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An exploratory study for product-as-a-service (PaaS) offers development for electrical and electronic equipment

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Abstract

Manufacturing enterprises continue to grapple with transforming from their existing business model, which revolves around designing and selling tangible products, to business models centered on providing a blend of products and services. Product-as-a-Service (PaaS) emerges as a business strategy capable of catalyzing the shift toward higher levels of circularity. However, effecting changes in operational methodologies and value delivery mechanisms is imperative, consequently prompting modifications in the core business strategies of these companies. The objective of this study is to discern and categorize prevailing PaaS business models for electrical and electronic equipment (EEE). The Business Model Canvas (BMC) is introduced as a foundational tool to facilitate this transition, emphasizing the central role of the value proposition within the business model. Additionally, the study underscores the importance of robust take-back systems and reparability in PaaS implementation, particularly within the EEE sector. It highlights the need for novel partnerships, redesigned reverse logistics networks, and efficient product assessment methods to facilitate environmentally responsible decisions. Furthermore, the research evaluates the financial implications of PaaS adoption through Life Cycle Costing (LCC), emphasizing its value in predicting and addressing temporary financial complications, thereby ensuring a smoother transition to service-oriented business models.

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Keywords: Product-as-a-service; exploratory; business model design; life cycle costing; take-back; repair; EEE products.

1. Introduction

The electrical and electronic equipment (EEE) industry, characterized by its substantial resource demands, presents a significant opportunity for waste reduction through the implementation of novel circular business models [1]. In this context, product-as-a-service (PaaS) aims to achieve lower environmental impacts than traditional business models [2]. PaaS represents a business strategy employed by conventional product-oriented firms to enhance the appeal of their offerings, ascend the value chain, and expand their customer base [3]. Nevertheless, the intricate nature of PaaS renders it formidable to accommodate alterations in its physical products to align

with novel customer prerequisites, adhere to emerging standards, or integrate innovative technologies, as any modification in a single component of the system invariably exerts an impact on interconnected elements [4].

An understanding of the business model simplifies the process for a company to effectively harness and orchestrate all the essential prerequisites for transforming from product-selling-centric approaches to solution-offered-oriented strategies, through the implementation of service-centric business models [5-6]. This shift from ownership to service-oriented usage can significantly impact the technological and functional aspects of EEE by prompting original equipment manufacturers (OEM) to design products with a focus on

durability, ease of repair, and upgradability. Additionally, the shift promotes technological innovation, sustainability, and an emphasis on prolonged product utility. To realize the shift, the business model canvas (BMC) situates the value proposition at its core, providing a comprehensive perspective of the business proposal [7]. This enables companies to scrutinize and assess their market position. However, complementary tools are, therefore, needed to assist managers in making informed decisions and validate the viability of business models. Life cycle costing (LCC) has been observed to improve the understanding and awareness of specific challenges they encounter [8], thereby facilitating the development of the knowledge and competencies necessary to overcome these obstacles [9].

In addition to financial barriers, many researchers have studied the importance of implementing product take-back. Current regulations set targets for the collection and recycling of EEE or its waste form at the aggregated level. EEE manufacturers usually delegate the take-back of products (at end-of-use or end-of-life) to dedicated third parties [10]. Organizing the take-back system when designing PaaS is often challenging due to the lack of experience.

In addition, any PaaS offer shall enable multiple use of the products by different customers between contracts and reduce the environmental impact. A consequence of the transformation is the redefined role of maintenance and repair integrated into the novel business paradigm. OEMs will bear the responsibility for addressing any malfunctions, and the costs to be encompassed within the contracted fees. This compels companies to enhance the reparability of their products and streamline maintenance procedures. It is much easier to conduct repairs or remanufacture products to be sold again, thus maintaining a circular product loop [11].

Hence, the research seeks to answer the following questions: (1) ‘What are the types of service-oriented PaaS market offerings for EEE other than buying?’, (2) ‘How are product take-back and reparability integrated into the business models?’; and (3) ‘How LCC can help enhance the business model?’. To answer these, the research aims to explore EEE PaaS offerings and propose business models with the help of BMCs with an emphasis on the role of take-back and reparability, as well as by applying financial assessments through the life cycle.

2. Research Background

2.1. Product-as-a-Service (PaaS)

The trend of amalgamating products and services to provide more circular solutions is on the rise among enterprises, particularly in the context of a fiercely competitive global market [2]. This transformation requires a shift from a product-selling-centric orientation to a service-offer-centric one [12–13]. Consequently, a PaaS amalgamates products and services within a unified operational system.

2.2. Business Model Canvas

The success of a company relies on its operational strategy and network [14], signifying the paramount importance of reconfiguring the business model (BM) to provide PaaS. As a result, it becomes imperative for a PaaS to simultaneously consider the amalgamation of both business and technical facets within its BMs [15]. Following a concise review of the literature on business model development [1, 4], it becomes apparent that the BMC is widely recognized as an effective tool to facilitate the design process of PaaS. Consequently, BMC plays a pivotal role in PaaS design.

2.3. Product Take-Back and Reparability

Value-retention processes (VRPs), allows the extension of the expected service life and activate the full potential of recapturing embedded resource value, beyond the recycling of materials [16]. The take-back system is needed to ensure that the cascading model is in place for PaaS. Redesigning the existing reverse logistics network is crucial, to avoid unnecessary transportation and damage to products during transportation and storage, and to provide quick and reliable visual inspection to check the ‘state of health’. Moreover, the take-back system can also provide cost-effective ways to obtain spare parts for repairs and servicing. However, fostering repair activities, which have experienced a protracted decline in the industrialized world, is integral to advancing the principles of economic, environmental, and social sustainability. Repairing products allows them to last longer and add value, aligning well with the concepts of closed-loop strategies and sustainable economic growth within the circular economy framework [17].

2.4. Life Cycle Costing

In the transformation from traditional business models to PaaS, companies enter new grounds with uncertain lucrativeness. Consequently, the short-term implications may not reflect the long-term as the intermediate state of the companies suffers from the shift in cost bearers. Hence, like classic examples of the implementation of lean manufacturing [18], structural changes can cause short-term complications, and if they are not anticipated, they could lead to a stop and return to business as usual [19]. Hence, in ensuring a smooth transformation, LCC is a valuable method to predict these temporary financial complications and provide reliable insights and strategies to reach the planned long-term state.

3. Research Method

This study employs an explorative research design where PaaS market offerings of EEE are interpreted through PaaS business model design propositions. The methodological procedure in Figure 1 encompasses six sequential steps:

1. Select different types of EEE on the market.
2. Screen current PaaS market offerings for the selected EEE.
3. Group the offerings based on their business models.
4. Develop the BMC for the grouped offerings.

5. Assess the impact of product take-back and repairability on the developed canvases.
6. Assess the financial implications of the developed canvases.

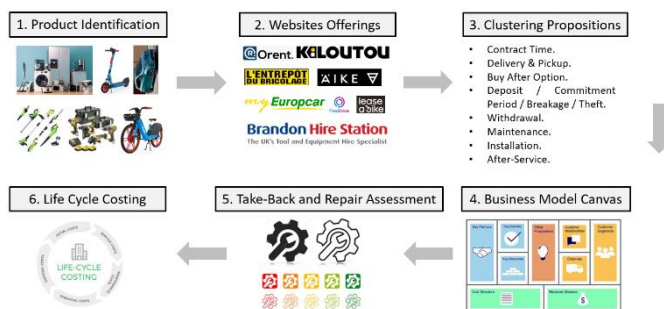


Fig. 1. Six-step methodological procedure of the study.

4. Results

4.1. Select different types of EEE

For this research, four types of EEE were selected for the analysis: home appliances, do-it-yourself tools, gardening tools, and electric mobility (scooters and bikes). The reasons behind this decision are: (1) most of these products incorporate electrical or mechanical components to achieve their intended functions, (2) they serve utilitarian purposes and are designed to perform specific tasks or functions, (3) they require user interaction to achieve their purpose, and (4) they require maintenance, cleaning, and occasional repairs to ensure they are functioning correctly and have a longer lifespan. For these reasons, these products satisfy the prerequisites to be offered in a PaaS context.

4.2. Screen current market offers

In the process of collecting and analyzing data related to these products, a comprehensive review of various retailers' and manufacturers' websites was conducted in both the European and North American regions. Google search engine was used with the criteria of finding offers of the PaaS business models. A total of fourteen websites were scrutinized: five for home appliances, two for DIY tools, one for gardening tools, and six for mobility. One important thing is that out of the 14 websites, only two were both manufacturers and service providers of the EEE, the other twelve acted as retailers with no influence on the manufacturing of the product.

4.3. Group the offerings based on their business models

After analyzing all websites, common characteristics were observed in the value propositions. Customer information typically available on the websites included: contract time, delivery and pick-up, buy-after option, deposit requirement, commitment period, breakage and theft rules, withdrawal

information, installation and maintenance services, and after-use service. Two types of offers were found for the studied EEE: subscription and pay-per-use. Subscription includes the provision of the product for a defined period of time, going from days and weeks (normally for DIY and gardening tools) to months or years (normally for home appliances). Pay-per-use is the most used for mobility products where the customer pays for the service of using the device for a short period of time going from minutes to hours.

4.4. Develop the BMC for the grouped offerings

To develop the BMCs, existing literature on the identified PaaS offerings from both scientific and web sources were reviewed. For the case of subscription offer, a total of three articles were identified [20–22] and for the pay-per-use offer a total of four [23–26]; see Table 1.

4.5. Assess the impact of product take-back and repairability

From the point of view of assessing the take-back system when developing the PaaS business model, there are several crucial elements, such as:

- Definition of entry points to take-back-system; centralized or decentralized possibilities to return a product, e.g., using e-commerce or brick and mortar channels);
- Pre-assessment of the state-of-health of products to avoid unnecessary transportation (e.g., products which are suitable only for recycling shall be directly sent to the recyclers);
- Cost-effective and environmentally friendly transportation (e.g., avoiding unnecessary transport);
- Storage of products to avoid damage and environmental burden;
- Visual inspection and final decision on VRPs;
- Quality assurance and repacking;
- Redistribution/transportation for the next PaaS.

The implementation of subscription or pay-per-use models might generate more transportation and other logistics activities than linear sales models. To avoid this, it is necessary to provide the assessment of the take-back system and related logistics operations (e.g., collection from customers, transportation to the repair facilities, storage in-between contracts) [27]. The Relog matrix (see Table 2) serves as a tool for designing PaaS for EEE with subscription or pay-by-use by identifying the gaps to be addressed when developing the canvas business models. It employs the traffic light analogy to identify *problematic* (red L), *awareness* (yellow M), and *well-developed* (green H) areas in performed processes in take-back systems for PaaS. When the red and yellow area are identified, it signals that there are existing (marked as *E* in Table 2), or new partners (marked as *N* in Figure 2) in the iterative process that should be included in the take-back system development for PaaS.

Table 1. Business model canvas of identified PaaS Offerings.

BMC Blocks	Type of PaaS Offering	
	Subscription	Pay-per-use
Value Propositions	High-quality and reliable products available for subscription. Competitive and affordable subscription prices / Convenient and fast delivery and pickup services / 24/7 customer support. Excellent maintenance and repair service / Customization, variation, sustainability, and less responsibility for product lifecycle / Wide variety of accessories / Convenience of online service / Package subscription possibility / Ownership possibility.	Ensuring the functionality of the product / Cost savings compared to a new component / Remanufacturing as an ecological sales argument. Increased integration with other systems with competition / Reduced CO2 emissions / Loyalty program and lower fares than the competition. Advertising space on the product / Personalization / Data analytics (demand management, town planning, service improvement, commercial, fleet planning, operation & maintenance) / Service area (local, city, region, national, international).
Key Partners	Partner with service providers and mechanics for repairs. Sub-contract delivery services to driver partners (Logistic third parties) / Growth partnerships with other companies in the industry / Financial actors (Banks and other financial institutions) / Service-provider / Competitors / Authorities. Advertising agencies, photo agencies, marketing agencies. OEM (procurement and buybacks) / Insurances / Consulting Companies.	Workshops / Logistics provider for reverse logistics activities / Suppliers of new components/ Third-party service providers for spare parts production and delivery, if applicable / Manufacturer (charging stations) / Maintenance company / Logistic company / Municipalities Technology providers / Branded equipment producers.
Key Activities	Product selection and purchase / Product maintenance and repair / Product delivery and pickup / Marketing and advertising / Customer service and support / Data gathering / Data processing / IT systems / Telecommunications / R&D. Influence customers to ownerless consumption / Consultancy. Maintenance (Maintain and repair products on an ongoing basis to ensure they are in top condition) / Solution providers.	Remanufacturing process of the components / Analysis of damage cases / Upgrades/Additive retrofitting /Reverse logistics and take-back of products / Continuous expansion of marketing and sales channels / Customer acquisition and retention / Service control / Maintenance and booking management / Development and production / Marketing/ Customer relationships management /service.
Key Resources	High-quality, reliable products / Maintenance and repair resources / Delivery vehicles and drivers for pickups and delivery / Marketing and advertising materials / Customer service staff / Human resources (Sufficient staff for equipment maintenance and delivery) / Machines and space / IT system Financial capital / Digital platform architecture (IT skills). Trained technicians / Physical space / Online payment processing systems.	Infrastructure, facilities, and equipment for production / Personnel qualification / Storage space for used parts / Used parts / Booking App Booking management platform / Data analytic tools Knowledge management system / People (Human resources Users) / Capital (Loans Private equity).
Customer Relationships	Provide personalized customer service and support / Build trust through transparent communication / Establish feedback loops to listen to customer needs / Build loyalty through generous discounts, rewards, and value-added services / Short, Middle, or Long-term contracts / The social and sharing experience as a key aspect to develop customer relationships. Customer relationship management over time: high rate of repeated rentals.	Direct contact with customers / Take-back systems / Support in the maintenance of the assets / Self-service relationships / Tailored business customer service / Active social media communities.
Customer Segments	Small businesses / Families / College students / Temporary workers / Apartment renters / Private individuals / Corporate customers.	B2B (municipalities, manufacturers, product sharing providers, workshops, public clients) / B2C (private customers) / Citizens. Tourists / Students / Universities / Companies.
Channels	Online store / Social media presence / Email campaigns / Direct mailers / Partnerships with local stores for referrals / Distributors / Affiliates / Subsidiaries / Word of mouth / Guerrilla marketing / Blog/live chat / Physical store / Delivery/Return.	Product manufacturers / Product sharing providers / Workshops and wholesalers / Offline & online marketing / Reverse logistics / Google Ads / Direct contact / Social network campaigns / Website/platform Apps (iOS, Android, Microsoft) / Social media profile.
Cost Structure	Wholesale product purchases / Delivery costs (vehicles, fuel, drivers) / Marketing and advertising costs / Repair and maintenance costs / Rental fees / Investments in IT and products / Digital platform management / Insurance expenses. Equipment cost / Trained workers' salaries / Consultancies.	Remanufacturing process of the components (production) / Distribution and Marketing / Reverse logistics activities / Disposal of waste / Procurement of new spare parts / Assets investments / Maintenance and repair costs / Energy costs / Licenses and subscriptions / Wages and indirect costs / Platform maintenance and customer relations / Policy instruments (Business tax Consumption tax Externalities).
Revenue Streams	Rental fees for products / Late fees for overdue items / Delivery fees / Advertising services / Maintenance and repair services / Long-term revenues and sales of second-hand / Providing consultancy services / Solution providers.	Sales revenue from remanufactured components / Increase in brand value / Increased market share through new offerings / Reduction of disposal costs / Frequent users: monthly: quarterly: yearly subscription + special fare per minute / Occasional user: fare per minute / Subscription fees / Usage fee (time-based) / Sponsorship / Advertising.

The last column in Table 2 reflects the additional actions or resources that need to be identified when iteratively developing the BMC. In the context of repairability, both the subscription and pay-per-use models yield comparable advantages, primarily attributed to the core characteristic of

both models: the product's ownership remains with the OEM. Consequently, the responsibility for product maintenance and upkeep does not shift to the consumer, representing a departure from the conventional linear sales model. When assessing

these two models concerning repair aspects, it is imperative to examine usage patterns within each.

Processes	PaaS provider Resources & Know-how			Outsourcing Resources & Know-how	
	L	M	H	E	N
Planning of collection from customer	Red	Yellow	Green	✓/✗	✓/✗
Visual pre-assessment	Red	Yellow	Green	✓/✗	✓/✗
Sorting at collection	Red	Yellow	Green	✓/✗	✓/✗
Packing at collection	Red	Yellow	Green	✓/✗	✓/✗
First mile-transportation	Red	Yellow	Green	✓/✗	✓/✗
Storage of used products	Red	Yellow	Green	✓/✗	✓/✗
Visual inspection & check lists for VRPs	Red	Yellow	Green	✓/✗	✓/✗
Repair and servicing	Red	Yellow	Green	✓/✗	✓/✗
Quality check & repacking	Red	Yellow	Green	✓/✗	✓/✗
Last-mile transportation	Red	Yellow	Green	✓/✗	✓/✗

Table 2. Relog-matrix employing traffic light analogy: red (L), yellow (M), green (H) providing low, medium, and resource and/or know-how availability, respectively. The matrix then signals whether there are existing (E) or new (N) partners in the development process.

The pay-per-use model offers incentives for less frequent product use, while simultaneously encouraging more comprehensive utilization during each usage session. For example, consider a washing machine offered under the pay-per-use model, which may produce fewer total washing cycles compared to a machine in the same environment offered through the subscription model and influence the user’s washing behavior, for example, by incentivizing a lower washing temperature by charging more for cycles at higher temperatures [28]. However, because each washing cycle carries a fixed cost, users are inclined to maximize each cycle’s capacity, potentially resulting in greater wear and tear per cycle as customers seek to optimize their resource utilization.

An additional differentiating factor pertains to the duration of product use under each model, significantly influencing the product’s handling, utilization, and consequently, its propensity for repair and the condition in which it is returned. Another important gap in the literature is the lack of methods for assessing reparability, especially for mechanical products [29]. The pay-per-use model, characterized by shorter rental periods, is more likely to experience less diligent treatment, potentially necessitating more frequent repair interventions. Conversely, the subscription model typically involves longer PaaS contract lengths, fostering a sense of responsibility and care among consumers, thus mitigating the frequency of repair requirements.

4.6. Assess the financial implications

When financially assessing business models, it is important to scope the LCC with the same functional unit and system boundaries, otherwise, the results are not comparable [30]. As such, fairly comparing the business models in Table 1 is challenging without access to large amounts of reliable data. Therefore, for the rough LCC presented in this research in supporting the case company, the focus lies in showing how the LCC supports the business model development. Figure 2 illustrates the profitability of the business-as-usual (Sales) business model compared to three PaaS proposals. Here, all

values are discounted relative a time-based discount rate, and the sales values are for comparability distributed equally over the PaaS contract length through the equivalent annual cost (EAC).

Through this approach, the value proposition of the PaaS business models could easily be adjusted, allowing the LCC to guide further development. For example, A and B yield lower profitability than the business-as-usual model, indicating that additional adjustments are necessary to avoid losses in the PaaS adoption. Meanwhile, the varied monthly profitability of A relative the same total profitability of B, is likely to enable dynamic value propositions that promotes loyalty, feeling of inclusiveness, or higher contract flexibility.

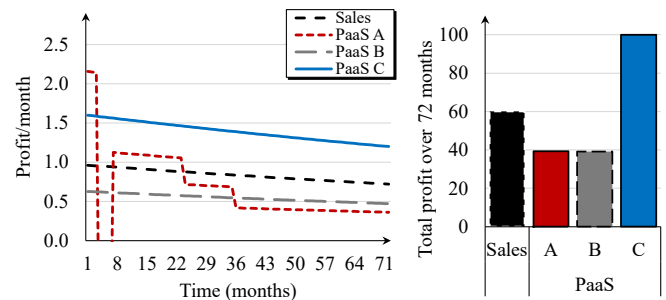


Fig. 2. A rough LCC of three PaaS business models in relation to the business as usual (Sales).

5. Discussion and Conclusion

The research presented here delves into the dynamic landscape of PaaS models, with a particular focus on their application in the EEE industry. BMC helps in organizing and visualizing essential components of the business model, with the value proposition at its core. Redesigning reverse logistics networks is essential to facilitate product assessments and make environmentally and economically viable decisions about reuse options. PaaS models operate as closed-loop systems, with used products returning to the manufacturer and being repaired/remanufactured, thereby contributing to a more sustainable product life cycle. LCC emerges as a valuable tool for understanding the financial consequences of this transformation, aiding companies in planning and decision-making.

Technologically speaking, PaaS incentivizes modular design, enabling easier repairs and upgrades, thus extending the product lifecycle. Modularity can also enhance the overall functionality of the EEE by ensuring quicker returns to optimal performance after repair and facilitating upgrades that reduce downtime. Additionally, OEMs have an incentive when offering PaaS to redesign their current products with an emphasis on longevity, reducing the frequency of parts replacements or small repairs and diminishing the life cycle costs. PaaS providers may prioritize energy-efficient designs to attract customers into a subscription by minimizing energy consumption during use compared to normal sales products. Due to the fact that the ownership remains with the OEMs, designers may be also inclined to integrate smart technologies (sensors, connectivity, and software updates) into the product, allowing to understand the use habits of customers in real time and perform maintenance before failure occurs through remote troubleshooting. All of these cascades in EEE design improvements mentioned start

with the change of paradigm from sales-centered to a service-centered through the implementation of PaaS business models, making the business model canvas a crucial tool.

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