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Study on Decision Support Tool Towards Circular Economy Practice - A Case Study for Electronics Companies

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Abstract

The study is a continuation of our previous research on the impact of business organization factors on circular economy (CE) practices towards the development of a decision support tool to facilitate the adoption, implementation, development and strategy of CE activities in the Vietnamese industry. The tool helps to quickly assess the status of CE practice in the enterprises and makes a structural chart according to the CE maturity models. Having a positive direction in the management organization and application of CE theory, the electronics companies are illustrated as a case study for the application of the tool. As the results, one organization form (namely, the System) aligning with three business models (namely, Resource Models, Design Models, Lifetime Extention Models) and five supporting processes (namely, Digitization and Datafication, Return Logistics, Competences, Technical Infrastruture, Setting Up Processes, Quality Monitoring) are proposed for visualization of strategic interventions and recommendations for the electronics industry on business sustainability, competitiveness, alignment between their business objectives, priorities, and key performance indicators towards CE practice.

Keywords: Circular economy (CE), decision support tool, electronics industry

1. Introduction

The circular economy (CE) focuses on the management and regeneration of resources in a closed loop, thereby extending the life of materials/products and avoiding the generation of waste [1]. Vietnam is one of the fastest growing economies in Southeast Asia with an annual growth rate exceeding 6.5% [2], but sustainable growth is constrained by environmental degradation, waste, depletion of natural resources and high carbon emissions. In that context, CE is a potential and sustainable solution to these challenges. However, most companies, especially small and medium-sized enterprises, are barely aware of its potential benefits. One of the barriers is the lack of knowledge, skill and experience of the workforce in CE, leading to the lack of necessary strategies and actions to gradually apply CE in Vietnam [3, 4]. Furthermore, the lack of an information system often makes it difficult for enterprises to track and reflect the impact of CE practices on business sustainability [5]. Therefore, this study focuses on a decision support tool [6] that helps enterprises leaders develop an organizational strategy to manage and apply the CE theory. Through a tool, enterprises may assess the current status of CE practice in the organization, create an organizational chart according to their CE maturity model, and visualize strategic interventions and recommendations for the organization.

The electronics is a manufacturing industry that plays a key role in the Vietnamese economy and has a strong spillover effect on other industries. According to the General Statistic Office, the GDP of electronics industry has accounted for 17.8% of the entire industrial GPD in 2021. In Vietnam, the main products of the industry are electronic components, mobile phones, assembled televisions, tablets, computers, components along with office equipment. The industry has been a leading sector in the industrial revolution 4.0 with the application of new and advanced technology. Therefore, electronics companies are recognized as having a positive direction in the management organization and application of CE theory. In the World Economic Forum 2023, it predicted that applying CE for electronics could reduce costs for consumers by up to 7% by 2030 and 14% by 2040. In this paper, a case study for the application of a decision support tool is illustrated by electronics companies.

2. Research Method

In previous related research [7], the impact of business organization factors on CE practices in Vietnam have been specified.

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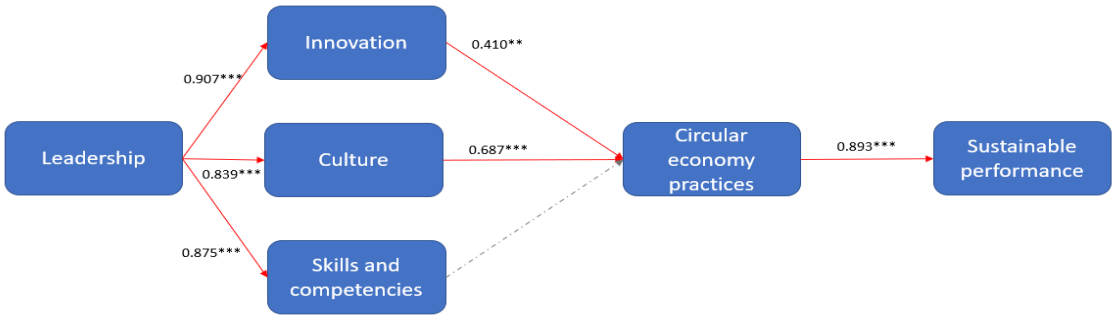

Fig.1. The impact of "business organization" factors

The principles of dynamic capability theory (DCT) are the premise to conceptualize and examine the interplay between organizational structures (leadership, culture, innovative thinking, skills and competencies) and the application of knowledge-based economy (new business model) to achieve sustainable business performance. A primary survey-based research method was used to capture responses from 205 small and medium-sized enterprises' employees in Vietnam, and then, Structural Equation Modelling (SEM) technique was employed to process the data and analyze it. The results give the normalized estimates shown in Fig. 1. All structural relationships with path coefficients above 0.7 are considered acceptable, so solid lines represent significant relationships, while dashed lines represent unimportant relationships. Specifically, the importance of leadership significantly positively impacts innovation, culture and skills and capabilities. Innovation and culture have a positive impact on the CE practice, while skills and competencies, on the contrary, have no significant impact on the CE practice. Eco-friendly activities have a significant positive impact on sustainable performance of enterprises.

In the "Theoretical implications" section of the above research, it was mentioned that "our theoretical model thus consolidates three very different concepts-internal organizational capabilities (stemming from leadership, skilled workforce, organizational culture and innovation mindset), CE practices (reduce, reuse and recycle across the upstream and downstream, reduce waste, energy and raw material consumption) and sustainable business performance (business economic productivity, socially responsible practices, and environmentally friendly operations), and findings outline how they collectively can enhance economic performance of businesses through environmentally friendly practices and socially responsible strategies" [7].

In this research, based on Saxion Hogeschool's Business Models [8], a decision support tool is further developed to facilitate the adoption, implementation, development and strategy of CE activities in Vietnamese enterprises. The tool includes two parts: 1) determing the position of an enterprise towards the CE; 2) developing or adjusting the business model for that enterprise. The tool may include many functions that can be built on a digital platform.

1) Determing the position: in this first part, primary survey questionaires are developed and used to determine where enterprise leaders stand with their organization when it comes to sustainable and circular business. This is done using 30 questions which the respondents are asked to score on a five-point scale. There are 4 separate set of questions for four analyses: i) Priority: what is the priority to look at sustainable and circular business? ii) Experience; iii) Ambition: where do the company want to go when it comes to sustainable and circular business? and iv) Current business model: to what extent is sustainable and circular business already included in current business model of the company? The questionnaire sets were forwarded to electronics companies among the 205 businesses mentioned above. After receiving feedback from the companies and analysis, the result provides insight into the question: Is the company a beginner, an advanced or frontrunner in the field of sustainability and circularity with a total set-score of less than 24 points, from 24 to 32 points and greater than 32 points, respectively.

2) Developing or adjusting the business model: in this second part, the enterprise leaders will be guided to design a sustainable and circular business model or adapt an existing business model. This depends on what future value proposition of the enterprises is/are: i) Processed virgin materials; or/and ii) Use; or/and iii) Responsibility. It respectively means that the enterprises: i) Offer client a tangible product; or/and ii) Provide users access to product functionality; or/and iii) Taking over Responsibilities from users. Corresponding to those options, there are 7 business model types, include: Resource Models, Design Models, Lifetime extension Models, Platform Models,

Product as a Service Models, End-of-life Models, Lifecycle Models. The essence of the business models is shown in Table 1. The enterprise leaders can choose one or more models which best fit their ambition from the offered classification of circular basic models.

Table 1. The business model types

Name	Essence of business models
Resource Models	Recovery of components and (processed) raw materials at the end of the life cycle (discard phase).
Design Models	Design products so that they fit within the logic of circularity. Design models focus on delivering designs for new and redesigning existing products and (re)designing production, distribution, and take-back systems that close loops for circular products
Lifetime extension Models	Retain the original qualities and functionality of products, components and (processed) raw materials for as long as possible. This type of business model focuses in particular on repair, maintenance, refurbishment, replacement / substitution of components, remanufacturing, repurposing and reuse.
Platform (sharing) Models	Increase the use of the functional capacity of assets that are already in circulation. Platform models aim to extend the lifespan by increasing the efficiency of the use of the product, its components and the raw materials they contain.
Product as a Service Models	Provide a user with access to the function of a product. The user no longer automatically becomes the owner of the product. Meritization leads to performance arrangements (dematerialization).
End-of-life Models	Give substance to obligations for producers arising from new European regulations such as the 'Extended Producer Responsibility'. Producers and importers retain their responsibility for the products they make even after the use or disposal phase.
Lifecycle Models	Producers retain ownership of the products they make throughout the life cycle (the principle of Producer Ownership). These business models then bet on full creditability. Producers achieve maximum control over the raw materials they use in their products, including the recyclates recovered from them, and can thus close the entire cycle.

After choosing the business models, and based on capacity of their company, the leaders will be guided to design the most appropriate R-strategies (Fig. 2), organization form (Fig. 3), supporting processes (Fig. 4), and revenue models (from the large range on their offer).

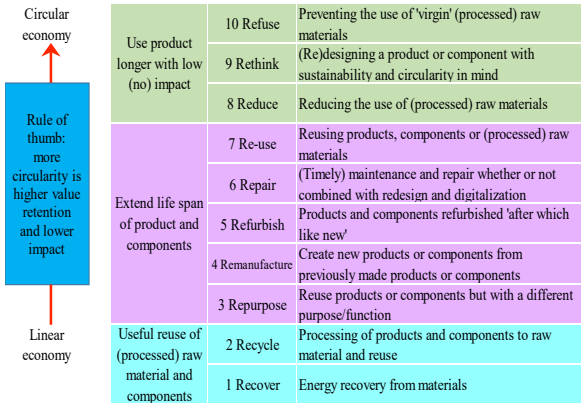

Fig. 2. R-strategy(s) for ambitions towards CE

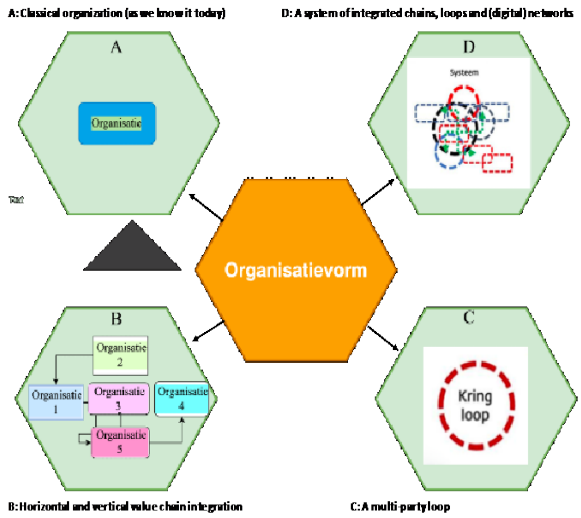

Fig. 3. Organizational form for realizing ambitions towards CE

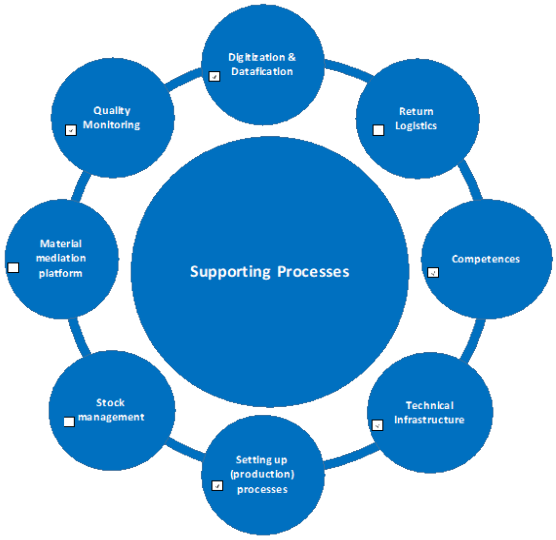

Fig. 4. Support processes for realizing business models towards CE

3. Result and Discussion

3.1. Position of the Electronics Towards CE Practice

The movement towards sustainability presents significant challenges for all industrial businesses, as presented in Fig. 5. It requires less attention to financial results and consideration of social and environmental impacts, which can make for risk-averse companies to operate with limited resources. As a result, businesses are finding difficulties to introduce sustainable practices. Therefore, four sets of primary survey questionaires were developed for all businesses and used to capture responses from some electronics companies in this study. Table 2 presents separate sets of questions and average score responsed from the companies for their priority, experience, ambition, and current business models towards CE practice.

After quick analysis, a “total picture” for the sector is shown in Fig. 6. The information in the figure helps to determine that Vietnamese electronic companies are “beginners” in the field of circularity. The scores for "Experience", "Ambition" and "Current Business Model" of the surveyed enterprises are all below 24 points, showing that their position is still "modest" in the CE transition roadmap.. The scores for “Determine Priority” of the surveyed enterprises is medium.

Studies on Vietnamese enterprises, in general, had also discussed that lack of leadership, CE awareness, experience among both the managers and workforce, and organizational culture inhibit business model innovation [9], resulting in lack of effective strategies and actions to adopt CE. Thus, the possibility of promoting CE practice in the electronic companies can be thought of from changing the ambitions and priorities of the enterprises by continuously providing them platform-based decision supports to design circular business models.

Table 2. The sets of primary survey questionaires and average score responsed from electronic SMEs

Why is sustainable and circular business important to your company?		*What have you done so far in terms of sustainable and circular business?*	
Determine priority	28	**Experience**	23
It is financially attractive due to subsidies, for example.	3	Sustainable and circular business is already familiar to us.	2
In order to get staff, we do need to be sustainable and circular.	4	Our production has already been made more efficient and we produce less waste.	3
As a company, our ambition is to be sustainable and circular.	4	We apply, if possible, recycled raw materials in our products.	3
Working on sustainability and circularity has a positive impact on our market position.	4	For us, circular business is not a choice but a strategic guiding principle.	3
We want to avoid problems with resource scarcity in the future.	3	We are doing energy conservation and have started generating our own energy.	4
It is already important for our company.	3	We are working internally toward a fully circular production process.	3
We will be forced by legislation soon.	3	We started to develop the chain in a circular way, in cooperation with parties in the chain.	2
Our customers will increasingly expect it of us.	4	We are in the process of taking back our own products (or parts of our products) after use.	3
How would you like to develop furthur in the field of sustainable and circular business in the coming years?		*To what extent is sustainable and circular business already part of your organization and incorporated into your business model?*	
Ambition	21	**Current Business model**	24
We have clear plans for the coming years.	3	Actually, we have been taking a critical look at our current business model for years.	3
We want to move towards production with recovered and recycled raw materials.	3	We are looking at how to embed further services in addition to the current ones	3
We are going to make the design and the maintenance of our products circular.	3	Increasingly, we are using our own waste as a raw material for new products.	3
Our customers will see/have our products only when they purchase a service.	2	For us, value preservation of products is central from the design stage onwards.	4
We are moving to integral life cycle responsibility of our products.	3	The law requires us to process a percentage of re-cycled materials; this is passed on.	4
We are gradually adapting to laws and regulations.	3	We try to close a loop with partners.	4
In about 10 years, we want to be a circular and sustainable business.	4	We offer our customers digitization and (service) tracking of products.	3

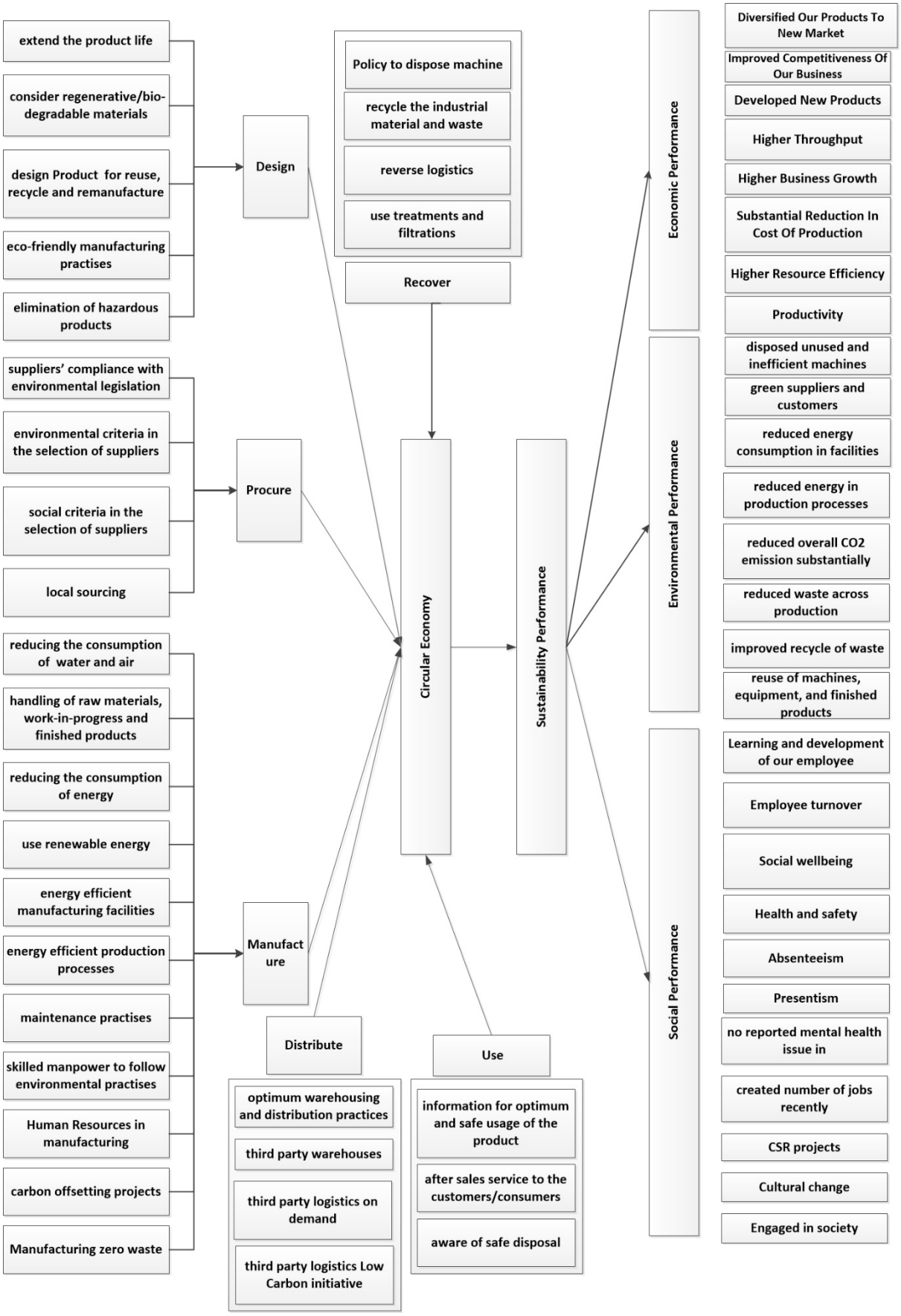

Fig. 5. Sub-constructs of the study

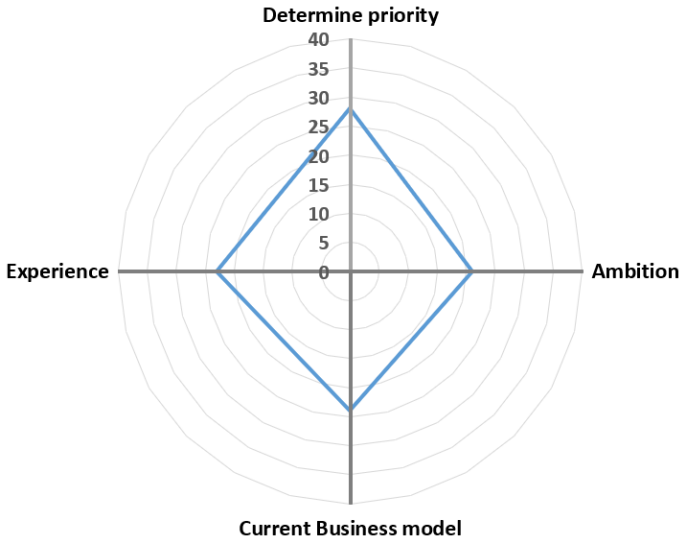

Fig. 6. Total picture after a quick analysis

Table 3. The matrix for business model analysis

	Resource Models	Design Models	Lifetime extension Models	Platform (sharing) models	Product as a Service Models	End-of-life Models	Lifecycle Models
Focus	Disassembly, reclamation, repurposing, remanufacturing	Designing products and production processes	(timely) Maintain, reuse	Use, maintain and reuse	Use	Use, maintain, reuse, recover	Designing, making, using, maintaining, reusing, recovering
Value Creation	Primary recycling for products in the value chain with indirect social (job creation) and environmental (lower raw material footprint) impact	Sustainability, circularity and recycling	Sustainability, circularity	Sustainability	Sustainability (through better utilization)	Circularity	Sustainability, recycling and circularity, social, environmental
Organization	(end) value chain and (possibly) a new cycle	Organization-internal, chain and loop	Organization, chain, network and possibly loop	Network	Chain, network	Chain, loop (system)	Loop, system
Strategy	Recycle, repurpose, reuse en recover	Rethink, redesign, reduce	Reduce, reuse, repair, refurbish, remanufacture, repurpose	Reduce	Reduce	Reduce, reuse	Rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose,
Support	Return logistics, technical infrastructure, disassembly protocols, quality assurance	Competences, design of (production) processes, return logistics	Appropriate designs (see various design models), competencies, digital, technical and logistical infrastructure	Digitization & datafication, material mediation platforms	Digitization and datafication, competences	Digitization & datafication, technical infrastructure, inventory management	Digitization & datafication, return logistics, competences, quality control
Revenue Model	Sales of residual streams and (gross) recyclates	Combination of design, functional use and maintenance sales of (modules) of a product	Different variants on product-as-a-service (PAAS), data and analytics-as-a-service, maintenance and inspection, buy-back	Shared ownership, open access, pooling, providing access	Subscription, non-ownership sharing concepts, leasing, pay-per-use, product-as-a-service, rental	Data and analytics-as-a-service, maintenance and inspection	Subscription, use of residuals and recyclables, buy-back, lease, maintenance and inspection, extended life, warranty
Impact	Material and raw material savings, job creation, CO2 reduction	Material saving, usage saving, better raw material recovery, CO2 reduction	(processed)Raw material saving	Material Savings	Material Savings	Material conservation, reuse, CO2 reduction	Material saving, CO2 reduction

3.2. Developing Business Models

As mentioned, the enterprise leaders need to choose business models based on the capacity of the company. It needs to study on the factors that facilitate the successful adoption of CE and their influence on the operations of enterprises. Enterprises will be aware of the impact of CE on the three dimensions of sustainability, which in turn will assist in strategic planning and implementation of CE practices. This will be dependent on the knowledge, skills and understanding of the managers with regards to the innovation, impact of the innovation on the business productivity and employee performance, and its alignment with the business priorities and goals of the enterprises. Innovative mindset within the enterprises resulting from the leadership practices within the organization will significantly and positively influence CE practices. This can be attributed to the fact that the aims of CE practices are to optimize the business processes through lean management and achieve resource efficiency through sustainable oriented innovation [10]. CE practices within enterprises will result in strategic changes aligned to the business priorities of the organization, incorporate both lean management and sustainable innovation, and these changes and innovative practices are put forward by the senior management [11].

In order to support enterprises to design the most appropriate R-strategies, organization form, supporting processes, and revenue models, a check-list

matrix that can be used for analyzing and selecting right business models is developed and described in Table 3.

The main aim of the circular economy is to reduce waste and increase resource efficiency [12]. This can be achieved through the closure of nutrients that can be re-entered into the biosphere or materials, and its turn, the biosphere or materials can be recycled in economic activities together with a reduction in overall resource consumption through conversion processes. That is the origin of R-strategies. Refuse means preventing the use of 'virgin' (processed) raw materials. Rethink means (re)designing a product or component with sustainability and circularity in mind. Reduce involves finding opportunities to modify raw materials, improve production and consumption processes, and modify process design. Reuse includes activities through the reintroduction of end-of-life products to reduce the use of raw materials along with other resources involved in the design, manufacture, and use of the product or component. Repair means (timely) maintenancing and repairing whether or not combined with redesign and digitalization. Refurbish means products and components refurbished “after which like new”. Remanufacture means creating new products or components from previously made products or components. Repurpose means reusing products or components but with a different purpose/function. In cases where it is not possible to reuse or reduce products, recycling and recover become useful alternatives. Recycling means processing products or components to raw material and reuse. Recovery mean recovering energy from materials or wastes. These are the most popular strategies as it allows to reduce the exploitation of limited resources through the conversion of expired items into useful materials [13]. The combination of R-strategies with ecological innovation approaches enables efficient use of resources with economic, environmental and social benefits [14-17].

Analysis of the link between CE practices and environmental performance, as well as the impact of sustainability practices on financial and environmental performance, has been analyzed, but literature on the topic is still inconclusive [18, 19, 20]. It is important to further understand the overall impact of CE practices on aspects of sustainable performance. That impact is key to providing useful insights for businesses, especially considering their risk aversion and the limited resources they have to invest [21].

Noting that the enterprise leaders obviously can decide R-strategies, organization form, supporting processes, and revenue models from the large range on their offer. The end result of this mix and match is an overview of the chosen features for circular business models for electronic SMEs (Table 4).

Table 4. Overview of the chosen features for circular business models for electronic companies

Name	Essence of business models
Basic Type of Business models	Resource Models, Design Models, Lifetime extention Models
R-strategies	Rethink, Reduce, Re-use, Repair, Remanufacture, Repurpose, Recycle
Organization Form	A system of integrated chains, loops, and networks (namely, System)
Supporting processes	Digitization and Datafication, Return Logistics, Competences, Technical Infrastruture, Setting up (production) processes, Quality Monitoring
Revenue models	Analytics as a Service, Circularity contribution, Data as a Service, Warranty, Use recyclates, Produce on demand, Sell

As the results, Resource Models, Design Models, Lifetime Extention Models are the proposed circular business models for electronic companies in Vietnam.

1) Resource Models specialize in the recycling of iron, metals and electronics. From this, new raw materials are made that can be used by smelters and producers. The company can offer two organizational options: parties can deliver their waste to the company, or it takes care of the entire process from collection to new raw material. The essence of resource models is the recovery of components and (processed) raw materials at the end of the life cycle (discard phase). These can be given new purposes. Raw materials can also be processed into a result with a higher or lower value (up- and downcycling). When these possibilities exhaust, the remains will be the recovery of energy.

2) Design Models focus on designing sustainable products that should last as long as possible. The company does this by focusing on replaceable modules that consumers can repair themselves. The essence of design models is to design products so that they fit within the logic of circularity. Circular design means designing for (1) longevity, (2) possibility of easy repair, (3) modular composition and easy disassembly, (4) use of reusable materials, and (5) use of bio-based materials. Design models for the circular economy focus on delivering designs for new and redesigning existing products and (re)designing production, distribution, and take-back systems that close loops for circular products.

3) Lifetime Extension Models specialize in reducing electronic waste and creating value from used electronics. For example, ecoATM owns 4.457 kiosks where consumers can sell their phones. Since 2009, ecoATM has bought up more than 28 million electronic devices and refurbished them, resold them,

or recycled them in an environmentally friendly way [22]. The essence of the lifetime extension models is to retain the original qualities and functionality of products, components and (processed) raw materials for as long as possible. This type of business model focuses in particular on (1) repair, (2) maintenance, (3) refurbishment, (4) replacement/substitution of components, (5) remanufacturing, (6) repurposing, and (7) reuse.

Aligning with three above basic types of business models, the most appropriate organization form is a System of integrated chains, loops, and networks; the most appropriate R-strategies are Rethink, Reduce, Re-use, Repair, Remanufacture, Repurpose, Recycle; the most appropriate supporting processes are Digitization and Datafication, Return Logistics, Competences, Technical Infrastruture, Setting up Processes, Quality Monitoring. For revenue models, the proposed models include Analytics as a Service, Circularity contribution, Data as a Service, Warranty, Use recyclates, Produce on demand, and Sell. Not limited to those models, the electronics company leaders can proactively make decisions within the large range of Table 3 based on their existing knowledge and capabilities.

Although the electronics industry in Vietnam is experiencing positive development, it still faces some challenges and limitations in CE practices. (1) The collection and recycling of reused resources in the industry has not been implemented effectively. (2) The recycling process of electronic products can be very complex due to the variety of components and technologies. The lack of technology and infrastructure for recycling is a challenge for CE implementation in the industry. (3) The lack of cooperation between business organizations in sharing information and experiences on reuse and recycling. Copyright and intellectual property rights are also a challenge, making it difficult to share recycling technology and processes. (4) The awareness of CE and reuse in the electronics industry is still limited. Awareness of the impact of not reusing and properly disposing of waste has not been widespread and consistent across the industry. (5) Government support is strongly needed through regulation and policy to support the CE implementation in the electronics industry.

4. Conclusion

This study is driven by the growing interest in the application of CE practices in industrial sectors, in line with the Vietnamese government's initiatives to reduce carbon emissions. Following our previous research on the impact of internal organizational factors on CE adoption and achieving sustainable business performance, this study focuses on the tool that will help overcome organizational barriers and support planners of the business organization to develop the right evidence-based initiatives and strategies towards CE practice.

Through the case study, a comprehensive understanding of the impact of CE practices in the electronics industry is provided, taking into account the internal influencing factors and the influence of the CE practices on sustainable performance and resilience of enterprises. The research relied on input from electronics companies participating in the survey to propose circular business models for themselves. Three proposed models have been analyzed based on the characteristics of the electronics industry. As the results, Vietnamese electronics companies are assessed as “beginners” in the field of circularity according to a defined scale. Central to their future value proposition are i) offer client a tangible product; and ii) provide users access to product functionality. Then, an organization system of integrated chains, loops, and networks aligning with three business models and five supporting processes are illustrated for electronics industry.

Future works can develop support system into a digital tool, so that this digital support system can facilitate developing case-studies to reflect on the current CE practices, maturity within the industry that will facilitate developing and co-creating new knowledge for both industry and policy makers; inform government policy makers to the needs of the enterprises, and help to develop policies and inquiries that will enhance CE practices, by providing a knowledgebase; help enterprises managers and employees to understand and compare the impact of CE practices pre and post implementation, which will facilitate in business process reengineering, modifying job configuration and enhance their reputation among the stakeholders, trading partners and competitive business environment.

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