

Article

Consumers' Acceptance of a Bio-circular Automotive Economy: Explanatory Model and Influence Factors

Simone Wurster ^{1,*} and Rita Schulze ²

¹ Department of Innovation Economics, Technische Universität Berlin (TU Berlin), 10587 Berlin, Germany

² Forschungsförderung und Tagungen, DECHEMA e.V., 60486 Frankfurt am Main, Germany;
rita.schulze@dechema.de

* Correspondence: simone.wurster@tu-berlin.de

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Abstract: Sustainability in the automotive sector and appropriate end-of-life (EOL) management options for car tyres are important and constitute global issues. There is currently an oversupply of EOL tyres and the potential of circular economy (CE) tyres and for bio-based (BB) tyres warrants further investigation. Likewise, BB and CE tyres might be an interesting approach to improve the overall sustainability of the tyre life cycle. Research on drivers for the acceptance of CE and BB tyres is currently missing. In 1989, a socio-economy model was created to understand the acceptance of various products. This model is still popular in many areas but does not address sustainability questions of the 21st century appropriately. This article aims to provide a better understanding of the factors which drive acceptance of sustainable tyres. It presents an acceptance model and related influence factors in three areas: variables related to the consumers, perceived product characteristics and stimulating moderator variables. The third aspect refers in particular to labels and certification influencing consumer views on existing product characteristics. This article ends by discussing how availability of such labels could be promoted through eco-labelling of tyres and related standardization, addressing the industry and policy makers to make the automotive sector more sustainable.

Keywords: sustainability; bio-based products; automotive industry; eco-labels; tyres; cars

1. Introduction

1.1. Motivation for This Research

In 2017, the Earthbound report issued an article on the web titled “What can the world do with 1.5 billion waste tyres?” In addition to the burden of this existing waste, around 17 million tonnes of used tyres have to be managed globally on an annual basis [1]. Various regulatory changes of the last years require appropriate solutions. In Europe for example, landfilling has been banned since 2003 for whole tyres and since 2006 also for shredded tyres [2]. Regarding incinerations, prohibitions exist as well. There is a need for action towards the creation of a circular tyre economy (CE): an economic system in which “the value of products and materials is maintained for as long as possible; waste and resource use are minimized, and resources are kept within the economy when a product has reached the end of its life, to be used again and again to create further value” [3]. While consumers become more and more sensitive to sustainability and climate issues in various topics, e.g., regarding plastic bags, food packaging and mobility in general, car tyres are still not in the focus of the conscious consumer. A specific issue in this context is the management of end-of-life tyres. End-of-life (EOL) tyres may offer the potential to create new markets if appropriate value-adding recycling technologies are identified. Therefore, appropriate knowledge to stimulate the demand for these tyres is needed.

1.2. Research Gaps and Objectives

This article aims to provide a better understanding of the factors, which drive acceptance of sustainable tyres. It focuses particularly on Europe. Based on the European Union (EU)'s CE action plan, at the end of life of a product (which is the tyre in the given case), priority must be given to those measures, which best guarantee the protection of man and the environment in the production and management of waste, taking into account the principles of precaution and sustainability. According to the CE action plan, the end-of-life waste hierarchy is as follows: 1. prevention, 2. preparation for recovery, 3. recycling, 4. other recovery, mainly energy recovery and 5. disposal [4].

Currently, only a fraction of the used tyre stock is utilized for re-use and re-treading (part worn tyres) [5]. In many countries, energy recovery is still the dominating end-of-life option, see [6]. In addition, the potential advantages of bio-based (BB) products and the goal of establishing a BB economy have been discussed in recent years [7]. In this context, BB products are "products wholly or partly derived from biomass" [8]. Based on this definition, also products whose BB share is only 1% can be labeled "BB". This shows that the products' contribution towards a BB economy varies a lot. Concerning the sustainability goals to secure non-renewable resources and to become independent of crude oil, analyzing opportunities to create and commercialize products with a high share of BB content appears to be promising. To date, tyres typically contain a mixture of BB and fossil-based rubber; thus, they are BB products. Nevertheless, tyres with a high share of BB content are already being developed and even available, in particular tyres made with rubber derived from dandelion biomass (e.g., Continental's Urban Taraxagum tyres).

Recycled rubber is currently added to new tyres in small amounts. Against the current oversupply of used tyres and the producers' interest to reduce the dependence on primary rubber (i.e., synthetic rubber made from fossil fuels), it is interesting to understand how well the goals towards a CE match with the consumer's needs. Only a small fraction of the rubber used in tyres is currently from secondary sources such as recycled tyres [5].

Quotes provided in [9] illustrate prejudices regarding retreaded tyres (translated): "What are retreaded tyres really good for? Retreaded tyres are a cheap alternative. But they are supposed to change the driving behaviour. Are they really a safety risk?" These quotes indicate information needs as well as a need for strategies to overcome prejudices and to stimulate the demand for environmentally friendly tyres effectively. For example, a search in Web of Science shows that there is a lack of scientific literature on the topic of retreaded tyres. The keywords "retreaded tyres" and "acceptance" provided no suitable hits in the relevant research categories (Engineering Chemical, Humanities Multidisciplinary, Environmental Sciences, Management, Biodiversity Conservation, Green Sustainable Science Technology and Ecology). Even the search term "retreaded tyres" alone led to only six hits. The most important contribution in this context [10] is eight years old. Two follow up-articles of 2017 [11,12], not listed in Web of Science) identified four research streams regarding used tyre management: legislation-oriented research, treatment options, mathematical modelling approach and application alternatives. The absence of research on consumer acceptance illustrates the research gap in particular. To address this gap, this article provides answers to the following questions to support the development and supply of sustainable CE and BB tyres:

1. How can the acceptance of sustainable tyres be modelled?
2. What are consumers' needs and interests with regards to tyres and sustainability?

Based on question 1, this article analyses current acceptance models regarding their applicability for sustainability topics. No current model addresses the relevant aspects appropriately. However, the model of [13] appeared to be suitable for further modification and served as the foundation for a new model with sustainability-oriented elements. Question 2 aims to develop this model further. It will be answered by the help of a comprehensive analysis of various research streams linked with sustainable automotive products and the identification of applicable content. After describing our methodological approach in Section 2, Section 3 provides a new acceptance

model for a CE in the automotive industry, together with specific sets of variables derived from literature. The article ends with a conclusion and a discussion in Section 4, also summarizing topics for further research.

1.3. Novelty of This Research

Based on our analysis, the current state in socio-economic acceptance models does not provide an appropriate frame to describe the acceptance of sustainable products regarding sustainable tyres and the specification of concrete characteristics of these products. The model of [13] was developed in 1989 to understand the acceptance of various products. This model is still popular in many areas but does not address sustainability questions of the 21st century appropriately. This article aims to contribute to overcoming this gap by presenting a new acceptance model, which considers sustainability aspects specifically.

2. Materials and Methods

According to [14], “recognition (of) the needs and acceptance of individuals is the beginning stage of any businesses and this understanding would be helpful to find the way of future development, thus academic are interested in (understanding) the factors that drive user’s acceptance or rejection of innovative products.” As mentioned in Section 1, the current research on used tyre management consists of four areas, while research on consumer acceptance is missing (see Figure 1).

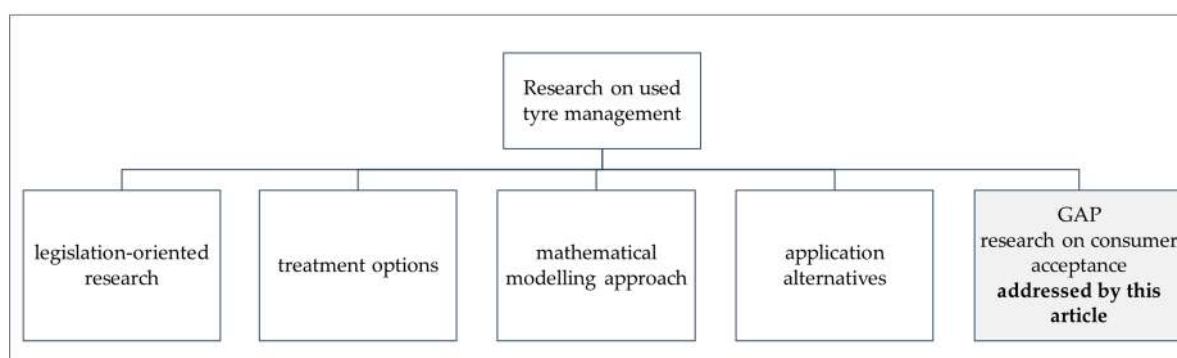


Figure 1. Current research on used tyre management and the research gap addressed by this article.

To address this gap, current acceptance models were analyzed, leading to the development of a new model and five clusters of acceptance variables. The iterative research process is shown in Figure 2.

The creation of the acceptance model started by joint analyses of the research topic and existing acceptance models based on the models presented by [15]. No model appeared to be suitable for the given purpose concerning sustainable consumption. One model, however, appeared to be suitable for further modifications and the systematic integration of sustainability elements, leading to the creation of an advanced acceptance model for sustainable products.

Its creation was linked with the specification of acceptance variables related to sustainable car tyres based on further literature analyses. For this purpose, the current state in surrounding research streams was analyzed regarding sustainable consumption in the fields of automotive products, BB products and CE products. Figure 3 illustrates the specific positioning of the products of our research.

The identification of acceptance variables started by a targeted identification of sources in the databases Web of Science (WoS) and Business Source Complete (BSC), published since 2009. Search combinations of the terms “acceptance” and “readiness for use”; “tyres” and “automotive”; “waste”, “bio-based”, “environmental-friendly” as well as “biofuels” were used. In each case, the search was carried out by using the displayed terms as well as synonyms selected for linguistic purposes with the support of experts.

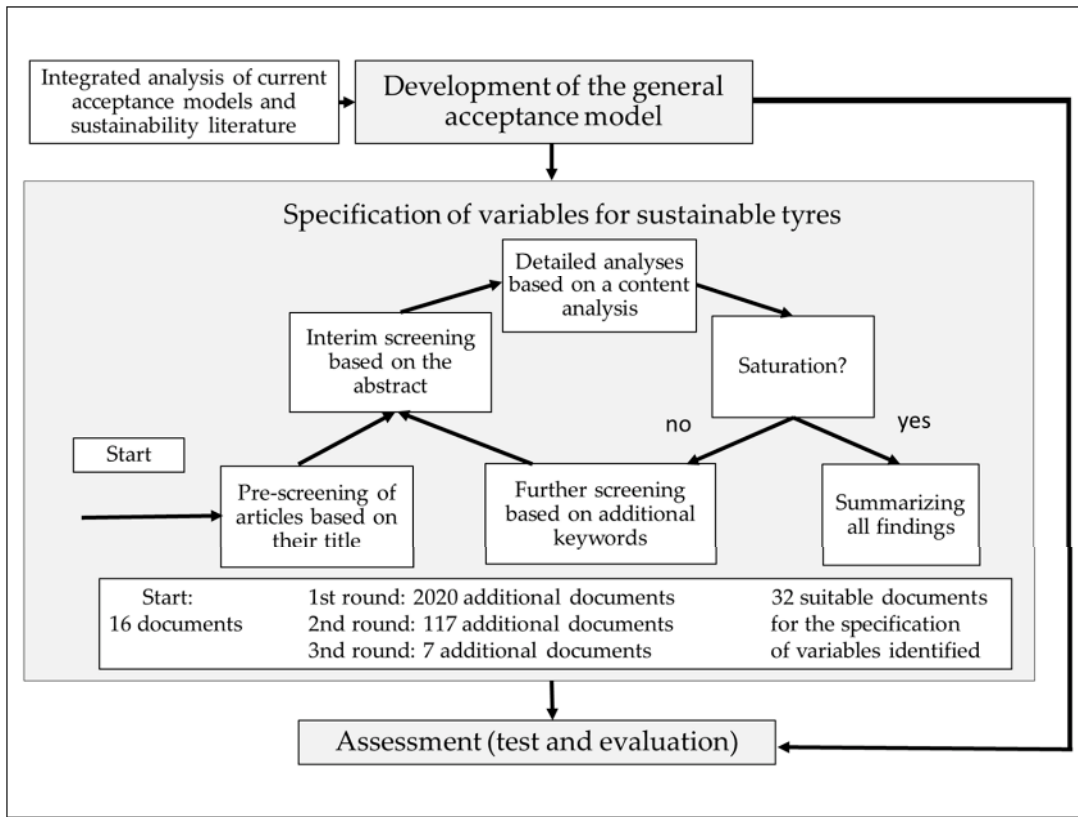


Figure 2. Stages of the model development and the specification of the acceptance variables.

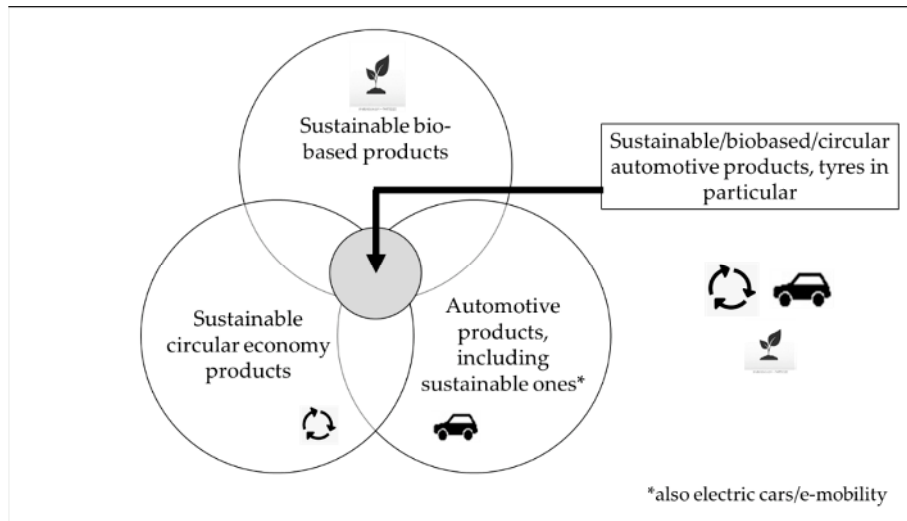


Figure 3. Positioning of certain car tyres in the broader sustainability context.

The 16 hits for the acceptance of BB and CE tyres and automotive components according to Figure 2 contained very few suitable results. Therefore, general findings on the acceptance of sustainable, BB and CE products were analyzed with regard to implications for the automotive industry (2020 documents). However, again only a fraction of them could be used for further analyses. In most cases, the articles referred to topics that were too far away from our product focus. They included, for example, the willingness to accept for municipal waste recycling, consumers’ perspective on CE strategies for reducing food waste as well as various articles on green building technologies, recycled water, sustainable clothing and even wind energy.

Of particular value in the analyses were findings from the field of electromobility to deepen the general understanding of consumer preferences regarding sustainability and innovation. Due to the restriction of the search to "automotive" AND "bio-based" or "recycled", some of these articles were not included in the group of the first 16 hits. At the same time, the biofuels sector's use of renewable raw materials suggested helpful implications for BB automotive components, which are made of renewable raw materials. Therefore, the acceptance of biofuels was specifically researched and included in the analyses, leading to 117 hits. Based on suggested cross-references and recommendations, seven additional studies were selected for the analysis.

In total, we screened 2,160 contributions. Examples showing why articles were eliminated from further analyses due to their product topics were already given regarding the first 2,036 hits. Another group of articles, which had to be excluded in all search rounds, referred to the key word "acceptance" but did not include acceptance criteria. Alternative topics not in our focus were, for example, design experiments, services and business models. In addition, the Web of Science database also included entries on articles to which no access was provided.

In summary, a total of 32 studies were selected for in-depth analysis. Table 1 provides an overview of these studies, for which the demand side of BB and CE car components constitutes the focal topic area for this article. A specific template was used for a structured analysis of the selected articles focussing stakeholder groups, acceptance factors and other influences, which is shown in Table A1, (Appendix A). In addition to our model, five clusters of acceptance variables were created on this basis.

Table 1. Analyzed research articles to specify the acceptance variables.

Topic	Authors
Environmentally sustainable products	Bhate & Lawler (1997) [16], Axsen et al. (2012) [17], Bossle et al. (2016) [18], Medeiros et al. (2014) [19], Hanss & Böhm [20], Liobikienė et al. (2017) [21], Liobikienė & Juknys (2016) [22], Luchs & Kumar (2017) [23]
Bioeconomy	Bröring et al. (2017) [24]
CE	Camacho-Otero et al. (2018) [25], Camacho-Otero & Pettersen (2017) [26], Russo et al. (2019) [27]
BB products	Russo et al. (2019) [27], Sijtsema et al. (2016) [28], Carus et al. (2014) [29], Lettner et al. (2017) [30], Peuckert & Quitzow (2017) [31]
Electric vehicles	Adnan et al. (2017) [15], Schuitema et al. (2013) [32], Egbue & Long (2012) [33], Li et al. (2017) [34], Liao et al. (2017) [35], Moons & Pelsmacker (2016) [36]
Alternative fuels	Lanzini et al. (2016) [37], Linzenich et al. (2019) [38], Chang et al. (2015) [39], Li & McCluskey (2014) [40], Li & McCluskey (2017) [41], Moula et al. (2017) [42]
CE cars	Despeisse et al. (2015) [43]
Other (green vehicles' digitalization)	Mihet-Popa & Saponara (2018) [44]
Other (life cycle assessment)	Tarne et al. (2017) [45]
Other (green information)	Wang et al. (2018) [46]
Comment: [46] was eliminated later. In contrast to the title, the authors write in the document that the article refers to laptops and not to cars.	

Our research resulted in an acceptance model with advanced sustainability elements, which were tested as part of a bigger survey among sustainability-oriented consumers. A total of 323 customers of the web platform for sustainable food "Meine Kleine Farm" in Germany were surveyed for this purpose. In addition, the model was evaluated based on critical rationalism principles according to [47,48]. Based on our findings, managerial implications and implications for policy makers were derived.

3. Results

3.1. Acceptance Model

3.1.1. Foundations and Fundamental Variables

The goal to support the market uptake of sustainable tyres and the fact that “the recognition (of) the needs and acceptance of individuals is the beginning stage of any businesses” [14] imply the question how the acceptance of sustainable tyres can be modelled. A specific issue in this context is the question of which specific characteristics these tyres should have.

To provide deeper insight in the acceptance of sustainable tyres, we analysed current acceptance models regarding their suitability for specifying the characteristics of sustainable products. We defined the user acceptance of a sustainable (here, BB and/or CE) product as the proven willingness of a user group to use this product for the tasks for which it was produced (derived from [49], who developed this definition in the context of information technology). The research literature offers a number of theories to describe the acceptance and adoption of environmentally friendly automotive products.

Authors in [15] review differences between five theoretical approaches and research streams, which we analysed with regards to sustainable tyres:

1. Theory of planned behaviour and theory of rational choice (e.g., [50,51]);
2. Normative theories and environmental behaviour (e.g., [52]);
3. Lifestyle, self-identity and symbols (e.g., [53] and [54]);
4. Diffusion of innovation and consumer innovation capacity (e.g., [32,55]); and
5. Emotions and consumers (e.g. [33]).

Although [15] had a special focus on electric vehicles (EV), many of the approaches considered have been developed without a specific product in mind. The five theoretical approaches show that the consumer and his/her behavior are at the center of the considerations. The theory of planned behaviour [50] with the core elements of attitude, subjective norms, perceived behaviour control, intention and behaviour provides an example of this. As mentioned in Section 1, the focus of our analysis is on the product side. Although, the concepts “product” and “user” are closely related from a model perspective in the research streams considered. A special product focus is required to address the needs of our analysis.

The considerations of [24] with regard to the bioeconomy are useful here. They refer to topic area 4 of the five above-mentioned priority areas, diffusion of innovations, and focus specifically on [55] diffusion theory. Focusing on the acceptance aspect, they refer to the technology acceptance model according to [13] and Figure 4. In addition to actual product use as a dependent variable, the two factors “perceived ease of use” and “perceived usefulness” play a central role in that model and are influenced by external variables, such as the age and gender of a potential user. Both factors determine the attitude towards the new technology, which corresponds to an emotional attitude.

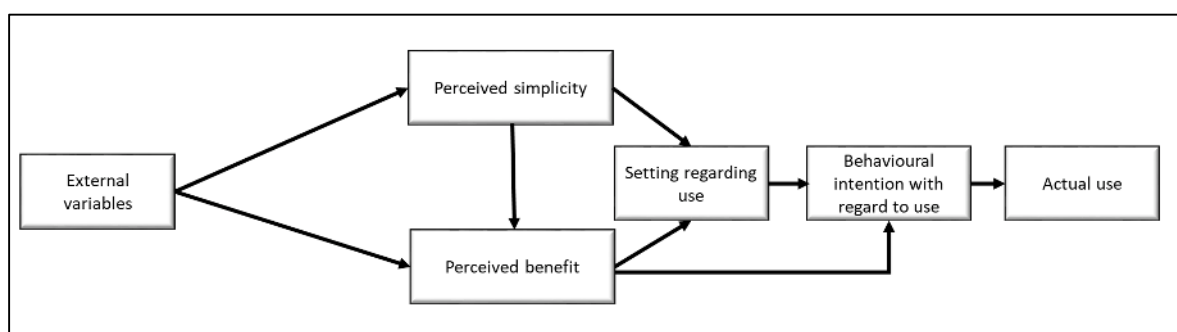


Figure 4. Acceptance model according to [32].

Together with the perceived benefit, it determines the strength of the user's intention, which ultimately determines the actual use or adoption of the technology.

3.1.2. Benefit and Simplicity Variables

In 2015 the United Nations Member States adopted the 2030 Agenda for Sustainable Development with its 17 UN sustainable development goals (SDGs) (see [56]) and set the starting point for a significant global societal change. The 17 SDGs include, for example, goals on "no poverty," "zero hunger" and "good health and well-being" (goals 1 to 3) as well as goals related to "sustainable cities and communities," "responsible production and consumption" as well "climate action" (goals 11 to 13). These goals are also reflected by the buying considerations of sustainability conscious consumers. In the given context of BB and CE products, it is therefore important to distinguish between different types of benefits that consumers can enjoy when using sustainable tyres. Therefore, we extend the model element "benefit" by not only considering the fundamental functional and monetary benefit for a potential but also the ecological and socio-economic benefit for society. In addition to the simplicity of use, studies in the various focal areas of our research (e.g., [16] and [25] for environmentally friendly and CE products and [38] for a related bio-economy area of the automotive industry: biofuels) demonstrated the importance of an easy purchase process. On this basis, the perceived simplicity consists of the elements "purchase" and "utilization".

3.1.3. Moderator Variables

The state of research shows the importance of product information on the perception of sustainable products (see [28]), for example, in the form of certificates and labels (see [24]). In this context, ecolabelling is "a voluntary method of environmental performance certification and labelling that is practiced around the world" [57]. An eco-label "identifies products or services proven environmentally preferable overall, within a specific product or service category" [57]. As described in more detail below, specific characteristics are specified in the ISO standards 14020-14024.

Information-based regulation, which encompasses certification schemes, labels, online inventories and other regulated disclosure practices, is increasingly popular in the environmental domain [58]. The disclosure of product-related information through standard-based labelling can support their uptake on the market. For example, the EU Ecolabel has greatly helped promote the acceptance for some product categories [37]. In general, the acceptance of information disclosure schemes is very much dependent on their credibility and the way the information is deployed [58]. Despite this, a large number of (private) labels that are not based on standards exists [59]. According to three ISO standards (ISO 14024-26), type I, II and III ecolabels are distinguished. ISO 14024: 2018 (for Type I, Environmental Labels), ISO 14021: 2016 (for Type II, Environmental Labelling) and ISO 14025: 2006 (for Type III, Environmental Declaration).

The importance of product information is visualized by a moderator variable, defined as "a variable that affects the direction and/or strength of the relation between an independent (. . .) variable and a dependent or criterion variable" [60]. On this basis, the model's moderator variable refers in particular to the existence of information and the information's influence on the perceived benefit and usefulness of a sustainable product. An important element in this context is the impact of certificates and labels on the perceived ecological benefit of a sustainable product. Figure 5 summarizes the model elements. The external variables refer to different consumer typologies.

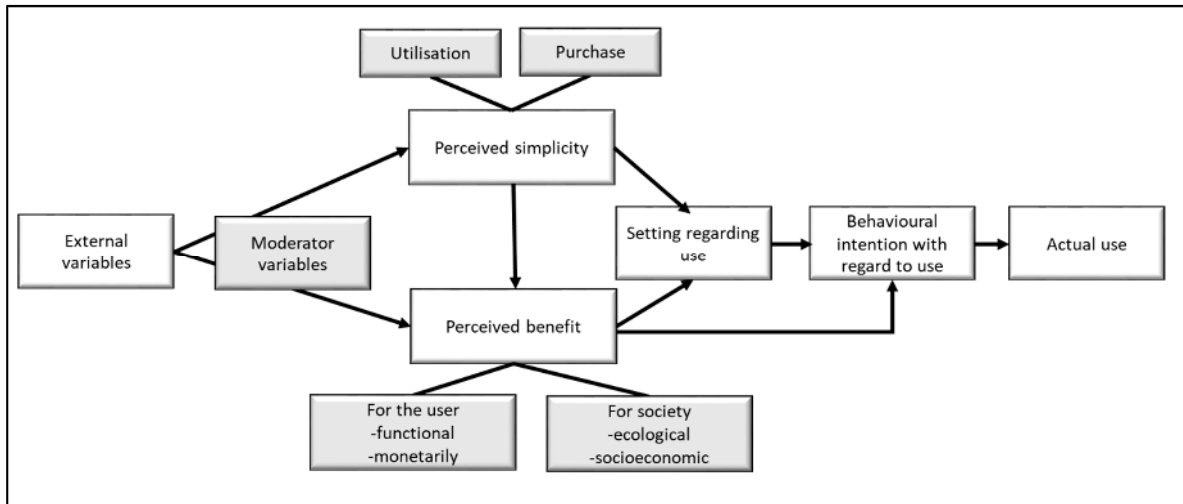


Figure 5. Acceptance model for sustainable physical products (modified model based on [13])

3.2. Specific Acceptance Variables

The new elements of our model require further specification. In addition, the external variables related to the consumers have to be specified. Guided by [25], our analysis included three topic areas (see Figure 6):

- External variables regarding consumer attitudes and typologies (A);
- Perceived product characteristics: benefits and simplicity of the purchase (B); as well as
- Information on benefits and simplicity to specify the moderator variables (C).

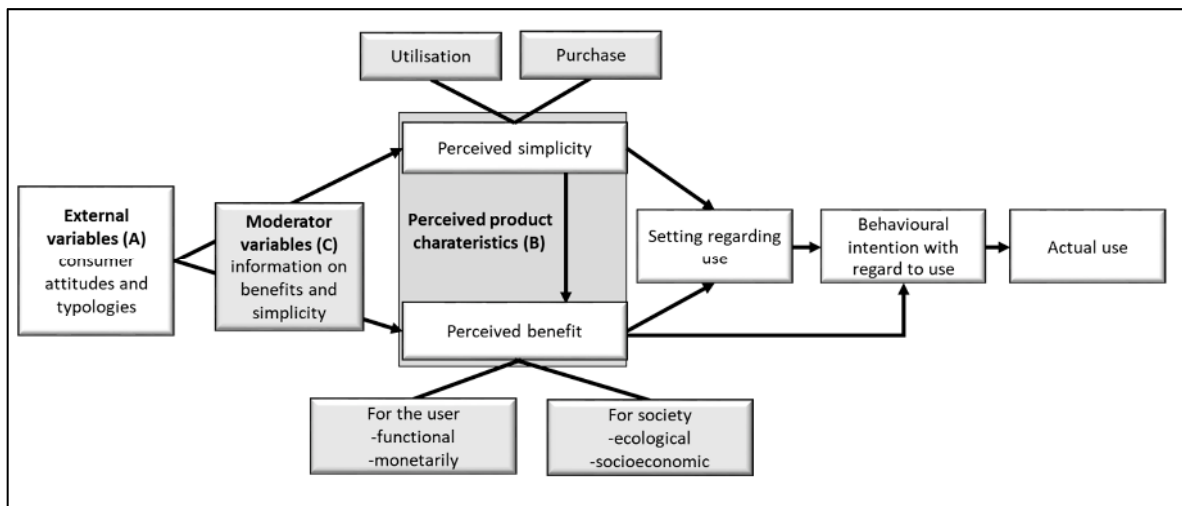


Figure 6. Model elements to be specified.

As the first item highlights, the focus is on consumers and end users. With regard to the demand in companies and public procurement, the work of [31] is central from our point of view. However, they refer only to BB products in general without providing a typology. All aspects with reference to [31] refer to these two target groups and not to end users.

Based on the model, we analyzed the three topic areas in detail. The results are summarized in Table 2.

Table 2. Current state of the model elements with regards to bio-based and circular automotive products.









Category	Subject	Findings	Product range	Authors
External variables related to the consumers (A)	Consumer attitudes and target group segmentation	<ul style="list-style-type: none"> • Generally important for "Bio-waste" products: green self-image, attitude towards BB products, age and previous purchasing experience with regard to environmentally friendly products. • Generally important for consumer typologies, especially in the automotive context: instrumental, hedonistic and symbolic attributes. • Consumer typologies in the EV context: <ul style="list-style-type: none"> - Five clusters: Engaged Greens, Aspiring Greens, Conservatives, Low-tech Greens and Technologist. - Pro-environmental Identity versus Car-authority Identity. • Consumer groups with regard to biofuels: persons who own an electric or hybrid car and/or buy organic food were more willing to buy bioethanol. 	    E  I	[17,18,21,27,32,41], various other authors
	Price (in relation with consumer segments)	<ul style="list-style-type: none"> • Socio-demographic consumer characteristics of BB fuels are not a good indicator of willingness to pay (WTP), specific other characteristics need to be considered (see sections on Consumer attitudes and segmentation). • WTP a premium price for biofuels higher for people who normally buy green products. 	 B	[37]
Perceived product characteristics (B), Benefits	Functionality	<ul style="list-style-type: none"> • Sustainability has a low weight in EV acquisition compared to cost and performance. • Uptake of a "green automotive innovation" by technology enthusiasts only in the case of performance superiority. • Incentives such as tax credits to subsidize EVs and fuel taxes have little impact on market penetration, if consumers do not trust the solution concerned. • CE-based solutions must not only convince functionally, but also provide additional advantages for consumer perception. 	 E 	[25,33]

Table 2. Cont.









Category	Subject	Findings	Product range	Authors
	Characteristics "BB" and "recycled"	<ul style="list-style-type: none"> • BB share is considered less important factor than recyclability and recycled content in a survey for BB products. However, automotive products were not considered. • Regarding general attitudes and information needs of consumers towards BB products [28] found: <ul style="list-style-type: none"> - Most participants were not familiar with the concept "BB" and wanted more information on environmental impacts, health aspects and functionality (etc.). - (As with [29]) it was not decisive whether a product is BB, but rather whether the consumer himself/herself has an advantage through the purchase. 		[28,31]
	Price	<ul style="list-style-type: none"> • End users in the automotive sector are unwilling to pay Green Premium prices for BB products and alternative fuels. • Hierarchy for innovative fuels in Germany: 1st price, 2nd availability, 3rd usage requirements, 4th range and only 5th pollutant emissions. • In order to be able to call up premium prices, quality seals are recommended. They signal compliance with reliable "quality standards". 	  	[25,29,38,40,41]
	Brand	<ul style="list-style-type: none"> • Brand loyalty influences acquisition of EV. • Green self-identity partly conveys the relationship between attitudes towards BB products and the intention to buy and change BB products. 	  	[16,27,36]
	Health impact for consumers	<ul style="list-style-type: none"> • Is of central importance for BB products in general, see line characteristics "BB" and "recycled" above. 		[28]

Table 2. Cont.






Category	Subject	Findings	Product range	Authors
	Safety and security	<ul style="list-style-type: none"> • A well-known brand, a moderate purchase price and strong PS are the main concerns of customers, while security and PS are the most influential variables ([15] on EV). • With regard to EV, only a minor security risk is considered. 	E 	[15,33]
	Product life expectancy	<ul style="list-style-type: none"> • Compared to other vehicle characteristics rather minor importance at EV (the importance of fundamental other issues was mentioned instead in this context). 		[39]
	Environmental factors (group approach)	<ul style="list-style-type: none"> • Reduction of hazardous substances, dematerialisation and dismantlability in 3rd, 4th and 9th place in a ranking of 18 product properties. • Important for end consumers: energy consumption in production, contribution to recycling made from waste, toxicity, environmental impact (e.g., of the product used). • Core factors in business-to-business markets: CO₂ savings, lower toxicity, recycling and recyclability. • Important for public procurement: Detailed criteria must be adhered to. Key factors are energy efficiency and global warming potential before recyclability, environmental pollutants other than CO₂, human toxicity and the use of recycled materials as feedstock. 	I  	[28,31,39]
	Environmental factor Resource-efficient	<ul style="list-style-type: none"> • Resource efficiency, closing material cycles in a sustainable way, weakening the consequences of climate change are important issues. 		[24]
	Environmental and social factor Waste exports	<ul style="list-style-type: none"> • Importance of avoiding illegal exports. 		[43]

Table 2. Cont.









Category	Subject	Findings	Product range	Authors
	Social factors (group view)	<ul style="list-style-type: none"> • Creation of jobs at local and regional level, adherence to social standards, fair pay, reduction of poverty, opportunity for greater distributive justice (Note: [24] presents general view without own survey). • Less important than other factors for [31] 	 	[20,24,31]
	Social factorland use	<ul style="list-style-type: none"> • See certification, highlighted in contrast to other social factors. 	B 	[37]
	Social factor land use, food prices	<ul style="list-style-type: none"> • Fifty percent of respondents to a survey in Finland felt that biofuel production had a direct impact on food prices and would not buy biofuels from food crops. 	B 	[42]
	Digitization	<ul style="list-style-type: none"> • Regarding EV, this aspect is more pronounced than for other vehicles. • A special aspect is the Internet of Vehicles, with automatic updates via the Internet and large digital displays on which the driver communicates with the car. In this context EV are more advanced than "normal" vehicles. 	E 	[44]
Perceived product characteristics (B), simplicity	Availability	<ul style="list-style-type: none"> • "Product and service offering" is an important aspect considered in the decision whether to purchase a product or not. • Convenient procurement options are very important. • "Availability" second in the influencing factor hierarchy for alternative fuels after "price". 	I   	[16,25,38]

Table 2. Cont.
















Category	Subject	Findings	Product range	Authors
Moderator variables (C), information on benefits and simplicity	Functionality information	<ul style="list-style-type: none"> • Are very important for recycled or remanufactured products that are subject to quality reservations. • Uncertainty and risk play a major role in "not-new" materials. A sufficient level of information is important to counteract reservations. 		[25,28]
	Sustainability information	<ul style="list-style-type: none"> • Barriers to the adoption of EV, as consumers were unclear about the actual sustainability. • For products that are supposed to be more sustainable, the consumers would like to have concrete information on whether they are. Otherwise, they may be unsettled and will not buy the product in question. • In principle, more information is required on the characteristic "BB" (see line "Characteristic "BB"...). • The sales volume of various types of bioplastics depends mainly on prices, but also on marketing activities. 	E   B 	[28,30,33,35,37]
	Labels based on standards	<ul style="list-style-type: none"> • "In order to be able to retrieve premium prices, quality seals are recommended. They ... signal compliance with reliable quality standards" (see line on price in the section "Product characteristics (B), Benefit," see also the comments regarding the concept of quality there) 		[24]

Table 2. Cont.

Category	Subject	Findings		Product range	Authors
Legend					
Automotive, Biofuels	B 	Automotive, innovative fuels	I 	Bio-waste products	 
Automotive in general		Bio-based (BB) products		Circular economy (CE) and recycling management	
Automotive, Electromobility	E 	Bioeconomy in general		Environmentally sustainable products in general	

3.2.1. External Variables Related to the Consumers

Consumer characteristics are the first element of our analysis (model element A). To be considered specifically with regards to bio-circular products are the existence of a consumer's green self-image, attitudes towards BB products, age and previous purchasing experience with environmentally friendly products [27]. Considering these aspects with regards to sustainable automotive products, our analysis showed clearly that there was a certain relationship between green consumption in general and green automotive consumption (see [17,32,33]). In addition, our analysis has shown that there was a relation between the consumption of green automotive products in different product segments. In this context, [32] identified two interesting consumer groups with regard to biofuels: persons who own an electric or hybrid car and/or buy organic food were more willing to buy bioethanol.

In the EV context, five consumer clusters were distinguished: Engaged Greens, Aspiring Greens, Conservatives, Low-tech Greens and Technologist (in terms of EV, solar panels and green power) [17]. "Engaged Greens" are characterized by pro-environmental and technology-oriented lifestyle practices. "Low-tech Greens" may reduce mobility rather than considering sustainable driving on their own, while "Aspiring Greens" are interested in pro-environmental practices but have not developed pro-environmental lifestyles. The Non-green clusters, who score low on environment lifestyles, are seemingly the least interesting target group for sustainable automotive products.

The findings on the three types of green consumers have implications regarding the intention to purchase CE and BB tyres as well: "Low-tech Greens" may reduce mobility rather than considering sustainable driving on their own. "Aspiring Greens" have not developed pro-environmental lifestyles. For this reason, convincing them to buy these tyres may be difficult. The characteristics of Engaged Greens however adds them to the consumer group of specific interest in the given context.

In addition to questions on the relation between consumer characteristics and product acceptance, [37] provides specific findings on the willingness to pay (WTP) for BB products in the automotive sector. It shows that socio-demographic consumer characteristics are not well-suited indicators for this: as our before-mentioned findings have also shown for green consumption in general, specific characteristics other than the traditional socio-demographic ones are to consider with regards to the WTP. Likewise, [37] found that the WTP a premium price for biofuels is higher for people who normally buy green products.

3.2.2. Perceived Product Characteristics

Regarding product characteristics (model element B), the analysis highlights in particular the item's safety and security, price, brand, health impact for consumers, product life expectancy, availability as well as various environmental and social factors. In addition, there are factors that have not proven to be important so far, e.g., the characteristic "bio-based" itself. Most participants of the study in [31] of BB in general were not familiar with the concept "BB" and wanted more information on environmental impacts, health aspects and functionality (etc.). Likewise [33] found that an uptake of a "green automotive innovation" by technology enthusiasts was wanted only in the case of performance superiority. Figure 7 specifies our acceptance model.

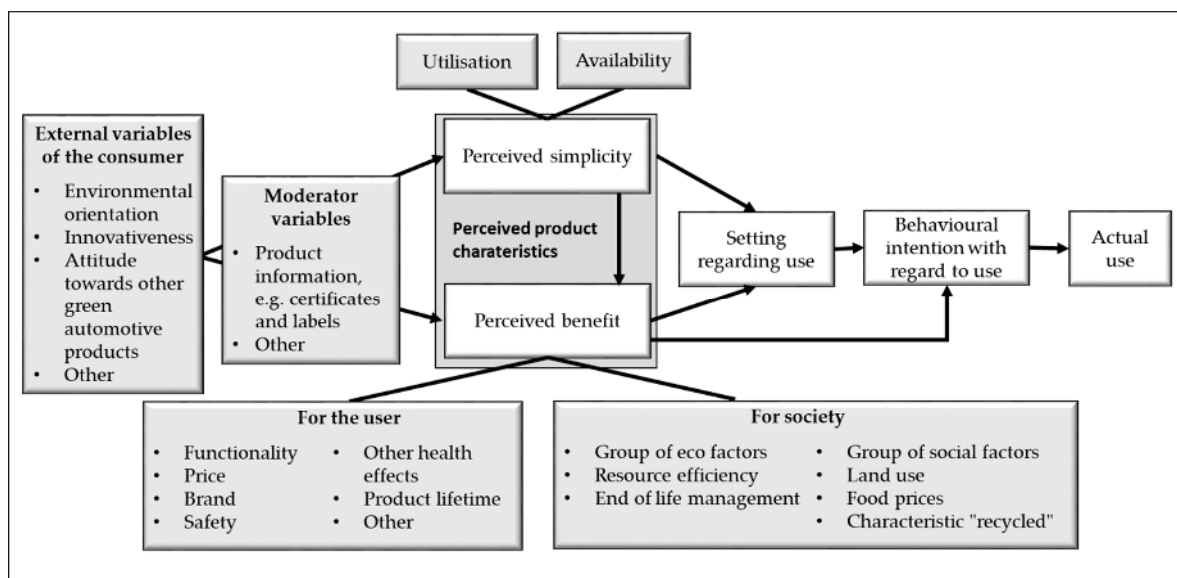


Figure 7. Specification of the acceptance model for sustainable tyres.

3.2.3. Moderator Variables

Special incentives for the acceptance of the products (model element C) refer to information needs and include information on functionality, information on sustainability as well as compliance with standards and certification.

Functionality information is very important for recycled or remanufactured products that are subject to quality reservations [25]. Uncertainty and risk play a major role in "non-new" materials. A sufficient level of information is important to counteract reservations [25,28].

Missing sustainability information may pose a barrier to the adoption of sustainable products, which has been observed in the context of electric vehicles [33], [35], as consumers were unclear about the actual sustainability in [33] and asked: "Show me they are truly sustainable". For products that are supposedly 'more sustainable' than others (e.g., BB or recycled products), the consumers would like to have concrete information and proof. Otherwise, they may be hesitant to purchase the product in question [25,28]. In principle, more information is required on the characteristic "BB" [28]. Likewise, the sales volume of various types of BB materials depends mainly on prices, but also on marketing activities [30]. Eco-labels and certificates also have to be considered in this context [37].

Findings from research on labels, certificates and other references from manufacturers show that consumers rely on these instruments when making purchasing decisions [25], [15]. In addition, [31] states generally for BB products: "The integration of BB content as criteria in existing eco-labels could help to promote acceptance in environmentally friendly public procurement. The criteria must be adapted according to the product group under consideration." At the same time, labelling products only as bio-based, without other relevant information (e.g., environmental and health aspects) is considered not useful and/or confusing [28].

4. Discussion

4.1. Summary of Findings

This article started by highlighting the importance of sustainable tyres and aimed to answer two questions:

1. How can the acceptance of sustainable tyres be modelled?
2. What are consumers' needs and interests with regards to tyres and sustainability?

To address question 1, a customized acceptance model for sustainable physical products was created, which considered characteristics of the consumers, their perceived benefits of the products for themselves and the society as well as moderating factors influencing the consumers' perceptions specifically. The model consists of consumer-related variables such as consumers' environmental orientation, moderator variables with regards to product information as well as perceived product characteristics.

A key insight from our analysis addressing question 2, which was based around this model, is that products containing BB material are not desirable per se, at least not without additional information on their (superior) sustainability (concerning the full life cycle of the product). In a similar way, it is likely that consumers will require information on the overall (environmental) sustainability of potential future tyres that better represent the CE idea, such as tyres that may contain a larger fraction of secondary raw materials, or with increased recyclability. Functionality is essential for the acceptance of all BB and recycled products, even more so for tyres, which have important safety implications. The clear communication of important functionality and sustainability aspects is, thus, essential for consumer acceptance. Further investigations to which extent this can be achieved by labels are necessary.

Our analysis has also shown that under consideration of additional factors, relationships between green consumption in general and green automotive consumption exists. In addition, there is a relationship between the consumption of green automotive products in different product segments. Likewise, it has shown that labels can positively influence green consumption and green automotive consumption in particular.

4.2. Managerial Implications

As summarized in Section 4.1, our analysis showed relationships between a) green consumption in general and green automotive consumption and b) between the consumption of green automotive products in different product segments.

One characteristic of pro-environmental consumer behavior is the purchase of 'green' products. However, on the other hand, buyers of green products are not necessarily interested in green automotive products. Authors in [17] clustered consumers according to their environmentally friendly consumer behavior in the automotive sector by distinguishing between Engaged Greens, Aspiring Greens, Conservatives, Low-tech Greens and Technologist. Our suggestion to market sustainable tyres successfully is to consider this segmentation and, in particular, the different types of green consumers appropriately.

In this context, Low-tech Greens are rarely interested in automotive purchases in general; Aspiring Greens have not implemented a pro-environmental lifestyle yet, while Engaged Greens provide specific potential to market green solutions. In addition, car drivers who use biofuels may be specifically interested in BB solutions.

For Engaged Greens, who also have specific technology-related interests, marketing CE and BB tyres in combination with digital tyre monitoring solutions may provide specific opportunities to support the sustainable use and exchange of tyres. According to [44], electric vehicles are often leading regarding car monitoring systems. Extending the suggestions of [37], we suggest to consider a focus not only on consumers who normally buy green products and organic food, but also on those who own an electric or hybrid car and/or buy bio-fuels.

Besides realizing appropriate environmental product characteristics, it will be important to communicate them to the consumers appropriately. Labels may provide specific support in this regard (see Section 4.3). Nevertheless, appropriate environmental characteristics alone are not sufficient to market CE and BB tyres successfully. Functionality is of great importance.

In the automotive context, safety is a key product characteristic. For this reason, it will not only be essential to ensure continuously that CE and BB tyres do not lack central functionality and safety characteristics but also that these characteristics are communicated appropriately.

In addition to individual marketing and selling considerations, collaborative standardization activities can be an appropriate tool to support innovation [61]. The potential contributions of standards for CE and BB tyres and the potential benefit of standardization to support labelling and, subsequently, label-based product acceptance were highlighted in Section 3.2.3. For this reason, vendors of sustainable tyres could investigate to what extent standardization could be an additional tool to support the communication of their tyres' product characteristics.

4.3. Implications for Policy Makers

Sustainability and issues of tyres and tyre recycling are topics which warrant further investigation, considering the importance of the topic based on the current issues with the oversupply of waste tyres. In light of the sustainable development goals of the UN, and the EU's CE action plan, which foresee a more efficient use of primary raw materials, it is worth investigating whether and how the tyre supply chain can contribute to these goals. Eco-labels for tyres may be a means to help highlight environmental benefits.

For tyres in general, a mandatory EU tyre label exists, which focuses on certain environmental but also safety-related aspects of the tyre's performance in the use phase. (Environmental aspects related to the use-phase dominate the environmental impact in a tyre's life cycle.)

However, the label refers only to the tyre's influence on the vehicles' driving behaviour, namely fuel consumption, wet braking behaviour and external rolling noise. According to the EU's plans for an extension of the label, it will include grip on snow, grip on ice, mileage/life, and abrasion/fine dust generation in the near future. Second-hand tyres are [62] however excluded from the label (unless these are produced outside of the EU), and so are retreaded tyres [9,62].

On a regional level, the German Blue Angel, a product label issued by the German government (Type I label), uses the same criteria as the EU tyre label. Instead of a rating (declared by the manufacturer itself), the label is awarded by a third party if certain threshold criteria are fulfilled [63].

In addition, a PCR (Product Category Rules) guideline for tyres has recently been published [64]. The guideline provides rules according to which life cycle assessment studies can be conducted. The results are communicated in so-called environmental product declarations, which are also verified by a third party (Type III environmental declarations). A number of tyre manufacturers and experts on life cycle assessment (LCA) were involved in the development of this guideline.

Section 3.1 described that the acceptance of information disclosure schemes is very much dependent on their credibility and the way the information is deployed [55].

The acceptance of the current tyre labels and certification by both the manufacturers and the consumers is crucial for their effects on purchasing behavior. The PCR guideline has been supported by industry. However, there are currently no published Environmental Product Declarations (EPDs) based on this guideline yet. The acceptance of the Blue Angel for tyres and the EU Tyre label both appear to be rather low, based on the prominence of the search criteria in online platforms for tyre sales [65], which show that strategies to improve the overall frame for their usage are needed.

The CE and BB material content of the tyres are not specifically covered by the reviewed labels. Regarding standards, the CE is a new topic in which the creation of standards has just began (the ISO TC 323 Circular economy was established in 2018).

As previously highlighted in the literature (see [66,67]), trade-offs between CE and BB goals and other environmental and sustainability aspects may exist. It is therefore important to clearly define and communicate specific sustainability goals and priorities before communicating them in the form of labels or through other evaluation tools. The knowledge on consumer preferences obtained from this study then needs to be presented to and discussed with the suppliers of the products, whose support for the (voluntary) declaration of BB- or CE-related aspects is a crucial condition for their implementation.

4.4. Limitations

This article provides a model for the acceptance of sustainable tyres with a number of acceptance variables. It also highlights the importance of labelling and certification to stimulate the consumers' acceptance. Previous studies have demonstrated the positive role of certification in promoting environmental consumption for other products, and future research could investigate the willingness to pay (WTP) in further areas. Extending this statement of [37] (made on sustainable fuels) to BB and CE car components, we call for more research on sustainability information in the automotive sector, which might be communicated in the form of eco-labels. In particular, it will be important to conduct further analyses to investigate the importance of each of the variables presented in this article in detail to derive eco-labelling priorities. Further research should also examine what specific characteristics the certification needs to have, leading to proposals for policy makers on the future use of ecolabelling schemes to make the automotive sector more sustainable.

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Appendix A

Table A1. Template of the analysis on acceptance variables.

Contribution
Research objective
Most important statements
Biobased properties of the product
CE-based properties of the product
Aspects of acceptance
Included yes/no
Description
Stakeholder groups considered
Private consumers
Companies
Other
General acceptance factors
Price
Functionality
Miscellaneous
Socio-economic acceptance factors
Environmental acceptance factors
Legal framework conditions
Norms and standards
Certificates and labels
Special framework conditions
Other remarks
Summary

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