	A mix of Formal and Informal Enterprises	(Tong *et al.*, 2018)

3.3.2. Resource recovery

Different authors have studied the EoL or EoU options for different products – for instance Uriarte-Miranda et al. (2018) studied the remanufacturing (retreading) and diversification options for car and truck tyres in Russia and Mexico (Uriarte-Miranda et al., 2018). Ortegon et al. (2013) explore the critical factors and remanufacturing and recycling for the end-of-service life of wind turbines (Ortegon et al., 2013). Singh and Ordoñez (2016) analysed over 50 examples of products developed from discarded materials and observed that these are mainly made into different types of products and not into the same product, which is one of the principles of a circular economy (Singh and Ordoñez, 2016). Recycling practices can also vary between geographies, as identified by Salhofer et al. (2016), while comparing WEEE management in Europe and China (more manual dismantling and separation of components in China versus mechanical processing in Europe driven by high costs of manual labour) (Salhofer et al., 2016). Identifying the most appropriate option for resource recovery can be an essential aspect of a take-back system not just from an environmental perspective (capturing the functional and or material value) but it can also have an impact on the economic performance (Bockholt et al., 2020). Decision models can help identify appropriate reprocessing option for take-back products based on technical, economic, and environmental factors (Abdessalem et al., 2012). Recovery can be categorised into material recovery (through recycling) or value-added recovery, which can be either direct (i.e. the product is put back into the market after the first period of use) or reprocessing and reworking of the product or its components (van der Wiel et al., 2012). Energy recovery (co-processing) could be an option for a wide range of products and industrial wastes (Kadel et al., 2014).

3.3.3. Regulation

Regulations can be one of the most significant reasons for initiating take-back; it's evident from the growing EPR regulations (Temur and Bolat, 2017). The waste directives in the EU for vehicles, electronic waste (WEEE), packaging, and batteries are some examples. Brazilian National Waste

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Management Regulation (PNRS), together with its sectoral agreements (SA) influence the drive towards Reverse Logistics in Brazil (Veiga, 2013). Other regulatory instruments could also influence the design of take-back programmes - for instance Bing et al. (2015) describe how relocating reprocessing centres from Europe to China under the Emission Trading Scheme (ETS) can positively reduce total costs and transportation emissions (Bing et al., 2015). Take-back network design should consider the risks from transporting hazardous materials (Yanık, 2015). Tax and subsidies could influence the decisions on take-back strategy for e.g., in reintroducing these raw materials into the product cycle (Rebehy *et al.*, 2019).

3.3.4. Performance management

Assessing the take-back performance can be an essential but challenging task given the difficulties in operating the flow of materials and information (Alkahtani *et al.*, 2021). Various authors have explored the use of performance indicators, primarily categorising them into financial or economic, environmental, social, and operational performance indicators. Table 2 covers some of these indicators.

Table 2. Performance management indicators for take-back

Reference	Economic Indicators
(Das, 2020)	Total Cost in Closed-Loop Supply Chain
(Sgarbossa and Russo, 2017)	Profitability index (PI), Payback time (PBT)
(Alkahtani et al., 2021)	Logistic Cost, Profit by recovery efficiency, Channel Profit
(Oliveira Neto and Correia, 2019)	Return on Investment, Internal Rate of Return, Discounted Payback
(Hammes et al., 2020)	Total Costs of Reverse Logistics

Reference	Environmental Indicators
(Das, 2020; Hammes et al., 2020)	Total harmful emissions
(Sgarbossa and Russo, 2017)	Energy self-sufficiency
(Alkahtani et al., 2021)	Disposal policies, GHG Emission reduction, Waste reduction
(Oliveira Neto and Correia, 2019)	Material intensity factor
(Kuczenski and Geyer, 2013)	Carbon Footprint, Eutrophication in Life Cycle Assessment

Reference	Social Indicators
(Sgarbossa and Russo, 2017)	Employment possibilities, Practices related to internal human resources, external population, stakeholder participation
(Alkahtani et al., 2021)	Customer Loyalty, Satisfaction

Reference	Operational Indicators
(Vegter et al., 2020)	Efficiency of recovery, Utilising end-of-life packaging materials
(Hammes et al., 2020)	Reuse rate, Rates of return
(Alkahtani et al., 2021)	Various process's costs

From a financial perspective, understanding the cost implications of various activities can be an essential task, hence Abdessalem et al. (2012) recommend Activity Based Costing to quantify the cost elements across activities for better management of the resources used (Abdessalem et al., 2012). The factors impacting financial performance, can be categorised into resource efficiency and resource effectiveness; the former affecting the costs (e.g., logistic and handling costs), while the latter influencing the revenues for e.g., turnover by choosing specific recovery option (Bockholt et al., 2020). Environmental performance management is an important factor due to various reasons, including compliance, corporate reputation, stakeholder pressure (Rao, 2014). Benchmarking environmental performances with industry standards or benchmark values can be a good practice. Brainstorming, if the differences are significant, can be done using a Fishbone diagram/ cause and effect/ Ishikawa diagram. The root cause often could be attributed to 'man,' 'machine,' 'materials,' and 'methods' (Rao, 2014).

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3.3.5. Consumer behaviour and incentives

Consumers' motivation to participate in returning products is a critical first step in a take-back programme. Several studies have attempted to understand consumer motivation and return practices (Agarwal *et al.*, 2012; Jafari *et al.*, 2017; Sari *et al.*, 2021). While many studies have focused on technical aspects of reverse logistics such as types and location of bins, or on behavioural aspects such as values, behaviour can be influenced by the interplay of personal and situational factors (A-Jalil et al., 2014). Botelho et al. (2016) investigated the attractiveness of various incentives such as exchange of used equipment for money, home collection, exchange for new equipment, tax benefits, and discount coupons (Botelho et al., 2016). Ghoreishi et al. (2011) while modeling for cost benefit analysis of take-back, explored incentives such as cash incentive, discount of certain value for purchasing new products (usually of similar type), or percentage discount, for purchasing new products (Ghoreishi et al., 2011).

3.3.6. Other aspects

Take-back may involve conducting a value chain analysis in order to assess the existing material and financial flow of products at the end of their life/use, and explore the opportunities for reorganisation (De Souza and D'Agosto, 2013). Identifying and addressing potential risks and barriers can also be a good strategy while designing and implementing take-back (Panjehfouladgaran and Lim, 2020; Prakash and Barua, 2016). Assessment of maturity using Maturity Models can be a useful strategy for evaluation of gaps and opportunities for improvements (Peña-Montoya et al., 2020).

In summary, the SLR provided valuable insights, across diverse aspects of take-back. It provided an overview of collection models for various products, and recovery options including decision support models. It highlighted the increasing global trends on EPR and the influence of regulations on take-back. Another aspect that came out from the SLR was around understanding consumer behaviour towards take-back and the role of incentives. A major focus in the literature was on identifying KPIs and ways of managing the financial, environmental, social, and operational performance of take-back.

4. Conceptual framework for take-back configurator

4.1. The need for a configurator and the design challenge

The insights from the SLR highlight how designing a take-back may involve making choices of different activities and decisions (for e.g., choice of collection models, resource recovery options, KPIs, who and where the various activities will be carried out, the need/ types of incentives etc). These choices may be influenced by the reasons for initiating take-back (for e.g., for economic benefits, compliance etc) but also other factors such as the product characteristics, existing or emerging legislations, consumer attitude and behaviour towards take-back, and the existing infrastructure for collection, transportation, storage, and resource recovery. The choices will consequently impact the success criteria defined for the take-back, along with costs, and the social and environmental footprint of the system. A take-back configurator would be ideal for providing options across the variety of attributes and flexibility to choose from the options while simultaneously making unavailable the features that would contradict those choices. The configurator will be able to help companies to evaluate different perspectives and approaches (for e.g., how to design the take-back network, factors that need to be considered, etc), plus opportunities and challenges for designing their take-back programme. The systematic approach to developing this configurator was deemed very similar to the design of a product or a system, for which reason, the design of the configurator is being viewed as a design task, within a design research project that is following the Design Research Methodology (Blessing and Chakrabarti, 2009).

4.2. Conceptual framework

The attributes identified through the SLR can be effectively incorporated into the DeBrito Model contributing to an overall architecture for designing a take-back configurator. Figure 4, below, provides a conceptual framework for designing such a configurator (the figures in parentheses refer to the relevant sections of the SLR findings, that contribute to the framework). The proposed framework expands the DeBrito model, particularly the 'how' part, by bringing in additional dimensions like mapping the baseline, in terms of the value chain and influence of legislation across the take-back

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channel. The framework, in its current form provides a practical approach to designing take-back through examples across collection models, KPIs and incentives as well as a decision support tool for recovery strategy.

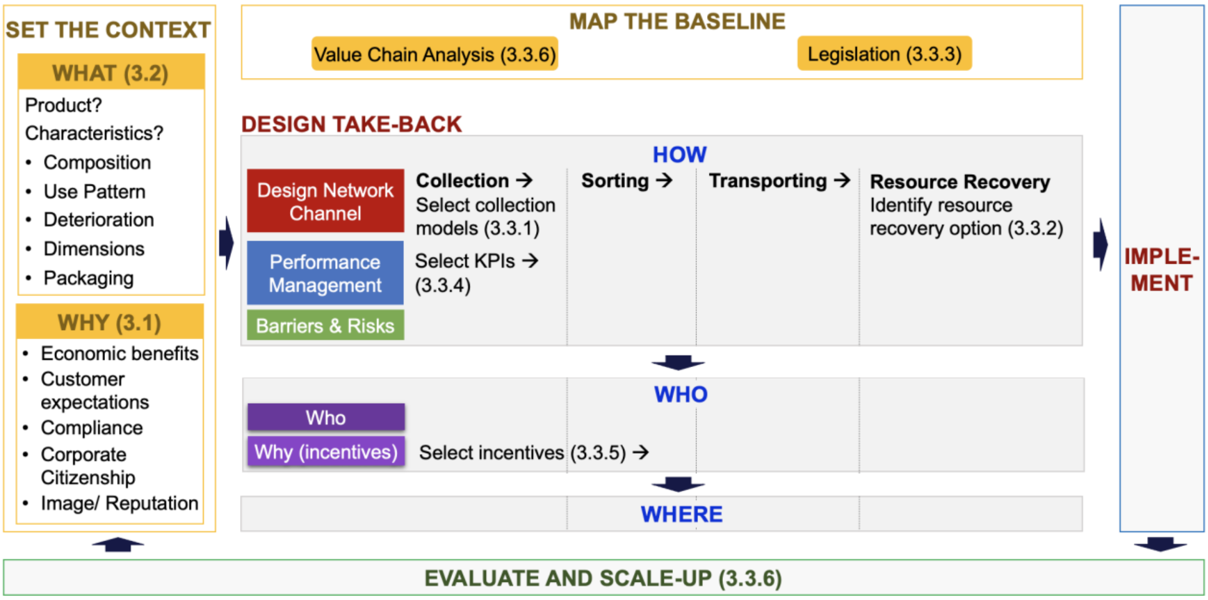

Figure 4. Conceptual framework for take-back configurator

The attributes identified through the SLR can be interrelated, and a successful take-back programme will need to consider the interplay of the attributes to best fit the objectives of the take-back. For instance, the choice of the collection model or recovery option is influenced by factors such as product characteristics, legislation, and consumer behaviour. As the consumer has a critical role to play in bringing back the product, the take-back programme design will need to balance convenience for the consumer, with costs of the set-up (a KPI). The costs, in turn, can depend on resource efficiency and resource recovery strategy i.e., resource effectiveness. The resource recovery strategy would depend on product characteristics. All these considerations will help determine whether the activities can be implemented by the company itself or a 3rd party needs to be engaged. Also, the real drivers (reasons) for initiating take-back can serve as a compass for decision making.

5. Conclusion

Through a systematic literature review, this paper aimed to draw a conceptual framework for designing a configurator that can help businesses implement a take-back system. The SLR provided various elements that can form the building blocks of the configurator, including many collection and recovery models, performance indicators and ways to drive consumer participation through incentives. The review built on the DeBrito Framework (What-Why-How), though adding numerous dimensions, particularly on the ‘how’ aspect. The current study does have certain limitations, which could be addressed in further research. For instance, the review covers certain aspects of take-back (such as implementation, evaluation, and scaling) at a high level; these areas of study, as well as feeding the KPIs with appropriate data, warrant more in-depth focus in future studies. An additional step for future research is the logical design and implementation of the configurator (including its IT system), to allow the linkages and interdependencies between the various elements, as well as a graphical interface that can help users to flexibly explore the configurator based on their requirements. These aspects constitute the next steps in the research development.

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