Strategic and operational remanufacturing mental models: a study on Chinese automotive consumers buying choice

Article (Accepted Version)

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STRUCTURED ABSTRACT

Purpose: Remanufacturing is the only end-of-life (EOL) treatment process that results in as-new functional and aesthetic quality and warranty. However, applying mental model theory, we argue that the conception of remanufacturing as an EOL process activates an operational mental model (OMM) that connects to resource reuse, environmental concern and cost savings and is thus opposed to a strategic mental model (SMM) that associates remanufacturing with quality improvements and potential price increases.

Design/methodology/approach: We support our argument by empirically assessing consumers' multi-attribute decision process for cars with remanufactured or new engines among 202 car buyers in China. We conduct a conjoint analysis and use the results as input to simulate market shares for various markets on which these cars compete.

Findings: The results suggest that consumers on average attribute reduced utility to remanufactured engines, thus in line with the OMM. However, we identify a segment accounting for about 30 % of the market with preference for remanufactured engines. The fact that this segment has reduced environmental concern supports the SMM idea that remanufactured products can be bought for their quality.

Research limitations/implications: A single-country (China) single-brand (Volkswagen) study is used to support the conceptualised mental models. While this strengthens the internal validity of the results, future research could improve the external validity by using more representative sampling in a wider array of empirical contexts. Moreover, future work could test our theory more explicitly.

Practical implications: By selling cars with remanufactured engines to customers with a strategic mental model that values the at least equal performance of remanufactured products, firms can enhance their profit from remanufactured products. In addition, promoting SMM enables sustainable business models for the sharing economy.

Originality/value: As a community, we need to more effectively reflect on shaping mental models that disconnect remanufacturing from analogies that convey inferior quality and performance associations. Firms can overcome reduced utility perceptions not only by providing discounts, i.e. sharing the economic benefits of remanufacturing, but even more by increasing the warranty, thus sharing remanufacturing's performance benefit and reducing consumers' risk, a mechanism widely acknowledged in product diffusion but neglected in remanufacturing so far.

1. INTRODUCTION

End-of-life (EOL) treatment of products has been associated ecological and economic benefits (Seitz, 2007; Wang et al., 2014). A wide array of EOL treatment processes (EOLP) is applied in practice and has been extensively researched. Such processes include recycling, repair, reconditioning, and remanufacturing, and can be distinguished according to the depth of product deconstruction and the quality of the process outputs (Paterson et al. 2017). These processes have gained in relevance in recent attempts to design products for effective EOL treatment in reverse logistics and to define industrial material flows as a circular economy (Subramanian et al., 2014; Kadambala et al., 2017) in which EOL products and components are kept in the lifecycle. Research has explored challenges such as scheduling production when availability of EOL products is uncertain or the impact of EOL on OEMs' business strategies with a particular emphasis on EOL products cannibalising new product sales.

While most EOLP result in reduced quality as compared to the new product, remanufacturing is distinct as it (a) returns EOL products functionally and aesthetically to as-new condition, (b) applies a rigorous process of disassembly, cleaning, testing, and in some cases, technical upgrading that (c) ensures full restoration of functionality and appearance under maximum maintenance of the value created during the initial production process (Guide and van Wassenhove, 2001; European Action Plan, 2015; Paterson et al., 2017; Abbey, 2017; BSI, 2002).

However, we argue that this distinction between remanufacturing and other forms of EOLP is not sufficiently captured in the current theoretical debates and in market realities. In spite of equal or even better quality of remanufactured products, practitioners and researchers believe they must have a lower price than new and original products (Ovchinnikov, 2011; Subramanian and Subramanyam, 2012; Abbey et al., 2015a). In exploring this phenomenon, we apply mental model theory (Johnson-Laird, 1983). Mental models are thinking frames that determine the categories that we connect with a certain concept. Mental models determine how we see and organise empirical facts and how we interpret reality (Fiske and Taylor 1984). We suggest that remanufacturing is mentally modelled through analogies with other EOLP. Consequently, we identify an operational mental model that assumes that lower production costs result in lower market prices for remanufactured products. We contrast this with a strategic mental model that takes a value-based approach and posits that remanufactured products should be priced equivalent to their quality and value, i.e. equal to or slightly above new and original products.

We then undertake an empirical study among Chinese car consumers and explore consumer preferences in a conjoint study that assesses consumer preferences for remanufactured versus new engines together with different options of fuel consumption, warranty and price. Applying cluster analysis, we identify four segments in our data, including the two mental models. Interestingly, the strategic, value-oriented segment has reduced environmental awareness, suggesting that consumers in this segment indeed choose cars with remanufactured engines for their functional value, and not due to environmental motivations. In developing our argument and connecting it to our empirical study, we make three contributions: (1) We identify a tension in the theorising and practice of remanufacturing: While the operations and productions management community assumes lower value and thus reduced prices compared to new and original products, this appears counterintuitive to marketing and economic theory as remanufactured products offer by definition equal or better functional and aesthetic performance and warranty. (2) We apply mental model theory to conceptualise two opposed mental models. First, an operational mental model (OMM) that builds on an understanding of remanufacturing as EOLP, thus adopting a disposal mind-set that highlights the environmental benefits to the consumers and expects lower prices based on reduced production cost. Second, a strategic mental model (SMM) that emphasises the equivalence of functional and aesthetic value created by remanufactured and new products and that would expect same prices for products offering the same value. We use data from a multi-attribute conjoint consumer study to empirically support the existence of both mental models in the market for remanufactured car engines in China. (3) The SMM offers a stronger business case for remanufacturing and may thus strongly support sustainable supply chain practices and a circular economy. We discuss the conditions of SMM and develop policy, research and practice implications.

We develop our argument as follows. In section 2, we define remanufacturing more precisely and distinguish it from other forms of EOLP. We also introduce mental models and their application in business contexts. In the third section, we conceptualise an operational mental model that reflects the dominant EOL debates and practices, and we contrast it with a strategic mental model. We empirically explore these two mental models in an empirical study among Chinese car buyers and identify both mental models in the sample (sections 4 and 5). Finally, we discuss conditions for and implications of a strategic mental model in section 6.

2. CONCEPTUAL BACKGROUND – REMANFACTURING AND MENTAL MODELS

2.1 Remanufacturing Defined

Remanufacturing describes the return of “a used product to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product” (BSI 2009: 3.34). This definition by the British Standards Institution (BSI) defines requirements with regard to performance and warranty of a remanufactured product (Paterson et al., 2017). Through remanufacturing, a product at the end of its use or life is processed in order to restore its original functionality; the remanufactured product can thus be treated as an as-new product (Chakraborty et al., 2019). The standard further specifies that “both functional and cosmetic components shall be as-new” (BSI 2009: 3.1). It is further important that the BSI definition is congruent with those of other national or supra-national institutions such as the United States government (Federal Act, 2015) and the European Union (European Action Plan, 2015). It also corresponds with the definitions given in a broad range of academic literature (Hatcher et al., 2014; Ijomah, 2002; Paterson et al., 2016).

With respect to the quality, remanufacturing needs to be distinguished from other EOL processes. It “… is the only end of life process where used products are brought at least to Original Equipment Manufacturer (OEM) performance specification from the customer’s perspective and at the same time, are given warranties that are equal to those of equivalent new products” (Ijomah, 2002 cited in Paterson et al., 2017). The second element is warranties that are equal to or better than for the new product. These are crucial to create users’ confidence that the quality is equivalent or better compared to the new product (Wang et al., 2013). Important types of safeguards are testing systems (Ylä-Mella et al., 2015) and warranties (e.g., Hickey and Fitzpatrick, 2008). It is further worth recognising that the BS 8887-2-2009 standard defines as-new “from the user’s perspective”. Taking this definition literally would mean that products can only be considered remanufactured when users consider them to be equal to the corresponding new product.

The basis of the distinct as-new quality of the remanufactured product is a well-defined process in which the product is completely disassembled, cleaned and worn-out parts are either replaced or machined in order to restore the original functional and aesthetic quality of the product (Kapetanopoulou and Tagaras, 2011). The British standard (BSI, 2010) requires the following ten steps as part of the remanufacturing process: Collection of technical documents; collection of core, i.e. the used product or component that undergoes remanufacturing; initial inspection; disassembly; detailed inspection of components; functional and cosmetic remediation of components; replacement; reassembly; testing to validate the remanufacturing process and the remanufactured process; and finally issuing of a warranty. It is this comprehensive processing that distinguishes remanufacturing from other EOL processes.

Two dynamic aspects are relevant in the context of remanufacturing: innovation and upgrading. First, BSI specifies that the quality specification “applies to like-for-like products” (BSI, 2009: 3.34, Note 3). This implies that the quality of a remanufactured product must match the quality of the same new and original product. Assume that a core that is remanufactured today was initially sold five years ago; the remanufactured engine thus meets or exceeds the quality standard of the original engine as sold at that time. A relevant question is how remanufacturing performs in relation to technological innovation (Zhang et al., 2019) Technological innovations such as a new compact exhaust-gas aftertreatment system (e.g. Daimler, 2019) that was introduced very recently would thus typically not be included in the remanufactured engine. The comparison of a remanufactured with a new and original product may thus only be realistic for models that have been on the market for some time.

The second dynamic aspect considers upgrading of the remanufactured cores. Upgradability is a process that improves product functionality during the use phase and thereby extends the useful life span of the product (West and Wuest, 2017). Upgrading is an option that allows introducing technological innovation to remanufactured products (Chierici and Copani, 2016). Through upgrading, a remanufactured core could be of higher quality than its new and original version (Khan et al., 2018). The challenge from a reverse logistics point of view is to design the upgradability into the product (Aziz et al., 2016). For the flow of our argument, we follow the BSI assumption "that remanufacture applies to like-for-like products". Quality dynamics through innovation and upgrading will be revisited in the discussion.

2.2 Mental Models

Mental model are cognitive representations, i.e. personal theories of how things work (Senge, 1990). They include core assumptions about the elements and relationships that are relevant to a certain problem and thus allow individuals to make sense out of their perceptions of the world. Humans use categories and relationships of existing mental models to make sense of new information, and such information is used to update existing models (Johnson-Laird, 1983). Mental models are the foundation of individual and collective human reasoning, decision-making and behaviours. Humans interpret new information against the background of their mental models and tend to integrate new information into existing models (Fiske and Taylor, 1984). Mental models operate subconsciously (Wicks, 1992) and are formed through analogical thinking (Collins and

Gentner, 1987). In this paper we argue that one possible understanding of remanufacturing is shaped by forming analogies with other EOLP such as reuse, recycle and reconditioning.

Collins and Gentner (1987) show that humans refer to a familiar domain in order to explain an unfamiliar one by copying the logical structures of the familiar one. For our argument, conceptions were historically shaped for the EOLP of reuse (second-hand) and recycling (aiming to capture some raw materials from old products). When EOLP became more elaborate and concepts of reverse logistics and circular economy were then developed, consumers and professional and academic communities began to build their understanding of newer EOLP concepts including remanufacturing on the existing models of reuse and recycle. Collins and Gentner (1987: 243) describe how people "create new mental models that they can then run to generate predictions about what should happen in various situations in the real world". For example, one can form an analogy between remanufacturing and other EOLP and predict that remanufactured products are priced lower than new and original products.

2.3 Collective mental models

While mental models are at first models of individual constructions of the world, they are also shared socially for intersubjective sense-making that enables communication with others (Denzau and North, 1994). Collective mental models are crucial for functioning human interaction (Moore and Golledge, 1976) and affect the way problems are structured and choices are made and implemented (Co and Barro, 2009; Hodgkinson, 1997). They are distinct from individual mental models as collective cognition includes mental conceptions about relationships and interactions within the community (Weick and Roberts, 1993: 360). The mental models that a community shares are highly normative in the sense that they not only facilitate the interpretation and understanding of reality, but they also impact the construction of economic and social realities (Lakoff and Johnson, 2008; Lakoff, 2010). Examples of collective mental models include the interpretation of currency deflation and inflation, with US fiscal policy focusing on avoiding deflation based on experience of the great deflation in the late 19th century as compared to avoidance of inflation in Germany based on experiences during the first half of the 20th century. In academic contexts, collective mental models shape the requirements of 'valid' research with psychological disciplines focusing on internal validity in highly controlled experimental settings, while communities with stronger connections to industry associations, e.g. in a supply chain management, may generally put more emphasis on external validity and the representativeness of the results for the wider market (e.g. Moosmayer et al., 2012).

Collective mental models also include assumptions about markets, competitive structures and common mechanisms between demand and supply, and thus influence strategic choices and behaviours of all stakeholders (Lant and Phelps, 1999). Mental models have been introduced to analyse team effectiveness (Cannon-Bowers and Salas, 1990) and have been broadly applied to the management of teams (see Mohammed et al., 2010 for a review). Rust et al. (2016) explore how mental models shape the effectiveness of quality management and show that units with a revenue mental model focusing on customer satisfaction and retention perform better than units with a cost mental model focused on cost reductions. Co and Barro (2009) discuss how mental models of stakeholder collaboration influence the choice and effectiveness of collaborative and competitive stakeholder strategies. Moosmayer et al. (2019) analyse the reluctance of the (academic) business system to move towards more sustainable and responsible practices. They argue that utility-maximising theories taught in early undergraduate business classes shape students' mental models and thus limit their ability to integrate conceptions of sustainability and responsibility in later stages of their study.

Similarly, we argue that the collective nature of the dominant remanufacturing mental model as one of cheap prices for processed waste makes marketers price remanufactured products below new ones, makes customers expect lower prices, and makes academics question arguments that claim otherwise. Connecting to waste reduction, resource reuse and cost savings, this mental model limits the extent to which remanufacturing is associated with quality improvements and potential price increases. We develop the former as operational mental model and the latter as strategic mental model of remanufacturing.

3. REMANUFACTURING MENTAL MODELS

Economic theory suggests that out of two products A and B, which have the same functional and aesthetic performance and with B having "a warranty that is equivalent or better" (BSI 2009: 3.34) than that of product A, consumers should be indifferent when the warranty is equivalent or even have a preference and increased willingness to pay for B when B's warranty is better. However, operations and product management theory and practice take for granted that the opposite is the case for remanufactured products, which are assumed to have lower prices in spite of equivalent performance (Zhao and Zhu, 2015; Zhu et al., 2016; Gaur et al., 2015; Cui et al., 2017). We suggest that this can be explained by an underlying operational mental model (OMM) and explore a strategic mental model (SMM) as alternative. The two models are summarised in table 1 and will be developed in detail below. The prevalence of the two mental models will later be explored in our empirical study.

+++ Insert Table 1 about here +++

3.1 An Operational Mental Model (OMM) of Remanufacturing

Substantial **terminological confusion** exists. The distinction between remanufacturing, which creates like-new products with the same warranty, and other EOLP is imprecise in industry standards (BSU 2002 vs 2009) as well as in academic literature (Chakraborty 2019, Kumar and Ramachandran 2016) and in business practice (Zhao and Zhu, 2015; Zhu et al., 2016). Due to this confusion, remanufacturing is associated with other EOLP processes and thus with using waste, with lower quality and with reduced reliability for the consumer. Consumers do not perceive the quality of remanufactured engines as equivalent. Guidat et al. (2015) identified general sceptical customer perception with regard to remanufacturing. More specifically, remanufactured products are perceived to be of lower quality (Hazen et al., 2012; Khou and Hazen 2017), which can easily be explained through mental model theory. The underlying mental model contains EOL analogies and thus shares the lower quality – lower price conception that is shared by all other EOLP. Price-sensitive consumers may be likely to buy buying remanufactured products because they feel that such products made from waste are cheaper than brand-new products (Cui et al., 2017: 1310).

Cost pricing argumentation. Chakraborty (2019) states that "remanufacturing cost can be 50-60 percent less than the production cost of a new product …" and concludes "Thus, makes the remanufactured products cheaper". This assumes cost-plus pricing by which a product's price is determined by the production cost (Schindler, 2011). While it is to be expected that remanufacturing cost is lower (Chakraborty et al., 2019), there is no immediate logic why the same functionality needs to be priced lower. Often, claims that remanufactured products have lower prices are presented without any conceptual support, so they appear to be axiomatic (e.g. Gaur et al., 2015). This is in line with an understanding of mental models as unconscious conceptions that guide our reasoning and construction of reality. In contrast, a strategic mental model would realise that the functional and aesthetic value created for the consumer is same for new and remanufactured products and prices should thus be the same. Similarly, Kumar and Ramachandran (2016) state without justification that remanufacturing "results in products that are cheaper but with comparable warranty". These reduced prices can also be found in business practice. E.g. Zhu et al. (2016) cite the example of Steyr truck generators that sell at ¥ 44,000 when remanufactured as compared to ¥ 70,000 when new. The same mental model underlies work that considers different consumer segments and assumes that price-sensitive consumers buy remanufactured products (e.g. Cui et al., 2017: 1310; Abbey et al., 2015a). The perceived gap in value between remanufactured and new products is even greater within the business-to-consumer (B2C) market opposed to business-to-business (B2B) (Atasu et al., 2008). This is largely due to B2C products having a considerable aesthetic emphasis whereas B2B products are purchased predominantly for their functional attributes (Goodall et al., 2014). Nevertheless, one should consider that the price can be too low, and customers may associate low prices for remanufactured products with inferior quality, thereby leading to a decrease in customer acceptance (van Weelden et al., 2016).

Disposal mind-set. Remanufacturing a product "…instead of throwing it in a landfill protects the environment" (Hsu et al., 2016). This makes remanufacturing one option for what to do with products ready for disposal. By OMM, remanufacturing follows an EOL logic that focuses on retaining some value from waste that is to be disposed of. The disposal mind-set is associated with lower value as compared to new products; this logic holds true for all EOL processes – except remanufacturing which (a) focuses most on maintaining the product value that was created during earlier production rather than decomposing and disposing of it, and (b) reaches a quality level that is not lower but rather equal or higher than that of the original product (e.g. BSI 8887-2-2009: 3.34). In line with the disposal mind-set is that remanufacturing is regularly conceptualized as a legal obligation to take care of EOL waste and to cover the cost of disposal (Hsu et al., 2016), rather than a process that maintains and enhances value.

Environmental value to the customer. "Increasing the demand for a remanufactured product requires gaining consumers' trust, increasing environmental awareness and reducing the price of the product" (Cui et al., 2017: 1309). This quote well summarises the OMM: The core value that remanufactured products create for customers within the OMM mental model is not the functional product value but the environmental value. In this model, remanufacturing caters to the environmental attitudes and preferences of consumers; these might compensate for the assuminged reduced willingness to pay for the functional value. It is believed that customers buy remanufactured products for environmental reasons (i.e. their process value) rather than for enhanced functional product performance (including reliability). Moreover, remanufacturers are concerned about whether customers pay for the "green" attribute of products (Guidat et al., 2015). In line with the OMM, an emphasis on 'green' implies that beyond these green characteristics, remanufactured products are of lower value. The remanufactured product's additional value is considered green and not functional.

Imposition model. Dealing with waste is a legal obligation, and violations against legislation are punished (Shou et al., 2019). EOLP is necessary to avoid fines and higher cost for waste disposal that is made expensive, e.g. through taxation or emission certificates. The main motivation for remanufacturing in this logic would be to avoid punishment for potential violations of legislation, rather than remanufacturing because it is a strategically wise business move.

Supplier push. In the operational OMM, remanufactured products are not wanted by the consumer. While consumers prefer new and original products, vendors need to push remanufactured products into the market by offering at lower prices (Wong and Zeng, 2015).

Cannibalisation. Brands and OEM lose revenue and profit because for each remanufactured product sold, the market will absorb one new and original product less. Because remanufactured products are sold at a lower price, this reduces revenue and profit (Chaowanapong et al., 2018; Goodall et al., 2014). An additional complexity is that firms might avoid cannibalisation of their own products by not engaging in remanufacturing but thereby creating business opportunities for competitors (Agarwal et al., 2015).

Reverse logistics logic. The OMM seems compatible with the idea of reverse logistics (Hsu et al., 2016) in which remanufacturing is to a substantial part a logistical challenge in a linear world in which the product is designed for best EOL treatment, i.e. starting from its decomposition process (Lo, 2014). While Kumar and Ramachandran (2016: p.2187) point to the profit maximization opportunities by "differentiating product categories or customer segments based on the differential willingness to pay across different categories", thus allowing a strategic, value-oriented view, they distinguish “price sensitive customers who prefer remanufactured products and quality sensitive customers who prefer new products”, thus promoting a OMM that offers remanufactured products with a discount. In the next paragraph, we thus explore the strategic mental model in more detail.

3.2 A Strategic Mental Model (SMM) of Remanufacturing

Terminological distinction: precision required. As indicated above, it is economically rational to assume that a product that has the same functionality and an equal or better warranty (which is how BSU 2009 defines remanufacture) should sell at a higher price. By definition, remanufactured products have at least equal value as compared to like-for-like new and original products. This distinguishes them from all other EOL processes. Within the SMM, this specification of equal value would be taken seriously and translated into price expectations. A precise understanding that is shared throughout the academic and practice communities is thus crucial for the logic of the SMM to be practically viable. A remanufactured automotive product or part can be a perfect substitute for a new product or any new part because of the same quality and same warranty as compared to the new one (Biswas and Rosano, 2011). If this precise understanding of remanufacturing as a process that is distinct from other EOLP by being at least equivalent in quality and warranty was shared throughout the community, then one should expect that consumers' willingness to pay should correspond and be equal to that for new products.

Above, we argued that remanufacturing as EOLP carries the inferiority and low-price burden of all other EOLP, which we explained through mental model theory. Similarly, the function of price as quality indicator constitutes a mental model in the opposite direction. While most research explores continuous relationships, thus postulating a negative price-demand relationship for the entire market, the concept of consumer segmentation suggests distinguishing different groups in the market (Ovchinnikov, 2011). In particular, among price-sensitive consumers, price would be negatively associated with demand; for quality-focused consumers, however, this relationship could be positive because consumers associate higher prices with higher quality (Schindler, 2011). In other words, because remanufacturing is offered at lower prices with a "re-…" name from the EOLP range, consumers perceive quality as lower. SMM suggests that some consumers might associate remanufactured engines with higher quality products, if they were sold as *field-tested and warranty enhanced* and at 5% above new engine prices.

Value pricing argumentation. Value pricing starts price setting from the economic value that a product creates for the customer. As argued above, remanufactured products which have like-new functional and aesthetic quality and an equal or enhanced warranty create at minimum the same functional and aesthetic value for the customer. Value pricing theory would thus suggest that remanufactured products should sell at the same or slightly higher prices than new and original products (Schindler 2011; Zhao et al., 2016). In line with the SMM, Zhu et al. (2014) demonstrated that quality assurance (e.g. warranties) is the important factor consumers consider in selecting remanufactured products.

Sourcing mind-set. As part of the OMM, we identified a disposal mind-set that treats remanufacturing as a process to dispose of a used product at the end of a product's life. The limitation of this view is that it focuses on the disposal of old products rather than the creation of new products. Within the SMM, the starting point would be the value creation for the customer of a (new or remanufactured) product; thus the question to be answered would be how to source the best (most suitable) components for the best (most suitable) product for a group of customers. Considering remanufacturing with a 'sourcing for new' rather than a 'disposal of old' mind-set, would change the focus from cost-efficient disposal to value maximizing sourcing and production. This sourcing view seems viable for remanufacturing as – in contrast to the other EOLP – it can constitute the solution with the highest functional and aesthetic quality.

Functional value to the customer. Remanufactured products are "as-new" (BS 8887-2-2009) and "provide levels of performance, reliability and lifespan that are equal to and, in many instances exceed, those of the original engine" (ivorsearle.co.uk). This definition focuses on the functional value of remanufactured products and clarifies that performance, reliability and lifespan are equal or superior to new and original products. While allowing for additional environmental value to be created, the focus of the SMM would be on the equal or enhanced functional value of the remanufactured product. One field in which remanufactured products are sold at the same price are products for which consumers cannot identify the EOLP characteristic of the product such as single-use cameras and various types of packaging (Akçalı and Çetinkaya, 2011).

Inducement model. The SMM sees remanufacturing as desirable because of the value it creates. In the SMM, remanufacturing comes with the inducement of lower costs of production and, as we argued, equal or potential increased price based on increased value creation (Shou et al., 2019 for the inducement concept). Another inducement that positively motivates firms to remanufacture may be seen in increased customer satisfaction. Firstly, increased satisfaction may result from enhanced quality experiences. Secondly, remanufacturing requires firms to closely track their products in order to manage the cores to be remanufactured in the future (Hsu et al., 2013). This improves firms' understanding of their customers and their products in use, and in this way allows them to better serve customers (Li et al., 2013). This stimulates an in-depth understanding of the customers' usage behaviours and thus enables product innovation to address common errors, process innovation to facilitate customers' use of the product along the lifecycle, and thereby allows the firm to more fully own the customer.

Customer pull. In the strategic mental model, customers would see remanufactured products as equal or better to new and original ones and would thus develop preferences for remanufactured products. If the "equal or better" definition applies, then remanufactured products would be best of their type in the market. This connects well with work on preferences in consumer markets Cui, Wu, and Tseng, 2017).

Remanufactured products as complements in firms' sustainable product portfolio. In the SMM, firms might sell fewer new and original products and more remanufactured products. However, consumers with a SMM would not distinguish between the two as the quality and warranty of the two is the same and both would thus generate the same revenues for the firm. This is already the case for products such as single-use cameras for which consumers cannot identify the EOLP characteristic (Akçalı and Çetinkaya, 2011). Moreover, in an idealized, sustainable, non-growth circular economy, all elements would move in cycles without any elements being truly 'new'. Note that some researchers use the term "Middle of Life (MOL)" (Östlin et al., 2009) to clarify that remanufactured cores have *not* reached the end of their lives. Even in a realistic model that combines new and remanufactured products, the negative effects of cannibalisation would not apply when OEM produce new and remanufactured products that are sold at the same price. In contrast, due to their reduced production cost, remanufactured products would result in increased profit while generating equal revenue.

Circular economy logic. Stereotypically, SMM is more compatible with the idea of circularity (MacArthur, 2013). In contrast to ‘reverse’ logistics that comes with a linear conception of the supply chain – from supplier to customer and then back to the supplier – the idea of circular economy focuses on the circularity of product and value flows, and value would thus not be understood as something that decreases throughout the flow but is defined by the performance an element delivers in a specific step of a theoretically endless cycle.

3.3 Hypothesis

Remanufacturing is the only EOL process that creates products which are potentially more valuable than their new and original counterparts. Nevertheless, the academic and practical community seems to be caught in an operational, cost-oriented mental model. Remanufactured products are sold at discounts and are not typically included in the strategic selling plans of most firms (Ilgin and Gupta 2012). This may be due to a lack of terminological precision in distinguishing remanufacturing from other EOLP. In addition, and along with mental model theory, the perceptions of objectively reduced quality of all other EOLP spill over to remanufactured products. While literature suggests that this is in part based on consumer scepticism (Guidat et al. 2015), we argue that perceptions of value, performance and prices may be shaped by producers, vendors, legislation, industry standards, and academic research. We argued that a strategic mental model exists in the market and that there are consumers with a preference for remanufactured over new engines but that the increased willingness to pay is not captured by current supply realities. The reason for expecting different segments is differences in consumer preferences (Hazen et al., 2012; Jin et al., 2016; Ovchinnikov, 2011; Zhu et al., 2014; Cui et al 2017). In our case, in addition to OMM segments that consider remanufactured engine cars only when offered with a compensation of lower price, longer warranty or lower consumption, we expect to find at least one consumer segment that follows the SMM with a preference for remanufactured engines when offered at the same conditions as a new engine. In line with the functional quality assumptions of the SMM, we expect this segment's preference for remanufactured engines not to be motivated by environmental concerns. This leads us to our fundamental hypothesis.

Hypothesis: A consumer segment that applies a strategic mental model exists in the market. Specifically, this consumer segment (a) has a preference for remanufactured over new engines and (b) does not have increased environmental awareness.

In order to test this hypothesis, we conduct an empirical study that aims at exploring Chinese consumers' preferences and at identifying different segments that may reflect the two mental models.

4. METHODOLOGY

4.1 Approach

We conducted an empirical consumer study at car dealerships in a Chinese tier-two city. The core of the study was a choice-based conjoint design that aimed at quantifying the utility that various product attributes generate for consumers. The relevant base product and its attribute were determined in a pre-test with 112 consumers. Specifically, consumers were asked to rank 18 different configurations of a VW Golf 1.4T (130 HP). The configurations had either a *new* or a *remanufactured* engine and varied in price (125,000¥; 150,000¥; or 175,000¥), warranty (1 year or 30,000 km; 3 years or 100,000 km; 5 years or 170,000 km) and fuel consumption (4.1 l/100 km; 5.6 l/100 km; or 7.1 l/100 km). Conjoint analysis was then applied to consumer ranking choices and the resulting utility scores were used as input for a simulation of market shares of remanufactured engine cars. As the simulation demonstrated relevant market potential for remanufactured engines, cluster analysis was used in order to identify consumer segments that may respond to different value propositions for remanufactured cars and market shares were simulated for each of these segments.

To understanding the empirical context of our study, it is worth noting that environmental issues in the Asian and particularly Chinese car industry have recently gained in importance (Wu et al., 2015; Cui, 2017). Admission restrictions for new cars have applied over the past ten years (Master in Auto Industry, 2018; Beijing Transportation, 2018). However, recently, these have been slightly softened (Cao, 2019). In particular, there are no restrictions imposed on the registering of electric cars and newly introduced legislation and subsidy programs (Wang et al. 2014; Tian et al. 2014) are better supporting remanufacturing processes (SCIO 2019, Automobile 2019), and registration numbers of new cars have thus recently further increased (Cao, 2019; CPCA, 2019). Exploring the extent to which remanufacturing adoption is influenced by these policies, one might find that for consumers, while registering a new car comes with administrative and financial burdens, there is no difference between cars with new and remanufactured engines. For manufacturers, because the restrictions determine the market size, cars with remanufactured engines cannibalize those with new engines. In addition, legislation around remanufacturing, while getting easier, is still quite complex (Shi et al. 2019). For instance, until recently, it was not allowed to import remanufactured products and components to China (Zhu et al. 2014). In addition, firms suffer from consumers' limited trust in quality claims around remanufacturing (Wang et al., 2013; PR Newswire, 2015, Abdulrahman et al., 2015).

Prior to the ranking task, participants were presented with "Information about remanufactured car" that provided a description of the remanufacturing process and the environmental properties of remanufacturing. In order to avoid any leading influence on consumer assumptions about product quality and functionality relative to a comparable new engine, no concrete definition or information with claims about engine performance was given. This reflects a realistic decision situation in that consumers may be exposed to various marketing claims about remanufacturing but may not possess accurate information regarding the quality and performance of remanufactured engines.

4.2 Sample

As participants of the main study, Chinese consumers were recruited on their way to visit VW ("4S") dealerships. A total of 202 respondents (of which 3 were excluded from the cluster analysis as result of the first step of the cluster analysis) performed the ranking task and filled out the associated the questionnaire. A majority of respondents (70%) were men and the average age was 32 years (range 19 to 60 years). Respondents' educational levels reflect the connection between education and economic possibilities in China with 17% reporting completion of junior or high school, 27% of professional college, 47% respondents completed a bachelor's degree and 9% postgraduate studies. Respondents were given 18 cards and requested to rank the hypothetical cars described on the cars from 1 (most preferred car) to 18 (least preferred car) by sorting the cards. The rankings were then transferred to separate survey sheets by the research assistants collecting the data.

4.3 Analysis

We applied conjoint analysis (CA) to the data resulting from the ranking task described above. This resulted in utility measures for each of the three continuous product characteristics (fuel consumption, warranty, and price) as well as for each dimension of the categorical product characteristics (new engine, and remanufactured engine) (table 2). We then used these results as input for two further analyses. First, we simulated consumer choice of a number of product couples applying Maximum Utility modelling to consumer responses (table 3). This allowed us to simulate consumers' product choices and estimate the associated market shares. We then applied the common three-step cluster analyses approach (Punj and Stewart 1983, Ketchen and Shook 1996) to the utility estimates that resulted from the CA. This enabled us to identify different consumer groups within our sample and to connect them to demographic and attitudinal variables (table 4). We then used the average utilities to describe each cluster and attribute a meaningful label. Moreover, we connected the clusters to the descriptive sample statistics and applied t tests and ANOVA to determine whether differences in the clusters discovered were significant.

+++ Insert Table 2 to 4 about here +++

5. RESULTS

The estimated utilities from the conjoint analysis show, as expected, that higher price, shorter warranty, and higher fuel consumption are associated with negative utility (Table 2). However, consumers often are not a homogenous group and utility functions and preferences tend to vary between consumers. Indeed, pair-wise simulations of market shares based on the utility weights from the CA show that that a model with a re-manufactured engine and no compensation in the other attributes (simulation 1 in table 3) would still gain 37.9% market share. This suggests that there is a portion of the market that regards the remanufactured engine as something good in itself. The market share of remanufactured engines in *Simulation 1* reflects participants who are not just indifferent to the engine type but who actually prefer the remanufactured engine. This supports part (a) of our hypothesis that a consumer segment that applies a strategic mental model exists in the market that has preference for remanufactured over new engines. *Simulations 2* and *4* are in line with the OMM showing that consumer preferences for remanufacturing can be increased when offering lower price or reduced fuel consumption as incentives.

When segmenting the market using cluster analyses based on utility estimates, we found four clusters (Table 4). Members of the first cluster attribute substantial utility to a new engine. We thus label this segment "*New and Original"*. All other characteristics, even price, are substantially less relevant to members of this cluster. This cluster is conceptually equivalent to the dominant cluster in Abbey et al.'s (2015b) simulation study. This cluster accounts for 20 % of study participants. Respondents in the second cluster attach the most utility to fuel consumption. Their average utility of fuel consumption (-2.86) is more than twice the amount of any other cluster. We thus label this segment "*Fuel Savers"*. It comprises 29 % of observations. The utility that this cluster attributes to remanufactured engines does not deviate significantly from the average. Respondents in the third cluster attribute above-average utility to price. All other attributes are evaluated with average utility. We thus label this group, which accounts for 22 % of respondents, as "*Price Savers". Members of the fourth cluster account for 30 % of respondents, attribute a positive utility to the remanufactured engine (1.57) and we thus label this cluster as "*Reman". In addition, this cluster also attributes high utility to price and average utility to warranty and fuel consumption. This is in line with the conceptualisation of our SMM mental model that sees positive value in remanufacturing.

Members of the fourth cluster "*Reman*" attribute positive utility to the remanufactured engine, thus supporting part (a) of the hypothesis. In addition, we establish that this cluster reports relatively low environmental concern, thus providing support for part (b) of our hypothesis: In combining preference for the remanufactured car engine but not increased environmental concern indicated that these consumers prefer remanufactured engines but not for their environmental benefits. This supports the notion of the strategic mental model that we developed; a model that shares an understanding that remanufactured engines can be preferred for its functionality and quality. This is further supported by the observation that, while Green Consumers are typically well educated, respondents in the *Reman* cluster are significantly less educated than respondents in the other three clusters (t = -2.54).

Both conjoint analysis and cluster analysis suggest that a consumer group with a strategic mental model of remanufacturing exists. Both analyses suggest around 30 % share. Cluster analysis as a realistic multi-attribute choice scenario suggests that there is a market segment that has a preference for the remanufactured engine without any compensation being offered and thus supporting part (a) of our hypothesis on the prevalence of the SMM concept. Cluster analysis then substantiated this claim by supporting part (a) of the hypothesis through an alternative method and further showing that this cluster does not have strong environmental values, suggesting that the created customer value is not environmental (OMM) but functional (SMM) and thus also supporting part (b) of our hypothesis. We thus see supported our claim that strategic mental model exists in the market that complements the operational mental model.

6. DISCUSSION

6.1 A segmented view on preferences for remanufactured engines

The results of the conjoint analyses for the entire unsegmented sample show that a remanufactured engine has negative utility compared to a new engine, and price is the most important decision criterion (weight 39.4). Thus, the initial results from the CA analysis suggests that consumers would be unwilling to purchase a re-manufactured engine unless they are offered an incentive that would compensate for the negative utility of the remanufactured engine. They also suggest that the most effective incentive would be to offer a lower price, which is the attribute given most weight. This is in line with the dominant OMM of remanufacturing that we identified and that is supported by existing studies (Abbey et al, 2015a): Consumers overall prefer new and buy at lower prices. However, the segmented view of our results supported our hypothesis about the strategic mental model. This result extends the study by Abbey et al. (2015b), who identified a segment indifferent to engine type: Consumers are not indifferent; we find that some consumers actually prefer remanufactured over new engines. This supports research emphasising differences in consumer preferences for remanufacturing (Cui et al., 2017). When neglecting consumer differences in preferences, managers will draw unsupported conclusions.

Conceptually, each of the car configurations that we included in the market share simulation (table 3) reflects a distinct argument. The discounted product reflects the view that any remanufactured product can be sold if the price discount is large enough (Abbey et al. 2015a). In contrast, the remanufactured engine with reduced fuel consumption reflects the fact that remanufactured products may have "better performance" (European Action Plan 2015: FN11) than the new product (e.g. Paterson et al. 2017). The third option, offering a remanufactured engine "with corresponding warranty" (European Action Plan 2015: FN11) also reflects the remanufacturing definition and in addition addresses the information asymmetry between producer and consumer regarding the actual quality of the remanufactured engine and sends a strong signal that the producer believes in the as-new or better performance. Increased warranty reduces the risk for the consumer. This is important because product and technology adaption research have found risk reduction to be an important driver of innovation adoption (Rogers 2003, Venkatesh et al. 2012).

Applying an alternative method and segmenting the market using cluster analyses, offers additional insight. The "*New and Original"* is conceptually equivalent to the dominant cluster in Abbey et al.'s (2015b) simulation study and reflects the OMM well. In contrast, members of the "*Reman*" cluster attribute positive utility to the remanufactured engine. The fact that the segment which tends towards purchasing remanufactured engines is also very price sensitive is consistent with the findings of Abbey et al. (2015b). In addition, we establish that this cluster reports relatively low environmental concern. This finding contradicts the OMM promoted in many studies, which postulate that consumers who are willing to purchase remanufactured products are members of a green consumer segment (Abbey et al., 2015b, Giannetti et al., 2012): Consumers considering the purchase of cars with a remanufactured engine are not attracted to do so by environmental benefits but rather by expectations of lower prices. The remanufacturing buyers in our study are thus not green consumers. This is further supported by the observation that, while Green Consumers are typically well educated, respondents in the *Reman* cluster are significantly less educated than respondents in the other three clusters (t = -2.54).

6.2 Implications of the Strategic Mental Model

6.2.1 SMM Shifts the Effects of Cannibalisation

Many OEMs fear cannibalisation, i.e. losing a portion of their new product sales to remanufactured engines (Chaowanapong et al., 2018; Goodall et al., 2014). By remanufacturing their own products, OEMs might create barriers to entry and avoid reputational risk from no-name firms remanufacturing their cores (Agarwal et al., 2015). However, the like-new quality of the remanufactured engine would promote internal cannibalisation (Atasu et al., 2010; Chakraborty, 2019). An additional challenge for OEM is that remanufacturing is a complex process that is more interrelated with outside stakeholders (as specified in the 10-step BSI process), and implementing remanufacturing strategies thus significantly complicates manufacturing and logistics processes and conflict with production of new and original engines (Kapetanopoulou and Tagaras, 2011). Our results suggest that remanufactured engines could be offered in a consumer market and cover about one third of market share. Due to the comparable quality of new and remanufactured cores, sales of remanufactured engines would reduce those of new engines. This is even more the case in a context like China where growth in sales quantity is highly regulated.

However, within the SMM, sales of remanufactured and new engines would be at the same price and cannibalisation would thus affect sales quantity but not the total revenue. Due to the lower cost of remanufactured cores, profitability would increase. The challenge for OEM would thus shift. It is important to develop a circular economy strategy and take ownership of the remanufacturing processes in order to protect the own brand and to tap into an attractive growing segment. OEM might even lobby for lawmakers to require branding of the remanufacturing process to ensure transparency to consumers and thus to allow them to actively choose remanufactured engines that have been processed by OEMs rather than any third party.

6.2.*2 SMM Emphasises the Strategic Benefits of Remanufacturing*

More strategically, our findings support Kumar and Ramachandran's (2016) idea that remanufacturing is compatible with disruptive, shared, and circular economy business models (also Kadambala et al., 2017), e.g. a service dominant logic (Vargo and Lusch, 2004). In the circular system, the distinction between new as compared to remanufactured will lose in relevance, and value generation from use will become more important than ownership or the question of whether components are new or remanufactured. In such a servitisation system, business success relies on owning and understanding the customer. Such owning and understanding would result from knowing when the user does what with the core: this allows better serving the customer and better maintaining the product. The complex processes of following the product and maintaining, remanufacturing, and potentially upgrading it throughout the lifecycle is thus a prerequisite for future success. While in the OMM, the increased complexity is a burden of a costly value recovery process for lower value products, in the strategic mental model, tracking cores over the life cycle and recovering them becomes a strategic competence needed for achieving high value sourcing with an in-depth understanding of a firm's customers.

6.2.3 SMM Requires Institutionalisation

Our empirical study shows that a consumer segment in the market does uses a strategic mental model. Serving this consumer segment could allow firms to harvest increased willingness to pay and thus to making remanufacturing as an important element of a circular economy strategy more attractive. In order for this potential to materialise, we see a need for stronger institutional protection and support of remanufacturing as distinct EOLP.

First, the British Standards Institute presented a clear definition for remanufacturing, requiring that remanufactured goods have the same aesthetic and functional quality and at minimum the same warranty (BSI, 2009). This is also reflected in academic literature (e.g. Paterson et al., 2017) and in business practice (Ivorsearle, 2016). However, there seems to be a lack of terminological precision and concise application of the remanufacturing term in governance, academia and industry. BSI notes in its 2002 Code of practice for remanufacture of spark and compression ignition engines (version confirmed in 2008) that "'remanufactured' is synonymous with 'reconditioned'" (BSI 2002) but then distinguishes the two in the process of remanufacture – Specification (BSI 2010). As long as even industry bodies are imprecise, it seems natural for many consumers that they act based on an OMM that associated remanufacturing with the inferior qualities of many other EOLPs. For remanufacturing to be more successful in the market, it needs to be more easily distinguishable from other EOLP. This requires on one hand legal protection of the remanufacturing term as one that is only granted to products that meet the requirements of the strict remanufacturing definitions. This would be similar to protections of terms such as “organic” or “bio” for food products in various countries. Introduction of clearly defined and well protected industry and consumer labels may facilitate this process.

Second, the U.S. government suggests that remanufactured engines should only be acquired when they result in a cost advantage (Federal Act. 2015), which seems to favour the new, less sustainable solution when new and remanufactured offer same quality at same price. In order to better support the sustainable remanufacturing practice, the remanufacturing business case needs to be better supported. In spite of an understandable interest of governments to save taxpayers’ money, a law that disadvantages a technological solution that offers the same quality more sustainably by enforcing lower prices, seems inherently unsustainable. As an implication, legislation would thus need to be adjusted to account for the precise benefits that remanufacturing has to offer in contrast to all other EOLP.

6.2.4 Future Research on SMM

Limitations of this study offer an avenue for future research. First, our study focuses on one brand in one regional market. We chose to do so to ensure internal validity and investigate consumer responsiveness to new as compared to remanufactured engine without distorting brand and country influences. Compared to Western markets, car purchase in China is more influenced by social context. (1) Cars are bought to create social identity and buyers make use of their social networks as informational source and are strongly influenced by social norms. (2) Moreover, as compared to U.S. consumers, Chinese are more focused on quality, reliability and brand. (3) Finally, they pay cash rather than taking a loan and adopt new models relatively slowly (Du et al, 2014). These differences have implications for the generalizability of the results. First, the social status and appearance of cars with remanufactured engines matters. Being functionally and aesthetically equivalent to new engines suggests that there may be substantial market potential if the reputation of remanufacturing is positive and is not communicated and perceived by consumers as just another EOLP. Second, price and fuel consumption are more important in the U.S. whereas quality and reliability dominate in China. The as-new quality claim may thus trigger more positive associations and lead to an increased simulated market share in our Chinese sample that would not be triggered in the price-centred U.S. market. Finally, car financing ensures that car buyers are traceable, and Chinese consumers' attitude to full payment may thus eliminate one mechanism that would otherwise facilitate the tracking processes that are crucial for remanufacturing. Exploring the influence of cultural differences on consumer remanufacturing response and theorizing cultural differences more explicitly is a promising avenue for future research.

Despite being an effective methodology for this study, conjoint analysis places limitations on the number of attributes and levels that researchers can investigate. Increasing the number of attributes and/or levels requires additional cards to be used for the interview and ranking. Even with our conservative use of 18 cards (and the gift incentive of a pen and ¥20), several participants complained about the number of cards involved. The large number of cards presents a challenge for some participants, who find it difficult to complete the ranking exercise and whose incomplete results must be discarded. Future research may thus aim to add methodologically by using representative real market data in order to increase the external validity of the claims.

Finally, the study did not consider the financial implications of warranty-based compensation for the manufacturing firms. Manufacturers would naturally want to know the impact of a longer warranty on their financial well-being before deciding to implement remanufacturing. However, given that we have established the presence of an over 30 % market share for remanufactured engines without any form of compensation, the financial impact analysis suggested should strengthen our findings.

6.3. Conclusion

Starting point of our study was the identification of a tension between the economic benefits that remanufacturing processes create as per their definition and the incomplete appreciation of these benefits in remanufacturing research and practice. In exploring this tension, we theorized two competing mental models of remanufacturing: an operational model that emphasises reduced resource input, environmental benefits and lower cost, and a strategic one that emphasises the performance benefits of remanufacturing as distinct EOLP that can strategically compete with new products. Data from a conjoint-based study among Chinese consumers supported our strategic mental model. Our findings suggest that approaching remanufacturing with a different mental model allows new perspectives on some core EOLP debates in operations and production management. Cannibalisation loses relevance when the two processes at stake result in the same sales prices. The complexities for following cores throughout their life cycle, while still being complex and costly, appear less as a threat to business when being understood as crucial competence leading to customer ownership in circular economy business models. While our study suggests that even today the majority of consumers may favour remanufactured over new engines when some remanufacturing benefits are shared (reduced price, reduced fuel consumption, or longer warranty), we feel that the core benefit in remanufacturing lies in the opportunity to facilitate business models such as sharing economy solutions.

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Appendix: Tables and Figures

Table 1: Operational and strategic mental model of remanufacturing

Characteristic	OMM – OPERATIONAL MENTAL MODEL	SMM – STRATEGIC MENTAL MODEL
Fundamental logic	Cost logic: remanufacturing saves material cost and is thus priced lower than new products	Value logic: remanufacturing creates the same or higher value compared to new products and thus achieve same or higher prices
Terminological relation to other EOLP	Terminological confusion with other EOLP. Cost pricing argumentation	Remanufacturing as only process to achieve as-new quality. Terminological distinction: precision required. Value pricing argumentation
Remanufacturing function	Disposal mind-set	Sourcing mind-set
Customer value	Environmental value to the customer	Functional value to the customer
Motivation	Imposition model.	Inducement model.
Market direction	Supplier push	Customer pull
Relation of remanufactured to new products	Cannibalisation	Remanufactured products as complements in firms' sustainable product portfolio.

TABLE 2: Estimated Utilities and Importance Weights from Conjoint Analysis

Attribute	Attribute level	Utility Estimate	Std. Error	Importance Weight
Engine	New engine	0.499	0.124	21.119
	Re-manufactured engine	-0.499	0.124	
Price	¥125,000	-2.662	0.150	39.401
	¥150,000	-5.323	0.300	
	¥175,000	-7.985	0.450	
Warranty	1 year or 30,000 km	1.104	0.150	18.227
	3 years or 100,000 km	2.208	0.300	
	5 years or 170,000 km	3.312	0.450	
Fuel Consumption	4.6 l / 100 km	-1.399	0.150	21.525
	6.1 l / 100 km	-2.797	0.300	
	7.6 l / 100 km	-4.196	.450	
Constant		13.674	0.471	

TABLE 3: Market Response Simulations Based On Conjoint Analyses Results

		Preference Probabilities		
	Preference Scores	Maximum Utility	Bradley-Terry-Luce	Logit
Base model: New engine ¥150,000 3 years or 100,000 km 6.1 l / 100 km	8.260			
Simulation 1 *Base model* against: – Remanufactured engine – ¥150,000 – 3 years or 100,000 km – 6.1 l / 100 km	7.262	37.9%	47.2%	42.5%
Simulation 2 *Base model* against: – Remanufactured engine – ¥125,000 – 3 years or 100,000 km – 6.1 l / 100 km	9.923	62.9%	53.9%	62.5%
Simulation 3 *Base model* against: – Remanufactured engine – ¥150,000 – 5 years or 170,000 km – 6.1 l / 100 km	8.365	58.7%	50.4%	54.9%
Simulation 4 *Base model* against: – Remanufactured engine – ¥150,000 – 3 years or 100,000 km – 4.6 l / 100 km	8.660	65.3%	51.4%	59.9%
Simulation 5 *Base model* against: – Remanufactured engine – ¥125,000 – 5 years or 170,000 km – 4.6 l / 100 km	12.426	76.7%	59.4%	77.3%
n = 202				

TABLE 4: Identified Consumer Clusters

			Average Utility of Engine Characteristics mean (standard deviation)				
Cluster Number	Cluster Label	Cluster Size (%)	New Engine	Remanufactured Engine	Price	Warranty	Fuel Consumption
1	New & Original	20.1	3.30 (0.79)	-3.3 (0.79)	-0.28 (1.61)	0.92 (1.10)	-0.65 (1.02)
2	Fuel Savers	28.6	0.64 (0.80)	-0.64 (0.80)	-0.83 (1.08)	1.76 (1.67)	-2.86 (1.64)
3	Price Savers	21.6	0.66 (0.69)	-0.66 (0.69)	-4.77 (0.51)	0.98 (0.52)	-1.22 (0.71)
4	Reman	29.6	-1.57 (0.74)	1.57 (0.74)	-4.56 (0.94)	0.76 (0.73)	-0.73 (0.74)
Total		100	0.52 (1.85)	-0.52 (1.85)	-2.68 (2.3)	1.12 (1.19)	-1.43 (1.45)

Socio-Demographic Analysis of Identified Consumer Clusters

Cluster Number	Cluster Label	Cluster Size	Age	Gender (Portion of Men)	Education Level	Environmental Concern
1	New & Original	40	30.1 (8.83)	0.641 (0.486)	3.63 (1.08)	5.19 (1.22)
2	Fuel Savers	57	32.5 (7.80)	0.702 (0.462)	3.51 (1.15)	5.92 (1.17)
3	Price-Savers	43	35.0 (8.57)	0.721 (0.454)	3.60 (0.86)	5.44 (0.76)
4	Reman	59	31.5 (8.48)	0.759 (0.432)	3.17 (0.93)	5.28 (1.10)
Total		199	32.3 (8.48)	0.711 (0.455)	3.45 (1.03)	5.48 (1.11)
F value based on ANOVA			2.60^{+}	$0.531^{n.s.}$	2.25^{+}	4.67**

Note: Values in brackets are standard deviations. +: p<0.1; **: p<0.01