Estimating the Potential Material-saving Effects of Automotive Parts Remanufacturing in Southeast Asia

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Abstract

Remanufacturing is an important element in enhancing the resource efficiency of economies. Automotive parts are a representative target of remanufacturing. This study has attempted to estimate the potential contribution of automotive parts remanufacturing toward reductions in material resource consumption in the Southeast Asian region. Material consumption for automobiles and automotive spare parts in the region in 2030 is estimated at 5.2 million tons and 314,000 tons, respectively. Of the materials, steel is expected to comprise 3.5 million tons and 213,000 tons, accounting for 2.7% and 0.16%, respectively, of steel use in the region. The material-saving effects of remanufacturing are then considered. The results indicate the potential contribution of automotive parts remanufacturing to the reduction of material consumption in the region in 2030 to be an estimated 251,000 tons of materials and 170,000 tons of steel, accounting for 0.13% of steel use in the region. This article also presents a discussion on potential market barriers to remanufacturing in the region. The major barriers include: 1) manufacturers' hesitation to undertake remanufacturing, and 2) consumers' non-acceptance of remanufactured products. The implications of a web-questionnaire survey the study conducted in four countries in the region to assess consumers' acceptance of remanufactured products are discussed along with items needing further study.

Key words: automotive parts, consumer perception, remanufacturing, resource efficiency, Southeast Asia, sustainable consumption and production

1. Introduction

Reducing material resource consumption is an essential requirement for realizing a sustainable society. Overconsumption of material resources has been widely warned about since as early as the 1970s. Still, global consumption has continued to increase over time, and it is expected to increase further in the future. The global annual consumption of metal materials has reached 8 billion tons today, and it is predicted to reach 20 billion tons in 2060 (OECD, 2019). The current study focuses on the Southeast Asian region. The region's economic development is remarkable, and the consumption of material and energy is also increasing rapidly. Today, the region has a population of 662 million, accounting for 8.5% of the global population, and substantially larger than that of Japan, the US or the EU (Table 1). On the other hand, the number of cars owned in the region is 58 million, 4.5% of the global total, and the annual consumption of steel there is 93 million tons, 4.9% of the global total (Table 1), representing the potential for car ownership growth. These factors indicate that the region's material and energy consumption is most likely to increase significantly in the following decades. Measures are necessary to mitigate the increase.

Remanufacturing is an industrial process in which used products are restored to their original as-new condition/ performance or better (UNEP-IRP, 2018). Remanufacturing has the effect of reducing material demand because it prolongs the usage of the components of a product and thus reduces the demand for new component manufacturing. Remanufacturing is even

Table 1 Basic economic indicators, automobiles and steel use in Southeast Asia and other regions.

	Population in 2020 (millions) [a]	GDP per capita in 2019 (USD current prices) [b]	Sales of new vehicles in 2019 (thousand units) [c]	Vehicles in use in 2015 (thousand units) [d]	Vehicles in use per 1000 inhabitants in 2015 [d]	Steel use in 2019 (thousand metric tons, crude steel equivalent) [e]	Steel use per capita in 2019 (kg crude steel equivalent) [e]
Indonesia	271.7	4,200	1,030	22,513	87	19,140	71
Malaysia	32.8	11,210	604	13,309	439	10,706	335
Philippines	109.6	3,510	410	3,823	38	11,697	108
Singapore	5.8	65,640	91	813	145	2,899	499
Thailand	66.5	7,820	1,008	15,491	228	21,416	308
Vietnam	96.2	3,420	277	2,170	23	27,318	283
ASEAN10 [f]	662.0	4,940	3,471	58,118	88	93,176	140
(global ratio)	(8.5%)		(3.8%)	(4.5%)		(4.9%)	
Japan	126.0	40,800	5,195	77,404	609	69,782	550
China	1410.6	10,240	25,797	162,845	118	947,519	659
US	329.9	65,250	17,037	264,194	821	108,500	330
EU27+UK	447.0	46,590	17,896	294,213	581	172,437	336
Global	7773	11,540	90,424	1,282,270	182	1,888,890	245

[a] Source: Population Reference Bureau https://www.prb.org/2020-world-population-data-sheet/
[b] Source: International Monetary Fund https://www.imf.org/external/datamapper/datasets/WEO
[c] Source: (OICA, 2021a) [d] Source: (OICA, 2021b) [e] Source: (World Steel Association, 2020)
[f] ASEAN (Association of Southeast Asian Nations) comprises 10 member countries – Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam, Brunei, Cambodia, Laos, and Myanmar. In this paper, "ASEAN10" and "Southeast Asia" are used interchangeably.

more essential, even compared with recycling, because it can be more economically viable, more resource-efficient and less energy-intensive than recycling.

Although remanufacturing has attracted attention in recent years in academia, industry and government, it is not clear how much of an impact remanufacturing will have on material saving at the societal or macro level. The market impacts of remanufacturing have become gradually clearer in the last decade. The production of remanufactured goods in the US in 2011 was estimated at 43.0 billion USD (USITC, 2012), and in Europe, at 29.8 billion EUR (ERN, 2015), but again, the material-saving effects are not known. This study has attempted to estimate the potential contribution of automotive parts remanufacturing in Southeast Asia.

The automobile industry in Southeast Asia, typically in Thailand, has developed through the attraction of foreign automobile manufacturers since the 1960s. Foreign automobile manufacturers have set up local factories, followed by which, foreign automotive parts manufacturers have also set up local factories. In recent years, local parts manufacturers have been growing. The number of parts manufacturers is largest in Thailand, followed by Indonesia and Malaysia (DBJ, 2015). This region has local parts manufacturers and potential for growth of the parts remanufacturing industry.

The automotive parts sector is where remanufacturing is most actively conducted globally. This study has attempted to address whether the potential impact is on the order of 1%, or 0.1%, or 0.01% material saving in the Southeast Asian region. Clarifying the scale of impacts is the first step in arguing for the priority of measures and policies.

The rest of the paper is organized as follows. Chapter 2 presents our estimation of the potential material-saving effects of automotive parts remanufacturing in Southeast Asia. The methods, assumptions, data and results of this estimation are presented. Chapter 3 discusses the market barriers to remanufacturing in the region. These barriers may include consumers' non-acceptance of remanufactured products and companies' hesitation to undertake remanufacturing. The final chapter discusses the results and concludes the study.

2. Potential Material-saving Effects of Automotive Parts Remanufacturing in Southeast Asia

2.1 Estimation Method

We estimated the potential material-saving effects of automotive parts remanufacturing in Southeast Asia in the year 2030 using the following procedures:

1) The materials breakdown of an automobile was estimated.
2) The amounts of flow (annual sales) and stock (products in use) of automobiles in the region in 2030 were estimated. Based on that and the materials breakdown per automobile estimated in (1), the material usage for automobiles in the region in 2030 was estimated.
3) The demand for spare parts stock per car, and the materials breakdown of spare parts were estimated. Based on those estimations and car stock estimated in (2), the material use for spare parts was estimated.
4) The material-saving effects of automotive parts remanufacturing at the product level were estimated,

and the share of remanufactured parts in the spare parts market was estimated. Based on these estimations and the material use for spare parts estimated in (3), the potential material-saving effects of automotive parts remanufacturing were estimated.

5) The CO_2-saving effect was also estimated. Based on estimates of CO_2-saving effects of automotive parts remanufacturing at the product level, and the amount of remanufactured automotive parts estimated in (4), the potential CO_2-saving effects of automotive parts remanufacturing were estimated.

The estimations in these processes involved uncertainties; therefore some of them can be regarded as assumptions rather than estimates. The processes are described in further detail in the following sections.

2.2 Flow and Stock of Automobiles

Material resources are used in developing all types of artifacts including, buildings, urban infrastructure, transportation infrastructure and all kinds of products. Automobiles are one of the prominent consumers of material resources. Today, 90 million cars are sold annually (flow), and 1.3 billion cars are in use globally (stock) (Table 1). The stock has increased for over a century and its trend shows it is not likely to reach saturation in the near future. Southeast Asia comprises 4.5% of the global stock (Table 1). It has sales of 3.5 million cars (flow) and 58 million cars in use (stock) (Table 1). While the number of cars per 1000 inhabitants is around 600 in Europe and Japan, and 821 in the US, it is 88 in Southeast Asia, and the figure varies highly country-wise in the region, from 439 in Malaysia to 23 in Vietnam (Table 1). These figures and trends indicate that both the flow and stock in Southeast Asia are likely to increase significantly in the coming decades.

2.3 Material Use for Automobiles

An automobile typically weighs 1.0 to 1.5 tons. Of the curb weight, approximately 70% is steel (ferrous metals), 10% is non-ferrous metals (Al, Cu, etc.), 10% (or less) is plastics and 10% (or more) is other materials (glass, rubber, fluids, etc.). Several studies have investigated bills of automobile materials (e.g. Mayyas et al., 2017; Bobba et al., 2021; Tahara et al., 2001). We used the figures shown in Table 2 for the weight of an automobile and its materials breakdown.

Assuming the figures in Table 2 represent the average figures for automobiles in Southeast Asia, we estimated the amounts of materials in vehicles sold in 2015 and 2030 in the region. Table 3 shows the results, where, in 2015, the vehicles (3.1 million units) are made up of 3.59 million tons of materials, of which 2.86 million tons are metals, of which 2.40 million tons are steel (Table 3). The amount of steel (2.40 million tons) accounts for 2.8% of the total steel used in the region (Table 3).

In our estimation for the year 2030, we first estimated the car sales and steel use in the region in the year 2030. They were estimated in both cases by extrapolating the linear approximations of their trends in the years 2010–2019. The car sales in 2030 were estimated at 4.5 million units, and the steel use, at 130 million tons (Table 3).

We assumed that the influence of increased numbers of electric vehicles (EVs) and other factors would be limited. Globally, more than 6.8 million battery EVs (BEVs) were on the road in 2020 (IEA, 2021), whereas in Thailand, only 7,250 BEVs were on road yet as of April 2021 (EVAT, 2021). EVs (total of BEVs and plug-in hybrid EVs (PHEVs)) are predicted to account for 7% of the car stock worldwide by 2030 (IEA, 2021). The ratio is expected to be lower in Southeast Asia. This study did not take the influences of car electrification into account.

The materials, metal and steel used in vehicles in the region in the year 2030 were estimated at 5.19, 4.14, and 3.47 million tons, respectively, and the steel for cars was estimated to comprise 2.7% of the total steel used in 2030 (Table 3).

The estimated fractions of steel used in automobiles in the region (2.8% and 2.7%) are smaller than those globally. According to Allwood and Cullen (2015), the steel used in cars and trucks in 2008 globally was 108 million tons, comprising 10.0% of total steel used globally that year.

2.4 Material Use in Spare Parts

We then estimated the amount of materials used in

Table 2 Materials breakdown and weight of an automobile.

	Weight (kg)	Portion (%)
Steel	773	67.0
Non-ferrous metal (Al, Cu, etc.)	147	12.7
Plastics	89	7.7
Others (rubber, glass, fluids)	145	12.6
Total weight	1153	100.0

Note: We referred to the data collected in the study by Tahara et al. (2001). Although not all the details on the data used in that study were indicated in the literature, we used those data in our study. The total weight (1,153 kg) does not include the weight of gasoline, although the 'curb weight' generally includes the weight of gasoline.

Table 3 Materials used in automobiles.

	2015	2030
Automobile sales in SEA (units) (a)	3.11 M [1)]	4.50 M [3)]
Weight (=a*1.153) (tons)	3.59 M	5.19 M
Metal weight (=a*0.920) (tons)	2.86 M	4.14 M
Steel* weight (=a*0.773) (tons) (b)	2.40 M	3.47 M
Steel use in SEA (tons) (c)	84.8 M [2)]	130 M [4)]
Steel use fraction (=b/c) (%)	2.8%	2.7%

Note: SEA stands for 'Southeast Asia'.
[1)] Source: (OICA, 2021a)
[2)] Source: (World Steel Association, 2020)
[3), 4)] Source: Authors' estimation (or assumption).

automobile spare parts. To estimate this, we estimated the materials breakdown of spare parts, and the quantities of spare parts traded in markets. Table 4 shows 11 types of automotive parts that are commonly traded as spare parts in markets. When an automotive part is broken, the driver can make a choice of repairing the part (repair), replacing the part with a brand-new one (new), replacing it with a remanufactured part (remanufacturing) or replacing it with a reused part (reuse). The 11 types of parts also represent the parts that are commonly remanufactured today in regions such as the US (Frost & Sullivan, 2011), EU (Bobba et al., 2021) and Japan (the authors' study). The table shows the parts' weight, parts' steel content weight, and our estimates of the ratio of spare part demands (units) to car stock amounts (units).

These estimated ratios indicate spare engine demand units, for example, in year Y, and are calculated as follows:

(car stock number in year Y) * (0.5%)

The weight of material used in these engines (total weight of the engines), and the weight of the steel used in the engines are calculated as follows, respectively:

(car stock number in year Y) * (0.5%) * 135.0 (kg),
(car stock number in year Y) * (0.5%) * 73.6 (kg)

Table 4 Top remanufactured automotive parts, their weight, steel content and demand per car in stock.

	Weight (kg)	Steel (kg)	Spare part demand per car in stock*
Engines	135.0	73.6	0.5%
Alternators	4.5	2.7	2%
Starters	2.5	1.5	2%
AC compressors	5.8	2.4	2%
Transmissions	102.5	82.0	0.5%
Driveshafts	7.6	6.9	2%
Electronic units	5	3	0.5%
Clutches	6	6	0.5%
Brake calipers	5	5	1%
Steering gears	6.6	6.6	0.5%
Water pumps	1.9	1.2	0.5%

*Note: Estimated ratio of the annual demand for spare parts (units) to the number of automobiles-in-use (cars in stock). For example, "2%" indicates that when there are 100,000 cars in use, there will be demand for 2,000 units of spare parts per year.
For the parts' total weight and steel weight, we referred to data collected in the study by Tahara et al. (2001).

We estimated the ratio (e.g., 0.5% for the engine) by referring to the estimated units of remanufactured parts sold in the EU (Bobba et al., 2021), the corresponding estimation in the US (Frost & Sullivan, 2011), and the authors' interviews with personnel in the industry in Japan. In the EU, for example, 3.22 million units of remanufactured alternators (spare parts) were sold in 2012 (Bobba et al., 2021). The ratio to the car stock number in the EU that year (260.5 million) was 1.2%. We presumed the potential ratios would be larger in Southeast Asia because the average age of the cars in the region was higher than in the EU, US or Japan. We assumed the ratio would be higher by up to 70% in Southeast Asia. For alternators, we hypothetically estimated the ratio at 2% (Table 4).

The car stocks in the years 2015 and 2030 in Southeast Asia were/will be 58.1 million (Table 1) and 90.0 million (authors' estimate), respectively. The potential demand figures for spare parts shown in Table 4 (11 types of parts) were calculated at 7.0 million and 10.8 million units, respectively. These have total weights of 101,000 tons and 157,000 tons, respectively.

In addition to the 11 types of parts in Table 4, we also took other parts into account. The parts considered additionally were mainly exterior automotive parts such as doors, bonnets, lights, mirrors and so on. These parts are more like to be reused than remanufactured today. We include these parts in our account because the potential demand for remanufactured parts of these types does exist. We assumed that the total weight of demand for these parts would be the same as that for the 11 types of parts.

Our results show the total weight of the demand for these spare parts to be 203,000 tons in 2015, and 314,000 tons in 2030. Of these amounts, steel accounts for 137,000 tons in 2015, and 213,000 tons in 2030. Figure 1 presents our estimates of the flow and stock of automobiles, spare parts and related materials for the year 2030.

The demand for spare parts, or the 'spare part demand per car in stock' in Table 4, can vary from market

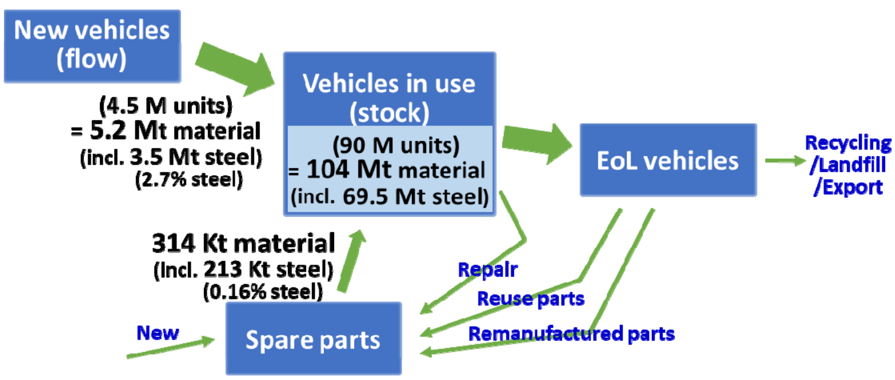

Fig. 1 Estimated flow and stock of automobiles, potential spare parts and related materials in Southeast Asia in 2030.

to market depending on the conditions under which cars are used. The factors can include: the average age of the car stock in the market, road conditions, climate conditions (temperature, humidity, etc.), quality of original components and so on. The available data for spare parts are limited. For reference, Table 5 shows the result of the authors' survey (web questionnaire survey) on drivers' experiences with repairing or replacing alternators or starters in six countries. The percentage of drivers who had experienced the need for repair or replacement was relatively high in the four Southeast Asian countries (50.2% in Malaysia to 74.8% in Vietnam), and it was also high in the US (55.6%) and low in Japan (11.3%). Although demand for spare parts may differ and change depending on conditions in the future (either increasing or decreasing), the estimates in Fig. 1 present a potential.

2.5 Automotive Parts Remanufacturing in Southeast Asia

Globally, the automotive parts remanufacturing industry is one of the largest remanufacturing sectors. It is the second-largest sector in the EU after the aerospace sector (ERN, 2015) and is the third-largest in the US after the aerospace and heavy-duty & off-road (HDOR) equipment sectors (USITC, 2012). In the aftermarket for automotive alternators and starters, for example, remanufactured parts comprise 90% in the US (Frost & Sullivan, 2011) and EU (Bobba et al., 2021), and about 50% in Japan (Matsumoto et al., 2018).

In Southeast Asia, reuse (or direct reuse) and repair are much more common than remanufacturing today. Generally, repair is more artisanal and labor-intensive than remanufacturing. In a long-term trend, as the country's economy develops and income and wage levels of the country rise, repairs are more likely to be replaced by remanufacturing (Matsumoto et al., 2018). The growth levels of automotive parts remanufacturing industries vary from country to country in Southeast Asia. The industry in Malaysia is growing (Yusop et al., 2016), whereas Vietnam does not have an identified remanufacturing industry yet (Guidat et al., 2017). The Malaysian government is also active in supporting the development of a promising remanufacturing sector within a local hub for remanufacturing (Yusop et al., 2016; Matsumoto et al., 2021). In Indonesia, the industry is still in a very early stage of development. Fatimah et al. (2013) describe remanufacturers as not very effective at producing remanufactured parts. The Indonesian government strictly restricts the import of used capital goods, which could partially limit the growth of the industry in that country (Matsumoto et al., 2021). Overall, in Southeast Asia, automotive parts remanufacturing is most likely to continue to grow in the coming decades, and the governments and industry should also support its growth to enhance the circularity of products.

Table 5 Drivers' experiences with repairs/replacements of alternators or starters.

		Have you ever repaired or replaced an alternator or starter (A/S) in your car, including the A/S of your current car and/or your previous cars?		
		Yes	No	I don't know
Indonesia	N=500	66.2%	33.8%	-
Malaysia	N=500	50.2%	39.6%	10.2%
Thailand	N=500	64.8%	35.2%	-
Vietnam	N=500	74.8%	20.4%	4.8%
Japan	N=600	11.3%	61.7%	27.0%
US	N=500	55.6%	38.8%	5.6%

Source: Authors' web-questionnaire survey of car owners in these six countries.

Notes: The survey in the US was conducted in November 2014. The surveys in the other five countries were conducted in January 2017. In the surveys in Indonesia and Thailand, the authors overlooked inclusion of the answer option of "I don't know".

2.6 Potential Material Saving Effects of Automotive Parts Remanufacturing

In remanufacturing, 65% to 95% of subcomponents on a weight basis are reused (Kim et al., 2008; Fatimah et al., 2013; UNEP-IRP, 2018; Bobba et al., 2020), This indicates that remanufacturing has 65% to 95% material-saving effects compared with brand-new parts manufacturing (manufacture of parts using only new subcomponents). Conservatively assuming that remanufacturing has an 80% material-saving effect, the potential contribution of automotive parts remanufacturing in saving materials overall and steel itself would be 162,000 tons and 110,000 tons, respectively in 2015, and 251,000 tons and 170,000 tons, respectively, in 2030. These amounts of steel correspond to 0.13% of the steel used in Southeast Asia in 2015, and 0.13% of the steel to be used in the region in 2030.

2.7 Potential CO_2-Saving Effects

We also estimated the potential effects of remanufacturing on reducing CO_2 emissions. First, the CO_2 emissions from manufacturing 203,000 tons of new spare parts (in 2015) and 314,000 tons of new spare parts (in 2030; Fig. 1) were estimated. The emissions were calculated at 629,000 tons of CO_2, and 974,000 tons of CO_2, respectively. The inventory data from the previous study (Tahara et al., 2001) was used in the calculation. Second, the CO_2 saving effects of remanufacturing were considered. Extant studies indicate that remanufacturing saves 85% of energy use (Kim et al., 2008), and 66–78% of global warming potential (GWP) (Bobba et al., 2020) when compared with new parts manufacturing. Assuming remanufacturing saves 75% of CO_2 emissions compared to new parts manufacturing, using 203,000 tons of remanufactured spare parts in 2015 and 314,000 tons in 2030 (Fig. 1) instead of using brand-new spare parts would save emissions of 472,000 tons of CO_2 and 731,000 tons of CO_2, respectively. The ratios of these figures to the total CO_2 emissions of Southeast Asia in 2015 (1.3 billion tons CO_2) are 0.036% and 0.056%, respectively.

2.8 Discussion

This section has provided estimates of materials used in automobiles and spare parts in Southeast Asia. It was estimated that 3.6 million tons of materials were used in automobiles in 2015 and for spare parts, 137,000 tons. Suppose about 20% of sub-components need to be replaced in remanufacturing with new sub-components. In that case, 80% of the material used in spare parts represents potential material-saving effects through automotive parts remanufacturing. For spare parts, reused parts and repaired parts are commonly used in the region today. However, as the economy grows in the area, brand-new spare parts may become more common (Matsumoto et al., 2018). It is vital to make the use of remanufactured spare parts widespread instead of encouraging use of brand-new spare parts.

The material for spare parts (293,000 tons) accounts for about 5% of the total amount of materials in automobiles and spare parts. It should be seen that it is of great significance that 5% of materials used in a sector can be circulated through remanufacturing. The estimated results also indicate that the effects of using automobiles for a long time are also significant. A simplified calculation shows that if the average life of a car increases by 10% (used for 1.5–2 years longer), the demand for new vehicles will be reduced by 10%, which corresponds to 360,000 tons of materials. Automotive parts remanufacturing can also affect the long-term use of vehicles because availability of inexpensive and reliable remanufactured spare parts gives drivers an incentive to maintain and repair their cars, which leads to long-term use rather than replacement with new cars.

There are several important issues regarding material use in the automotive sector. First, as it is often argued, there can be trade-offs between material saving and CO_2 reduction. Prolonged use of cars can eliminate opportunities to replace CO_2-inefficient cars with the latest CO_2-efficient vehicles. Both the material and CO_2 aspects should be adequately considered. Second, there can also be trade-offs between material saving and car safety. The average weight of a car has increased over the decades in the US (Mayyas et al., 2017) and in Europe (Allwood & Cullen, 2015). There are several reasons for this trend, one of which is that car weights have increased to improve the safety of cars. If it is challenging to save materials on account of safety issues in automobiles, long-term use and circulation are even more critical. Third, promoting the use of secondary materials in automobiles may have a significant material-saving effect. In the automobile sector, there is plenty of room for material recycling. Forth, as a long-term trend, internal combustion engine (ICE) vehicles will be replaced by EVs. Adopting remanufacturing and circulation for EVs and EV spare parts will be a significant challenge.

3. Discussion: Market Barriers for Automotive Parts Remanufacturing

3.1 Barriers to Remanufacturing

The barriers to remanufacturing are mainly derived from the difficulty of integrating products issued from a circular manufacturing process into a business ecosystem dedicated to maximizing the number of products from traditional linear systems in the market. Figure 2 presents the perceived barriers to remanufacturing from the point of view of a manufacturing company (Widera & Seliger, 2015). Typically, there are four categories of barriers to remanufacturing (Fig. 2; UNEP-IRP, 2018). They include: (1) core acquisition barriers, (2) technological barriers, (3) market barriers (product sales barriers (Fig. 2)), and (4) regulatory barriers.

The technological barriers include a lack of technical solutions for optimizing material and information flows. The market barriers refer to a range of obstacles, the major ones of which include: 1) original equipment manufacturers' (OEMs') hesitation to undertake remanufacturing, and 2) consumers' non-acceptance of

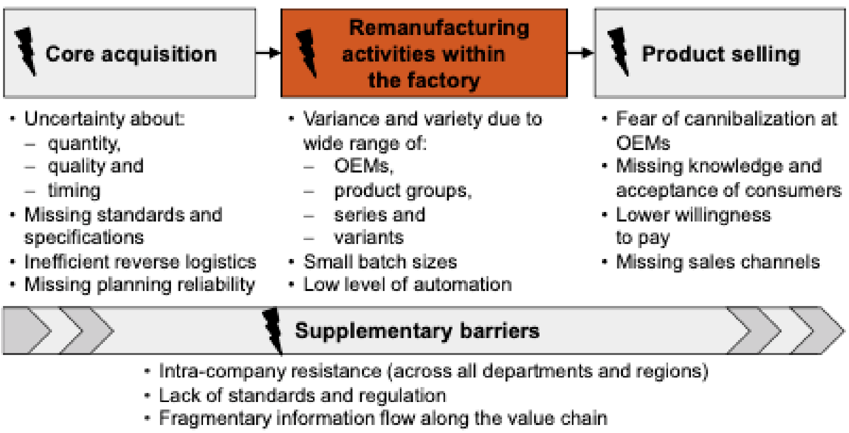

Fig. 2 Barriers to remanufacturing. Source: Widera and Seliger, 2015

remanufactured products. A market barrier specific to OEMs is the fear of cannibalization (Fig. 2), which shows that remanufactured products are considered as replacing the sales of new and more profitable product ranges with their potential to tap new markets or customer segments. The obstacles in this context in the region are discussed below, where the discussion of OEMs is based on a literature review.

3.2 Market Barriers on the Supply Side

In the spare parts market in Southeast Asian countries, as well as in other countries, including the US, EU and Japan, independent remanufacturers rather than OEMs are the main actors in supplying remanufactured automotive parts today. From a long-term perspective, OEMs are expected to play a significant role in the remanufactured automotive parts market. A market barrier specific to OEMs is the fear of cannibalization. Many OEMs offering remanufactured products encounter internal resistance from departments in charge of new products over the perception of competition, resulting in fewer financial and sales channels specific to the remanufactured products markets. Especially in North American and European automotive parts markets, OEMs have launched remanufactured product lines only to face competition from independent remanufacturers. This reaction causes most producers in this field not to consider remanufacturing part of their long-term development strategy. Therefore, it can be assumed that the relative lack of independent remanufacturers in Southeast Asia, combined with the small market size, can explain the lack of application by OEMs of remanufacturing in such countries. As imports of used products are increasingly restricted, the option to offer imported remanufactured parts may also not be seen as an economically attractive solution.

Further consideration of business models for automotive parts is needed. In general, remanufacturing works best when the cost savings compared to new parts benefit the OEM in the case of product-service systems where use of the product is sold without transfer of ownership. As per example in the case of copy machines leased as “pay per use” on customer premises, these models are widely accepted within the providing companies, and customers focus solely on the reliability of the product instead of its production origin.

3.3 Market Barriers on the Demand Side

The spread of remanufacturing largely depends on consumers’ acceptance of remanufactured products. Consumers are often unfamiliar with remanufactured products, and even if they know about them, they may have concerns about the quality of remanufactured products. These hinder their acceptance of remanufactured products (Matsumoto et al., 2018). A web questionnaire survey to investigate consumers’ knowledge, purchase experiences, and purchase intentions regarding remanufactured automotive parts was conducted in a total of six countries, including four Southeast Asian countries – Indonesia, Malaysia, Thailand and Vietnam. The survey targeted consumers who owned and drove cars. Table 6 shows the question items and the results, which show that consumers in the four countries have a relatively high acquaintance with remanufactured auto parts. While in Japan, only 22.2% of consumers have heard of remanufactured auto parts, many more consumers in those four countries know about the products. Also, many consumers in the four countries answered they had experienced purchasing of remanufactured auto parts, while in Japan, only 16.3% of consumers answered that way. The average intention to purchase remanufactured auto parts is also high in the four countries compared to among consumers in Japan. These results indicate that the four countries in Southeast Asia are in favorably suited in terms of consumers’ level of knowledge, familiarity and intention to purchase remanufactured auto parts. The industries and governments in these countries should make efforts to maintain that level.

Although the four Southeast Asian countries in which the survey was conducted comprise the majority of the region, having 92% of the car stock in 2015 and 71% of population in 2020, the other six countries in that region

Table 6 Consumers’ knowledge, purchase experience and purchase intention of remanufactured automotive parts.

		[Knowledge] Q: Have you ever heard of remanufactured auto parts?		[Purchase experience] Q: Have you ever bought remanufactured auto parts?		[Purchase intention] Q: If I need to repair an alternator or starter (A/S), I am willing to buy remanufactured A/S. 7-point Likert scale (“1: strongly disagree” to “7: strongly agree”)
		Yes	No	Yes	No	Average (middle=4.0)
Indonesia	(N=500)	80.8%	19.2%	51.4%	48.6%	4.43
Malaysia	(N=500)	73.0%	27.0%	42.0%	58.0%	3.98
Thailand	(N=500)	69.2%	30.8%	48.8%	51.2%	4.44
Vietnam	(N=500)	95.2%	4.8%	66.8%	33.2%	4.93
Japan	(N=600)	22.2%	77.8%	16.3%	83.7%	3.28
US	(N=500)	70.8%	29.2%	41.8%	58.2%	4.25

Source: Author’s web-questionnaire survey to car owners in the six countries.

Notes: The survey in the US was conducted in November 2014. Surveys in the other five countries were conducted in January 2017.

have different economic properties. Those six countries include more wealthy nations such as Singapore and Brunei, and also countries less developed than the four countries surveyed. Consumer behaviors could differ in those countries, and future research should include a market study in these six countries.

4. Conclusions

This article has presented estimates of the potential material-saving effects of automotive parts remanufacturing in Southeast Asia. The potential for the year 2015 is estimated at 162,000 tons of material, 110,000 tons of steel and 0.13% of the steel used in the region. The potential for the year 2030 is estimated at 251,000 tons of material, 170,000 tons of steel and 0.13% of the steel used in the region. For steel use, the automotive sector (automobiles and spare parts) uses about 3.0% of the steel in the region, and spare parts remanufacturing has the potential for saving 5% of the sector's steel use.

There are other sectors that consume large amounts of steel. Globally, 42% is used in buildings, 14% in infrastructure and 13% in mechanical equipment, among others. (Allwood & Cullen, 2015). Each sector should promote material saving through long-term use, maintenance and remanufacturing. In addition to the market barriers discussed in the previous chapter, auto parts remanufacturers face core acquisition, technological and regulatory barriers. Governments are expected to help industries overcome these barriers and support the realization of a circular economy.

Acknowledgement

This research was supported by the Environmental Restoration and Conservation Agency (ERCA) of Japan, Project ID: JPMEERF16S11603 of the Environmental Research and Technology Development Fund.

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(Received 31 May 2021, Accepted 27 July 2021)