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Concept of a Data-Driven Business Model for Circular Production Equipment

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Abstract

New legislation and the social movement around circular economy issues are currently forcing manufacturing companies to reassess the sustainability of their production and value chain. The circular economy is becoming an important economic concept, challenging manufacturing companies to develop approaches for realising resource-efficient production and usage of products. One potential area for sustainable production lies in the production equipment used for example in automotive production, such as robots, grippers and fixtures. However, new business models are needed to realise sustainable and recyclable production equipment, as existing ones do not take this into account. This paper presents an approach that deals with business model innovation and a digital platform ecosystem for circular production equipment. First, established business models are analysed for their transferability to automotive production. In particular, the use of subscriptions for production equipment is focused on and evaluated. The assessment is based on interviews with experts from equipment manufacturers and is quantified by them. The result is a presentation of the potential of the developed business model and a corresponding "as-a-service" concept for implementation using a digital platform.

Keywords

Business model innovation; Digital platform ecosystem; Automotive production; Production equipment; Circular economy; Pay per use

1. Introduction

The sustainability debate has established itself as a central issue in society and politics worldwide. The increasing demands on sustainability and the unstoppable development of digital technologies have led to a paradigm shift. It is no longer sufficient to focus only on the production of sustainable products. Rather, the entire value chain must be considered and the focus also has to be placed on sustainable production. The German government, for example, has revised its sustainability strategy and defined six prioritised transformation fields. One transformation field is the circular economy with the goal of sustainable production [1]. The automotive industry is responsible for a significant part of global CO2 emissions and is therefore under immense pressure to make its contribution. Accordingly, the transformation approach is forcing the automotive industry, Germany's leading industrial sector, to re-evaluate and rethink its previous linear economic orientation [2]. The urgency to implement sustainable production practices thus results from the growing environmental and climate problems. At the same time, customers and stakeholders are increasingly aware of the impact of automotive production on the environment and are demanding more sustainable solutions. By establishing a circular economy, sustainable design of production, manufacturing

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equipment, and processes could be realised in equal measure. This should reduce energy consumption, optimise the associated data cycles and reuse production equipment wherever possible rather than disposing of it at the end of its lifecycle [3].

In parallel, digital technologies are revolutionising the way products are made. The Internet of Things (IoT) and artificial intelligence offer enormous opportunities to optimise production processes, achieve efficiency gains and open up new business opportunities [4]. Automation, connected vehicles and smart factories are just a few examples of how digitalisation is transforming the automotive industry [5]. As a result, automotive manufacturers and suppliers must find new ways to implement sustainable production methods, strengthen their competitiveness and meet the demands of an increasingly digitalised world. In this context, this paper presents the concept of sustainable automotive production with a data-driven business model innovation approach for a digital platform ecosystem. The aim is to reorient conventional linear automotive production towards circular production. The focus will be on the production equipment used in automotive production, such as grippers, robots and fixtures. These production equipment are generally used in every automotive production line, and their consideration makes a significant contribution to the main focus of circular production.

In a first step, suitable business models for establishing the circular economy at production equipment level will be identified and selected. The selected business models are then evaluated in a utility value analysis based on defined criteria in collaboration with experts from the field of equipment and fixture construction in vehicle production. The business model innovation developed is described for the integration of a digital platform ecosystem. This platform should enable the exchange of data and, above all, the service behind the business model.

2. Fundamentals and methods

2.1 Business Model

A business model is a representative definition of entrepreneurial action to generate profits or revenue for a company while adding value for the customer [6]. The business model innovation methodology can be used to increase profitability or reduce costs in a company [7]. However, the methodology can also be applied to achieve innovation and sustainability [8]. The St. Gallen Business Model Navigator (BMN) describes 55 different model concepts for business model innovations. The authors assume that nine out of ten business model innovations are a recombination of known ideas, concepts and elements of business models from other industries. According to the BMN, the process of business model innovation is divided into four phases: Initiation, Ideation, Integration and Implementation [9]. In addition, the authors identify three basic strategies for developing new business models based on the 55 existing business model concepts:

- Transferring an existing business model to another industry
- Combining two or more existing business models to take advantage of both
- Replicating a successful business model in other product areas

2.2 Digital platform ecosystems

Digital platforms are becoming increasingly important in the industry as they can enable new business models, increase efficiency and enable collaboration easier. A digital platform in industry is a virtual environment that acts as an interface between different actors, processes and technologies to enable information sharing, collaboration and increased efficiency in production [10]. The digital platform is the focus of a digital ecosystem and maps its service, see Figure 1. It enables the interaction of the ecosystem's various stakeholder groups of partners, developers, customers and other stakeholders. The ecosystem itself is a socio-technical system, it includes not only digital and technical systems but also the organisations and

people and their relationships with each other [11]. Usually the ecosystem is organised as a two-sided market. On the one hand, the supply and on the other hand, the demand is coordinated on the platform [12]. The platform ecosystem is characterised by the interactions and interdependencies between the participants [13]. Each participant contributes to increasing the value of the entire ecosystem. For example, if more providers are present on a platform, the offer for customers increases, which in turn attracts more customers. This creates a network effect where the value of the platform increases exponentially with the number of further users [14].

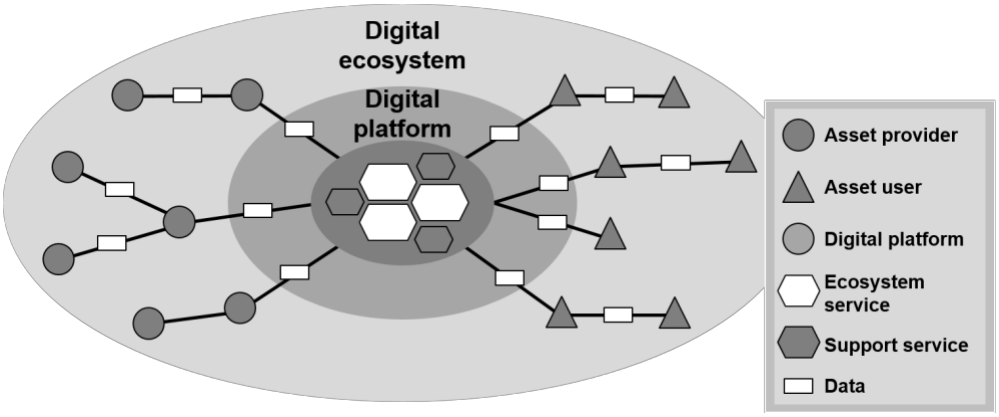

Figure 1: Digital ecosystem framework [15]

2.3 Circular Economy

The circular economy is an approach to reducing resource consumption, minimizing waste and creating a more sustainable economy. This approach is based on the concept that products and materials are kept in closed loops so that they are reused as much as possible [16]. Circular production aims to replace the current largely linear production chain, in which raw materials are extracted, processed into products, used and then disposed of. Instead, products are to be designed in such a way that they can be broken down into their constituent parts at the end of their life cycle and these can be fed back into the production process in a way that adds as much value as possible [17]. To implement such circularity, the 9-R-framework from KIRCHHERR presents an approach [18]. This comprises 9-R-strategies for returning products and components to the process in the most value-adding way possible. These are, for example, Reuse, Repair, Remanufacture and Recycle [19]. According to KIRCHHERR, a classification can be made between R-strategies for smarter product use and manufacturing, extension of the life of the product and its parts, and the useful application of materials [18]. Depending on the R-strategy, materials can be extracted from products and reused in new products. The nine R-strategies are sorted in descending order of circularity.

3. Application

In this paper, the implementation of business model innovation is based on three steps and is illustrated in Figure 2.

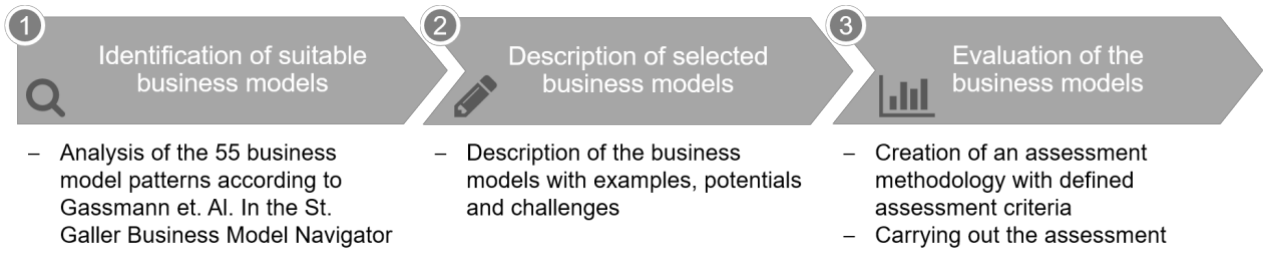

Figure 2: Methodological approach of this paper

The first step is to identify suitable business models. The focus of the business models to be selected should be on the possibility of establishing a circular economy in automobile production. In the context of this work, the 55 business models of the St. Gallen Business Model Navigator are used for the implementation of a business model innovation. The methodology shows a high suitability for the identification of suitable business model concepts for the implementation of a new business model innovation. In a second step, the concepts behind the selected business models are described and examples of companies that are already successfully using the business models are presented. Furthermore, the potentials and challenges arising from the use of the different business models are highlighted. The last step is an evaluation of the identified business models using two evaluation methods: pairwise comparison and utility analysis. For the evaluation by means of pairwise comparison, corresponding criteria are first defined and then weighted accordingly. After defining and weighting the evaluation criteria, the business models identified as suitable in step 1 are evaluated using the utility value analysis method. The results of the assessment by pairwise comparison and utility analysis are based on interviews with experts from the field of equipment and fixture manufacturing. In the second part, the focus is placed on the digital platform ecosystem for the feasibility of the business model innovation. For this purpose, a concept for the implementation of the business model through a corresponding digital platform will be developed.

3.1 Identification of suitable business models for circular automotive production

The business model concepts to be developed must enable sustainable automotive production. The focus should be on using one of the 9-R-strategies to extend the life of the production equipment and its components. For this, the principle of leasing, renting and sharing of durable products shall be supported and the possibility of managing is to be ensured through a corresponding digital platform. In his research on business model innovations, SCHALLMO defines three classes for categorising business model ideas. These classes are Pursue, Consider and Discard [20]. In the context of this paper, the 55 business model concepts of the St. Gallen Business Model Navigator are examined and assigned to the three categories mentioned:

Pursue: The circular economy principle is fulfilled. Fact sheets are prepared for the business model concepts, which present the relevant information on the respective concepts. The identified business model concepts are then evaluated by the assessment methodology in cooperation with experts from the automotive industry.

Consider: The principle of circular economy is not directly fulfilled. The business model concepts are therefore considered for use as a supplement in the conceptual design. No profiles are created for this category.

Discard: The circular economy principle is not present. Therefore, these business model concepts are not considered further in the assessment and subsequent conceptualization

3.2 Description of selected business models

After examining the 55 business models with regard to their possibility of establishing circular automotive production at the production equipment level and classifying the models into the three categories mentioned above, six suitable business models were identified. The identified models are described below.

Crowdfunding is the outsourcing of a product or project to several customers or investors. The investors, also called crowd funder, are private individuals or companies, who are free to decide how much they want to contribute to the project [21]. For money contributed, a right to use the product is acquired. Crowdfunder are usually not interested in maximizing returns, but in the implementation of the project [22].

The *Fractionalised Ownership* model represents a business model in which a community of buyers exists, in which each buyer receives a pro-rata right to use the object of purchase [23]. The company that offers the fractional ownership of its services is usually responsible for the management of the object of purchase. Car-

sharing concepts have already successfully implemented the business model pattern in which several customers share a car. This makes the use of the car more economically viable [24].

In the *Pay-per-Use* business model, the customer does not buy any products, but pays a monthly or annual fee for the use of the products. A costumer pays within the framework of this business model exclusively for the effective use of resources [24]. A successful business model that uses the pay-per-use method is the Car-Sharing concept Car2Go by Daimler, which was established in 2008. Unlike conventional Car-Sharing services or car rentals, where a automotive is typically only rented on an hourly or daily basis, Car2Go charges the rental exactly by the used minutes [25].

In the *Rent Instead of Buy* business model, the customer acquires a temporary, paid right to use a product. The concept is like the pay-per-use business model. The difference is that the customer commits to paying a fee for the temporary use of the product, irrespective of the actual effective period of use [26]. SolarCity, which was purchased by Tesla in 2016, represented a company, that successfully applied the Rent Instead of Buy model in their business [27]. The solar equipment manufacturer designed and installed solar panels on residential rooftops. The customer could choose between two options, the immediate purchase of the system or the Rent Instead of Buy option.

In a *Subscription* model, the customer acquires a temporary right of use or takes out a subscription to a product. The frequency and duration of use are contractually agreed with the company and paid by the customer in advance or at regular intervals [28]. The software provider Salesforce transferred the model to the software industry over more than 15 years ago. The customer pays an amount in return for which he receives the company's software, including all updates, via the internet [29].

The *Trash-to-Cash* pattern represents a concept of sustainable economy. Used goods that are waste products at the end of their life in the value chain are recycled and then reused [30]. One company that has established the principle of the business model pattern in the company, is Caterpillar. The company has introduced a remanufacturing program, in which used parts are refurbished and resold. By reintroducing them into the product cycle, waste is reduced and, on average, about 85 per cent of the individual components can be recycled [6].

3.3 Evaluation method of identified business models

Table 1: Overview of the business models to be evaluated

	Product Financing	**Potentials**	**Challenges**
Crowdfunding	Leveraged	Product financing by costumers	Product manufacture only if financial targets are met
Fractionalized ownership	Self-financed	Denomination of the purchase amount	Limited adaptability
Pay-per-use	Self-financed	Payment only for actual use	Precise forecast of future revenues
Rent instead of buy	Self-financed	Short-term rent for capital-intensive goods	Forecast of rental income
Subscription	Self-financed	Long-term rent for capital-intensive goods	Client must conclude long-term rental agreement
Trash-to-cash	Self-financed	Sustainable economic model	New product manufacturing requires new warehousing

For the six business models identified and described, a classification was made within the levels of product financing, potentials and challenges, seen in Table 1.

The methodology of utility value analysis was used to evaluate the business models. For this purpose, corresponding evaluation criteria were first developed for the identified business models. The evaluation criteria are based on the objective of identifying the most suitable business models for establishing the circular economy approach within automotive production at the operating resources level. The criteria are based on SCHALLMO [20] and are listed in table 2.

These evaluation criteria were first weighted through expert interviews from the automotive industry with a focus on equipment manufacturing using a pairwise comparison. To carry out the utility analysis, a corresponding evaluation of the criteria was carried out for each business model using dimensionless evaluation numbers. The calculation of the individual utility value per criterion is carried out according to the following formula:

$$Utility\ value = Rating * Weighting\ in\ \% \quad (1)$$

By adding up the individual utility values accordingly, an overall utility value could then be summarised for each business model. On the basis of the total utility value, a raking could then be created that determines which business model optimally fulfils the previously defined guiding question. For the utility value analysis carried out in this work, the following evaluation numbers from 0-3 were chosen:

- Rating 0: the alternative does not fulfil the criterion
- Rating 1: the alternative hardly fulfils the criterion.
- Rating 2: the alternative partly fulfils the criterion.
- Rating 3: the alternative fulfils the criterion completely.

4. Results and discussion

4.1 Business Model Innovation

This chapter presents the results of the pairwise comparison and the utility analysis. Both methods were carried out in cooperation with experts from the equipment manufacturing industry. When conducting the comparative methods, the experts' assessment was made from the perspective of introducing the respective business models in their own companies.

A total of the four expert interviews were conducted. The results of the pairwise comparison were used to weight the evaluation criteria in the utility value analysis. The average results of the four utility analyses carried out are shown below in Table 2.

Table 2: Average results of the four utility analyses

		Crowdfunding	Fractionalized Ownership	Pay-per-Use	Rent Instead of Buy	Subscription	Trash-to-Cash
	Weighting	Utility Value					
Customer benefits (focus: sustainability)	11,1 %	0,2	0,1	0,3	0,3	0,2	0,2
Acquisition of new customers	15,7 %	0,2	0,2	0,5	0,3	0,3	0,3
Corporate image	11,8 %	0,1	0,1	0,4	0,4	0,4	0,4
Market acceptance	12,5 %	0,1	0,1	0,4	0,3	0,4	0,3
Technical feasibility (internal)	5,6 %	0,1	0,1	0,2	0,2	0,2	0,1
Financial feasibility (internal)	12,9 %	0,3	0,3	0,4	0,3	0,3	0,3
Need for know-how for employees	8,0 %	0,2	0,1	0,2	0,2	0,2	0,2
Customers' willingness to pay	16,3 %	0,3	0,3	0,5	0,5	0,5	0,3
Differentiation in competition	6,3 %	0,1	0,1	0,2	0,1	0,1	0,1
Total utility value		**1,6**	**1,4**	**2,9**	**2,4**	**2,5**	**2,1**

The aim of the evaluation is to make the currently largely linear car production sustainable by introducing the principle of circular economy, i.e. renting, leasing and sharing production resources at equipment level. The examination of the results shows that the pay-per-use business model achieves the highest utility value, followed by the subscription and renting instead of buying business models. For the experts, therefore, the classic rental models are the most attractive solutions for business model innovations to implement the principle of the circular economy in the currently largely linear automotive production. According to the experts, the pay-per-use business model is a good way to support car manufacturers in making their automotive production sustainable. In addition, the business model is expected to attract a large number of new customers. The reason for this is the fact that the customer only pays for the actual use of the respective production equipment. Although the trash-to-cash business model is a business model for sustainable business in the literature, it does not achieve the highest utility value. According to the experts, the technical and financial feasibility of the business model leads to an increased effort. The two business models crowdfunding and fractionalised ownership achieve the lowest utility values and are thus at the end of the ranking. The acceptance on the market and the customers' willingness to pay for the business model are not considered to be given.

With the establishment of the pay-per-use business model in car production, the scenario arises that automotive manufacturers do not buy capital-intensive production equipment such as grippers or fixtures, but acquire the right to use the product for a certain amount of money. However, it is agreed that the customer only pays for the actual use of the product. In the chosen concept, the supplier in the field of operating equipment retains ownership of its own product. This means that the supplier can refurbish and reuse the product at the end of its useful life if possible. Reusing the production equipment prevents it from being disposed of at the end of its life. The identified business model establishes the principle of the circular economy and makes the currently largely linear automotive production sustainable at equipment level.

4.2 Concept digital platform business model “as a service”

As digitalisation progresses, "as a service" approaches are becoming increasingly important in the field of business model innovation. The "as a service" approach enables companies to offer their products or services in the form of a subscription-based model in which customers pay for access to the use and added value of the solutions offered. For the realisation of a circular automotive production, this approach lends itself to the "pay per use" business model. At the equipment level, this concept is called "Equipment as a Service", whereby production equipment is rented instead of purchased. This not only ensures that resources are used as needed, but also makes it possible to recycle production equipment. After the utilisation phase, the production equipment is to be returned to the manufacturer and reprocessed according to an R-strategy (Reuse, Recycling, Remanufacturing,...) and re-rented as often as possible. The business model "equipment as a service", which is based on the pay-per-use approach, is to represent the core of a digital platform ecosystem. For this purpose, stakeholder groups from different equipment manufacturers will make their production equipment available to the corresponding user group. Besides the easily calculable costs, another main advantage of this approach is its flexibility. It allows manufacturers to offer their customers customised solutions that are tailored to their specific requirements. Customers thus have the option of using production equipment as needed and are no longer tied to long-term contracts, allowing them to adapt their production to rapidly growing requirements and changes. Similarly, in-house storage of production equipment will be eliminated in the long term, saving storage costs. In 2020, Porsche and Munich RE founded the joint venture Flexfactory, which was to implement the Production as a Service approach on a large scale. In August 2023, however, the dissolution of Flexfactory was announced. The exact reasons for this are not known, but the following challenge could be considered [32].

One of the main challenges behind this approach is internal company standards, which makes it difficult to use the same production equipment more than once in different companies. However, 85% of entrepreneurial respondents to a BCG survey said they would share their newly built factory, while 62% said they would share existing facilities [32] . Similarly, data must be collected during the use phase in order to be able to derive an appropriate R-strategy after use. The security and data protection of customer data plays an essential role here, as it is transmitted via the internet and stored in the cloud. Thus, a distinction must be made between data relevant to the production and utilisation phases, but with successful implementation, the user of the production equipment can also benefit from appropriate monitoring.

5. Conclusions and Outlook

The focus of this paper is on designing sustainable automotive production by conceptualising through business model innovation. The aim was to establish the circular economy approach for renting, leasing and sharing durable production equipment. Looking at sustainability aspects in automotive production at equipment level, it was found that the concept of sustainability is already firmly anchored in the corporate strategy of leading car manufacturers. Measures are being taken to increase energy efficiency in automotive production. However, the potential of the circular economy in automotive production is not yet exploited. Currently, there are no existing circular business models in automotive production. This shows how important it is to develop innovative business models to establish the circular economy in automotive production for production equipment. The evaluation showed that the four experts agree that the pay-per-use business model is the best solution for establishing a circular economy for production equipment in automotive production. The pay-per-use business model approach reduces the share of investment costs in capital-intensive production equipment. The user only pays for the actual use phase, and the equipment manufacturers can then recondition the production equipment and rent it out again. The conceptualisation of sustainable automotive production through recyclable production equipment was described in this paper through the "Equipment as a Service" approach. However, the business model alone is not sufficient. For the realisation, in addition to the modularity of the production equipment, a suitable sensor concept must

also be identified in order to be able to classify it into an R-strategy after the utilisation phase. The core of further consideration will be the realisation in the digital platform. Suitable data interfaces must be created between all business partners, such as the customer and the service provider of the equipment-as-a-service model, in order to guarantee effective and efficient implementation.

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Biography

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