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Emerging Issues on Urban Mining in Automobile Recycling: Outlook on Resource Recycling in East Asia

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1. Introduction

The continued depletion of resources in today's consumerist society has put countries in East Asia to rethink and embrace recycling as a sound approach to sustainable consumption of resources. Recycling is not an "outside-of-the-box" approach but rather an "inside-of-the-box" method that has long been considered but was overtaken by the notion that resources are infinite. With societies' hunger for raw materials to feed into their industrial demands, production of new materials has become challenging and economically inefficient. In the automobile industry, the demand for rare earth metals is exponentially growing with increasing demand for vehicles. China, which is a top source of rare earth metals, has imposed limits on the export of such product due to increasing internal demand. Japan, which sources metals from China, has had to make innovative steps to address the problem through "urban mining." It refers to the recovery of rare earth metals from end-of-life (ELV) vehicles and electronic waste or e-waste (Saito & Yu, 2011). It does not require new materials to be extracted and it helps close the loop of sustainable resource circulation.

The concept of urban mining came to fruition with the advent of recycling technologies. Japan, which is a leader in the automobile industry, has devised ways to recover and recycle used metal parts from ELVs. With the large volume of new vehicles produced each year, it was imperative to reduce the volume of waste from old vehicles thrown into incineration plants and landfills. Used car parts are deemed valuable to be discarded in the midst of competing demand for rare earth metals all over the world. The way to move forward with a booming automobile industry is to incorporate environmental responsibility through recycling. The benefits cannot be overemphasized from the point of a resource-deficient

Japan. It is also paving the way for economic and social opportunities in the recycling sector. However, challenges abound in terms of supply and how urban mining could be sustainably done in developing countries where technologies are lacking. Likewise, exposure to toxic metals is high due to the manual nature of recovering used car parts.

Recovery and recycling per se are good but accompanying issues need to be addressed in developing countries so that real societal benefits are achieved. It is necessary that countries like Japan, Korea and China identify emerging lessons from the implementation of their respective ELV recycling laws so that developing countries can learn from them and craft laws that are appropriate and tailored to local needs and existing resources. This paper discusses the experiences of Japan and China in the field of urban mining and concomitant issues and challenges and how they will shape ELV recycling policies in East Asia. Outlook for the future will also be tackled as a way to create a road map for East Asia in the field of automobile recycling.

2. Urban mining opportunities and markets in Asia

The term “urban mining” was coined by Professor Nanjyo of Tohoku University in the 1980s to encourage and promote the reuse of precious and rare-earth metals found in used and discarded electronics. Japan, a heavy user of rare earth metals for its electronic and automobile industries, depends largely from China which produces 90% of the world’s rare earth metals. The table below shows the top producers of rare earth based on 2009 data:

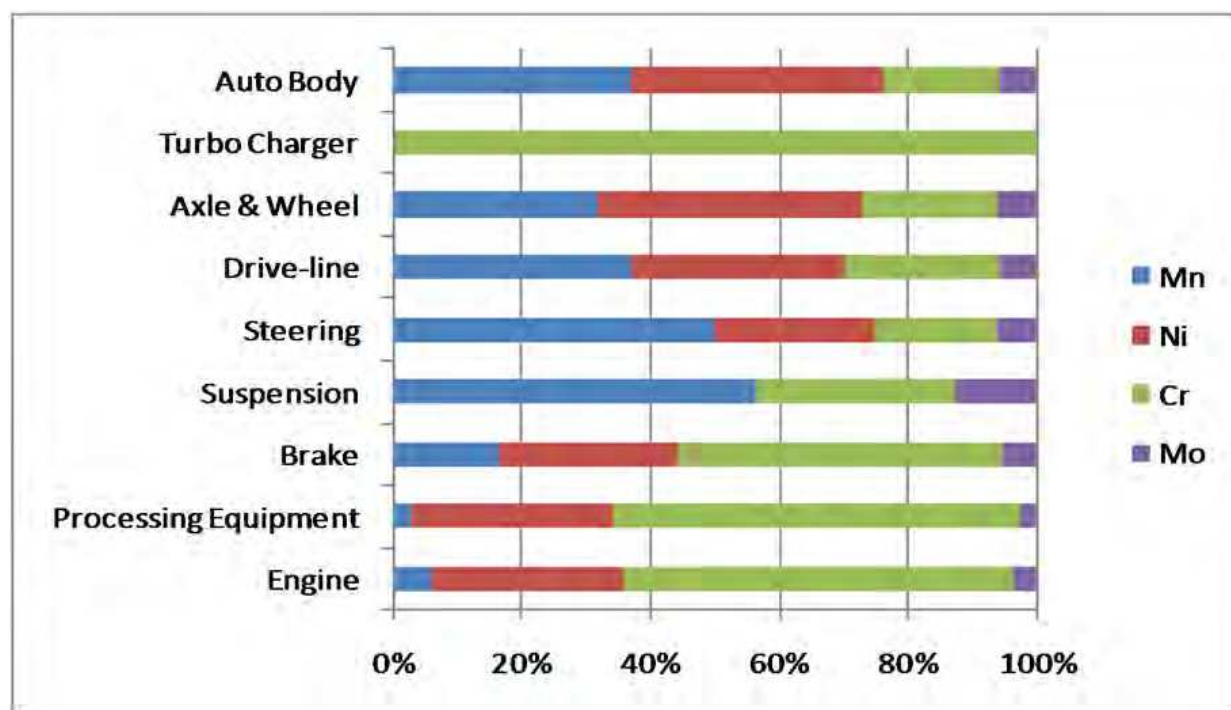
Country	Production (Metric Ton)	Reserves (Metric Ton)
United States	insignificant	13,000,000
Australia	insignificant	5,400,000
Brazil	650	48,000
China	120,000	36,000,000
Commonwealth of Independent States	Not available	19,000,000
India	2,700	3,100,000
Malaysia	380	30,000
Other countries	Not available	22,000,000
World total (rounded)	124,000	99,000,000

Source: <http://geology.com/articles/rare-earth-elements/>

Table 1. World Mine Production and Reserves (2009)

In July 2010, China announced a 72% reduction of exports due to increasing domestic consumption. This prompted the Japanese government to search for alternative sources and a research made by the National Institute of Material Science, a research organization affiliated with the Japanese government, announced that 6,800 tons of gold can be recovered from used electronics in Japan. This massive reserve is projected to be equivalent of 16% of the world’s total reserves. Other reserves that can be generated are silver with 22%, tin with 11% and other materials at 5% (Kawakami, 2010). Clearly, the study showed the vast potential of internally sourcing rare earth metals in Japan rather than depending solely from foreign markets. It is sitting on mountains of used appliances and ELVs on its backyard where necessary resource inputs for new cars abound.

In ELVs, various metals can be found from different parts of a car. The following figure shows the distribution of rare earth metals from the exterior components of a car:



Source: Nagamura, 2010

*Mn – Manganese; Ni – Nickel; Cr – Chromium; Mo - Molybdenum

Fig. 1. Rare earth metals in auto parts

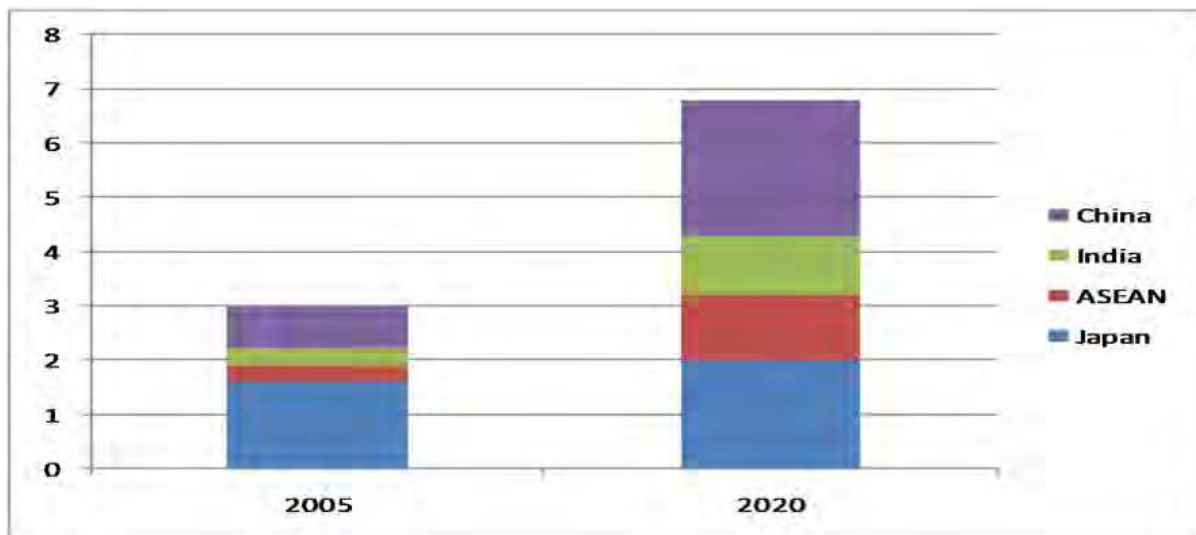
It will be noted from the above figure that Chromium has the highest concentration in engines and processing equipment while Manganese is abundant in suspension and steering parts. The rest of rare earth metals are spread in other auto parts. In terms of the price of earth metals, the following table shows the resource market fluctuation for iron ore, iron scrap, copper, silver and gold:

Metals (\$/t)	Jan 2010	Jan 2011	Range of Elevation(%)
Iron ore	135	189.5	40.37
Iron scrap	313.5	462.5	47.53
Copper	7,065	9,585	35.67
Gold	1,084.80	1,340.70	23.59
Silver	1,621.20	2,791.90	72.21

Source: Asahi Newspaper, 2011

Table 2. Resource market fluctuation

The prices of valuable earth metals in the world market have significantly risen from 2010 to 2011 with silver achieving the highest increase. In terms of recycling market, the top three countries which have captured substantial markets for recycling are China, India and Japan as shown on the following:



Source: Ministry of Environment, Japan

Fig. 2. Recycling markets in Asia

3. Existing ELV legislations examined

The momentum towards ELV recycling was jumpstarted by the European Union (EU) with the passage of an ELV recycling law in 2000. Japan passed the “Law for the Recycling of End-of-Life Vehicles” in 2005. Korea legislated the “Act for Resource Recycling of Electrical and Electronic Equipment and Vehicles” in 2008. China, on the other hand, has “Statute 307” which was enforced in 2010. One of the salient features of this law is that vehicle producers of imported vehicles shall be responsible for the recovery and treatment of used vehicles (Serrona, Yu & Che, 2009). There are distinct variations in each of these laws but they all fall under the principle of “Extended Producer Responsibility” or EPR. Producers are largely responsible for recovery but consumers are also entrusted with certain responsibilities. It may be worth to comparatively revisit these laws as follows:

	European Union	Japan	Korea	China
Implementation year	2000	2005	2008	2010
Dismantlement method	Machine and Manual	Machine and Manual	Machine and Manual	Manual
Accountable entity and associated recycling costs	Manufacturer	End users	Manufacturer	Manufacturer
Operating principle	Market-based	Fund system (Air Bag, Freon gas & Automobile Shredder Residue or ASR)	Market-based	Market-based
Institutional mechanism	Member states	Japan Automobile Recycling Promotion Center	Korea Environment Corporation Eco Assurance System (ECOAS)	China National Resources Recycling Association

Table 3. Comparison of existing ELV laws

The above table reflects the uniqueness of Japan in terms of who is responsible in ELV recycling. The end users are the main actors as far as financial obligations are concerned such as payment of recycling fees. However, manufacturers are liable too like setting and publication of user fees and collection and disposal of shredder residues. Further, the above laws put both the manufacturers and users at the helm of recycling. This characteristic represents the necessary symbiosis that stakeholders play in resource recycling (Yu, Omura, & Yoshimura, 2008).

4. ELV Recycling in Japan and China

Japan has been implementing its ELV law since 2005. The vehicles covered by the law are four-wheeled passenger cars and commercial vehicles including mini-cars. The obligations of the car manufacturer comprise of collection and disposal of freon gas and airbags, collection and recycling of automobile shredder residue and setting and publication of user charges. Unlike other countries with ELV laws, financial responsibility is with the users where they are required to deposit a recycling fee at the time of sale. For old vehicles, deposit is required at the time of automobile inspection. The fees are managed by a fund management corporation (Kanari, Pineau, & Shallari, 2003).

Car recycling in Japan is not encompassing as it only covers three parts: airbag, freon and automobile shredder residue (ASR). As of the present, recycling rate in Japan is pegged at 95%. Table 1 shows the change in the generation of ELV and used car export of Japan for the period 2005 to 2008:

	2005	2006	2007	2008
ELV Generation	305	357	371	358
Cancelled registration of used car for export	107	144	161	130
Sales of used car	811	807	753	718

Source: Japan Ministry of Economy, Trade and Industry (METI)

Table 4. ELV generation and used car export figures (Unit: 10,000 cars)

ELV generation grew rapidly from 2005 up to 2007 and a decline was noted in 2008. This was due to the introduction of an ELV bounty system or subsidy. However, it is not only the recycling rate of used car parts that is important but also the reduction in the volume of ASR because of its harmful effects to human health and the environment, in general. Table 5 reflects the recycling rates for both ASR and airbag:

	Recycling Rate (%)	
	ASR	Airbag
Goal (%)	70% (until 2015)	85%
	50% (until 2010)	
	30% (until 2005)	
2008	72.4-80.5	94.1-94.9
2009	64.278.0	92.0-94.7

Source: Japan Ministry of Economy, Trade and Industry (METI)

Table 5. Recycling rates for ASR and airbag in Japan

ASR remains a challenge for Japan as recycling rate is still not catching up with say airbags. The goal in the next five years is to increase the rate from 50% to 70% in 2015. In summary, the flow of automobile recycling in Japan is shown in the following figure:

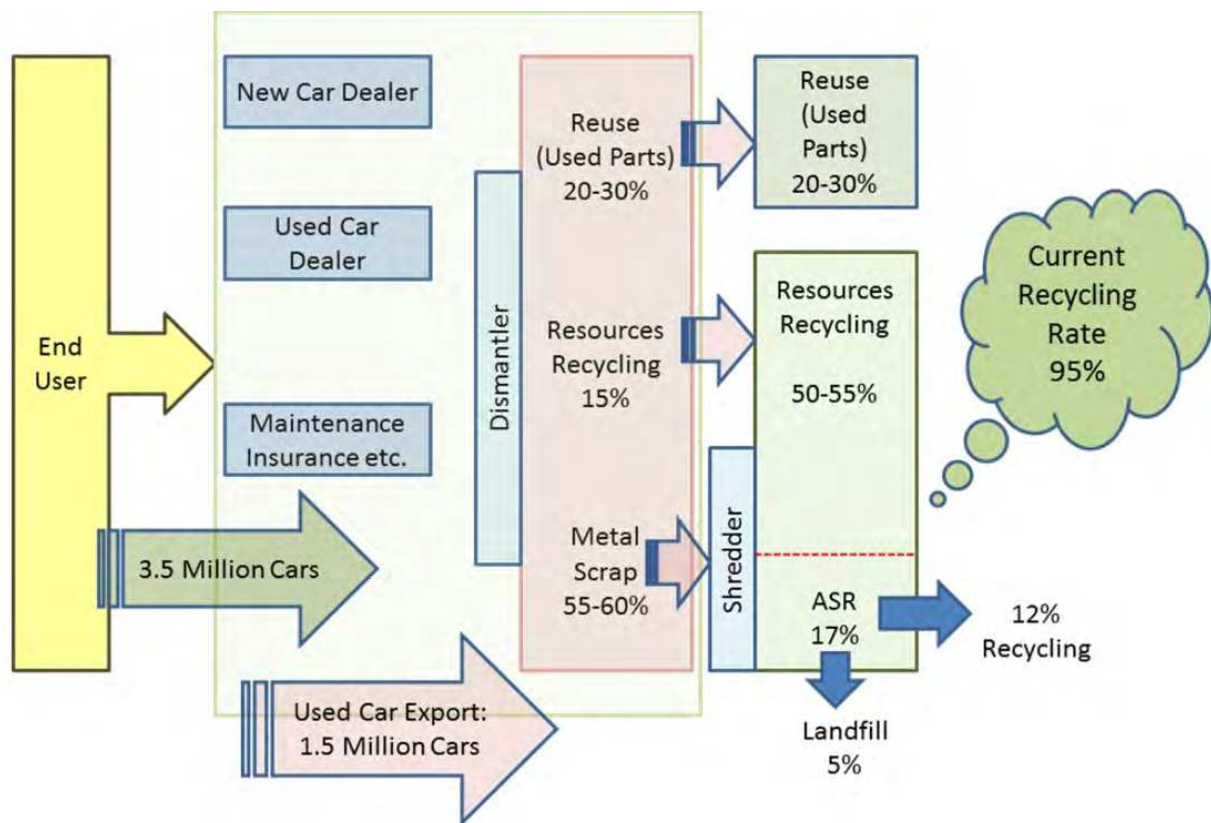


Fig. 3. Flow of automobile recycling in Japan

The above figure shows the efficiency of car recycling in Japan as used car parts are categorized. For example, reuse of used parts is about 20-30%, resource recycling is 50-55% while ASR recycling is 12%. Only five percent (5%) goes to the landfill (Yu, 2010).

4.1 Dismantling experiment in Japan

Rare earth metals are not the only valuable resource found in used cars. Plastic materials are also abundant. As part of the 3R Research and Development Project by Miyagi Prefecture in Japan, an experiment was conducted to demonstrate the time element involved in dismantling a used car with plastic as the main material recovered. Two types of used cars were dismantled: commercial car and luxury car. Methodologies were manual and machine dismantling (note that dismantling was done by non-experts). The following are the results:

Methodology	Time	Responsible
Manual dismantling	15 minutes	1 person (non-expert)
Machine dismantling	5 minutes	
Separation and collecting plastic	10 minutes	1 person (non-expert)

Table 6. Dismantling of a commercial vehicle

Overall, the recovered amount of plastic was 20 kilograms. The following picture shows an image of a commercial vehicle dismantled by a machine.



Fig. 4. Commercial vehicle to be dismantled for waste plastic recycling

Waste plastic recovered are shown below:



Fig. 5. Recovered plastics from a commercial vehicle

It was observed that it is very easy to retrieve plastic materials from a commercial vehicle because of the simplicity of its interior and a single type of plastic was used. In addition, commercial vehicles are designed where it is easy to dismantle and recover plastic materials. On the other hand, a luxury car was dismantled with the following results:

Methodology	Time	Responsible
Manual dismantling	40 minutes	2 persons (non-expert)
Separation and collection	10 minutes	2 persons (non-expert)

Table 7. Dismantling of a luxury vehicle

The recovered amount of waste plastic was only five (5) kilograms compared to the commercial vehicle which was 20 kilograms. The reason was that a luxury vehicle has complex interior and is made of composite plastic materials. Also, many adjoining materials are used which complicates the dismantling process and is time consuming as well.



Fig. 6. Luxury car dismantled for waste plastic recycling

Sample of recovered plastic materials is shown below:



Fig. 7. Waste plastic from a luxury car

A dismantling experiment was also made for a small sedan with amount of plastic materials recovered shown below:

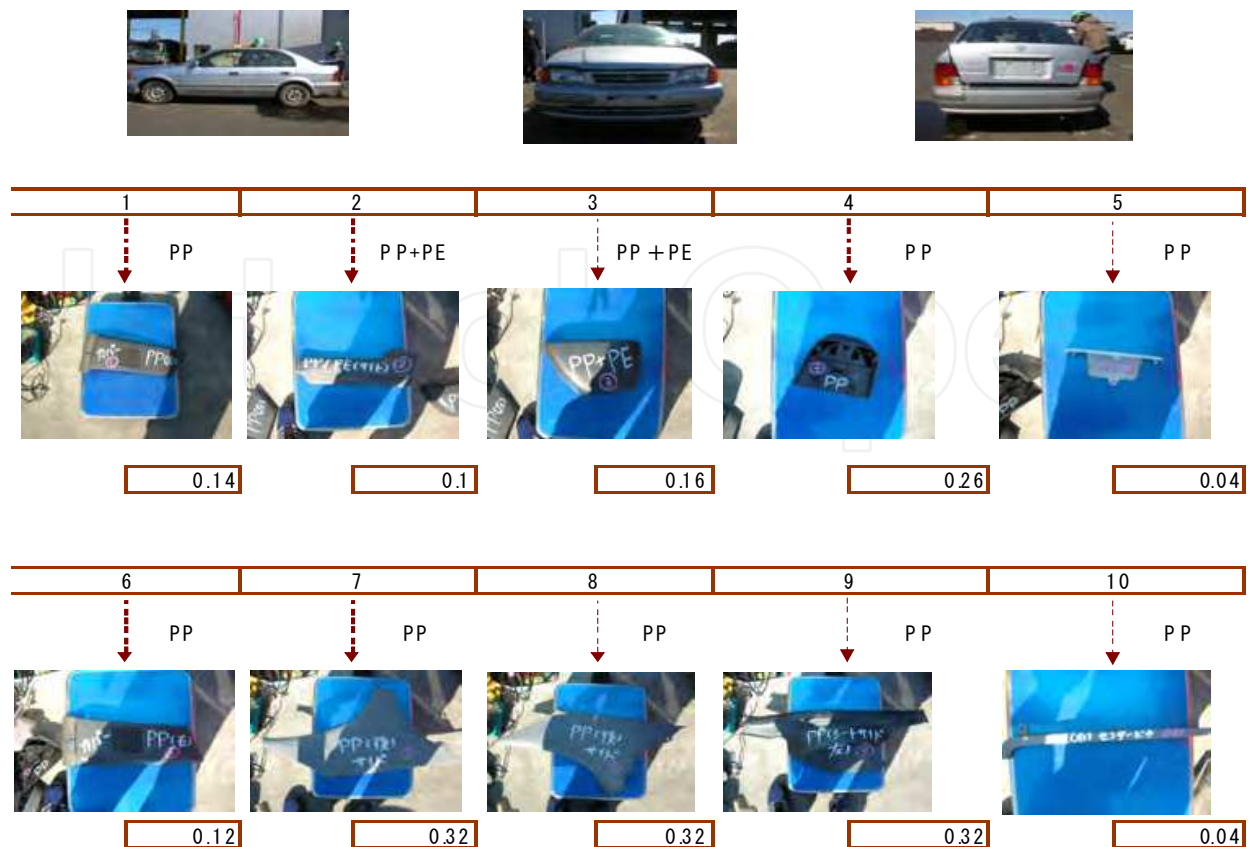


Fig. 8. Waste plastics recovered from a small sedan

In summary, the amount of plastics recovered are as follows:

	Polypropylene (PP)	PP+Polyethylene (PE)	PE	NA	Composition	Total (kg)
Weight (kg)	19.5	2.90	2.72	0.52	0.8	26.44

The downside of the experiment was the time it took to dismantle the vehicle. The total amount of time consumed was 2.5 hours by four (4) non-expert persons with a plastic recovery of only 19.5 kilograms. It was concluded that waste plastic recycling from a small sedan is not good considering the lengthy dismantling time and poor recovery efficiency. Sample of plastics recovered are:



On the left side are plastic pellets and on the right side is the internal part of a fender. In summary, the volume of plastics that can be recovered as well as the recovery efficiency depends on the type of vehicle. Figure 9 shows this type of variation.

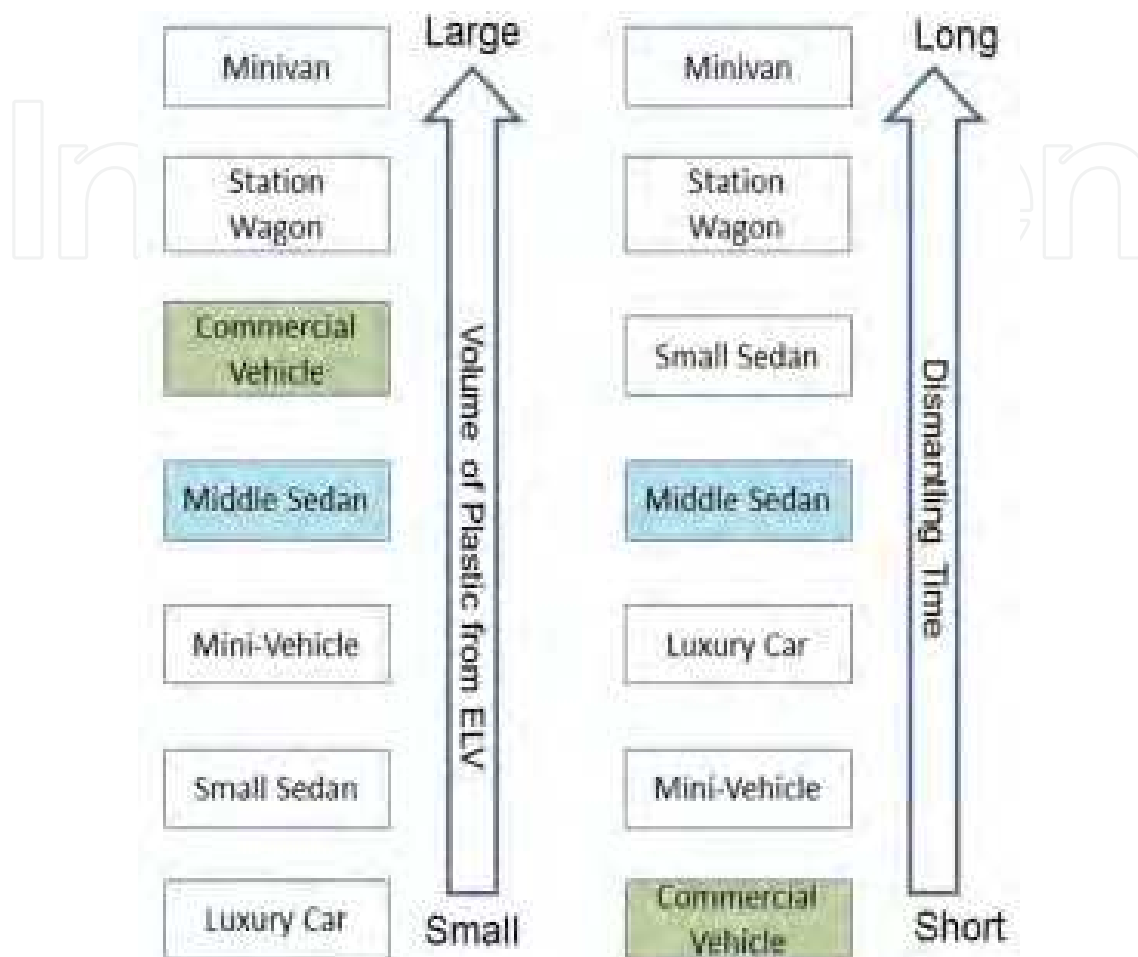


Fig. 9. Recovery efficiency for various types of vehicles

Based on the experiment, it can be concluded that for dismantling time, commercial vehicles are quick to be dismantled while minivans take time. In terms of volume of plastics recovered, relatively big cars like commercial vehicles, station wagons, and minivans have large amount of plastic materials.

4.2 Economic potential of ELV recycling in China

China's economy is booming at an unprecedented rate. Looking at car possession alone, the following table shows the rate for the period 2005-2008:

Year	Volume of car (million)
2008	49.75
2007	43.58
2006	36.97
2005	31.6

Table 8. Car possession rate in China (2005-08)

It is projected that the number of cars in China will increase a million per year in the near future due to increasing purchasing power and demand for personal transportation. From the data mentioned, it is also worth to examine the volume of cars that will become “used” in the near future. Using the following formulae:

$$E=A+B-C$$

Where:

E number of presumed used cars at current year

A number of car possessions in previous year

B number of sales at current year

C number of car possession at current year

Thus, the number of projected used car between 2005 and 2007 is as follows:

Year	Projected used car (million)	Rate (%)
2007	1.97	4.5
2006	1.79	4.8
2005	1.05	3.3

Table 9. Projected used cars in China (2005-2007)

It is, therefore, projected using the above data that China will have a large volume of used cars in the years to come.

There are about 10.33 million passenger cars in China in 2001 with an engine displacement of 1,600 cc or less. In several years, these will become used cars. A study made in Shanghai City and the City of Beijing showed that recovery percentage of ELVs in China is only 20%. To validate this, Tohoku University through the environmental research fund of Sumitomo Foundation conducted a dismantling experiment of a car commonly sold in China as shown below:



Fig. 10. Popular type of car sold in China

Considering the costs and difficulty involved in dismantling a new car, the research group selected a model closed to the picture as shown in Fig. 11.



Fig. 11. Replacement car used for dismantlement

The recovered materials are as follows:

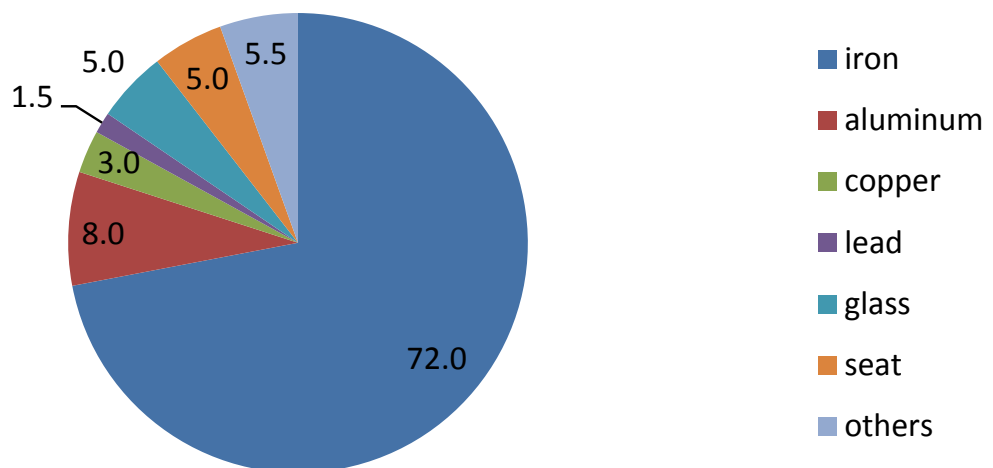


Fig. 12. Material composition of a passenger car

If only 20% are to be recovered from the 7.2 million passenger cars sold in 2009, the projected economic loss is about 200 billion Chinese Yuan based on the metallic market price in China. Thus, the need to find ways to increase recovery rate of ELVs is necessary in the country where car possession is increasing at a rapid rate (Che, 2011).

5. Monitoring system: A prerequisite in ELV recycling

The importance of establishing a monitoring system in ELV recycling is essential in so many aspects. ELV recycling is about collating information or data needed to make it more efficient and useful for key stakeholders like manufacturers, recyclers and even those who manually recover used car parts. In the case of EU, it ensures the inventory of ELVs while in Korea, every ELV is checked including weight, type and main parts like bumper, fuel cell, engine, exterior and interior parts and so on (Yu, Omura, & Yoshimura, 2008). In the case of Japan, monitoring focuses on airbag, Freon gas and ASR as mentioned earlier. The actual benefits of having a monitoring system abound. It helps in increasing dismantling efficiency when each part is identified i.e. weight, type, time consumed during dismantling and the amount. Having these data will be useful for sharing purposes between the manufacturers and recyclers (Yu, 2010). The data could also be used in life cycle analysis (LCA) and cost-benefit analysis (CBA). Another benefit is the potential of determining who is responsible for what and what roles should relevant stakeholders play in the whole gamut of ELV recycling.

6. Emerging issues and challenges

Advance technology in used vehicle recovery and recycling does not necessarily apply in developing countries. They can recover resources using labor-intensive and manual strategies. Efficiency remains a question but in a research in China (Serrona, Yu & Che, 2010), a comparison between manual and machine-based dismantling was made. It was discovered that the former recovers more valuable parts which means more parts sold or recycled while the latter destroys more parts. In terms of value, manual dismantling provides more monetary compensation with more recovered parts. It also translates into more job opportunities and feeds people. The downside is that manual labor exposes people, engaged in the recovery of used car parts, to hazardous and toxic chemicals due to the absence of protective gears. It also consumes a lot of time. Manual recovery is good from the standpoint of local community participation. It allows them to be important stakeholders in the resource recycling ecosystem.

There is no blueprint for ELV recycling across countries. Each country has its distinct characteristics of stakeholders and geographical location. The formulation of recycling laws should be based on the unique features of communities rather than applying blanket legislations which may or may not be effective at all. To come up with sound laws is to have good documentation of vehicle database i.e. registration, type of vehicle and other ELV data. Policy makers should take these into consideration in order to arrive at legislations that incorporate locality-based conditions, needs and characteristics into national policies.

7. Conclusions and recommendations

Urban mining is driving ELV recycling into sustainable waste management. Just like solid waste management, various stakeholders or players are involved such as manufacturers,

recyclers, users, waste reclaimers and the communities where waste recovery is done. There is a wide range of opportunities in this field and what is significant is that it has tremendous impact in terms of reducing toxic waste and providing local employment. In addition, it helps mitigate climate change by reducing greenhouse gases as recovering and recycling rare earth metals consume less energy than extracting raw metals. Closing the loop of rare earth metal utilization is a necessary attribute of sustainable consumption and production.

The experiences of Japan and Korea in this aspect are worthy of emulation by other countries in East Asia. Developing countries, being the destination of used cars, should formulate legislations that will address the collection, trading and disposal of ELVs which consider local conditions and capacities. There is a vibrant informal ELV waste sector in the Philippines, for example, but there is neither database nor monitoring system of what comes to the country as other ELVs are brought in illegally. The challenge lies in coming up with a legislation that strongly advocates safe and sustainable resource recovery. The role of Japan and Korea is to provide technical assistance based on their best practices. And being the leading manufacturers of vehicles in Asia, they should incorporate LCA in the production process so that the end users in developing countries are able to responsibly dispose used cars. Likewise, regulatory institutions will be able to promote the development of appropriate, labor-intensive and simple technologies to recover and recycle used metal parts. This kind of symbiosis will allow for a sound partnership between these countries through job promotion and people to people exchange of ideas. To strengthen ELV recycling regulations, the following are recommended:

1. Establishment of a resource recycling network that integrates economic and social dimension of ELV recycling. It should serve as a platform for exchanging innovative ideas, appropriate technologies and best practices in both developed and developing countries. There should also be component for capacity-building and community organizing to strengthen local waste reclaimers doing manual recovery. Organizing them into a legal entity will allow them to be accorded with rights, privileges and access to social and health services.
2. Build up a communication system between car manufacturers and recyclers. Currently, there is limited information exchange on ELV recycling processes. In the context of sustainable consumption and production, auto makers need to design cars that are easier to scrap and recover recyclable parts. Furthermore, they should provide the method of resource recovery including rare metals. And it is important to collect data on the content of materials as well as the cost and time involved in the recycling process.
3. In the formulation of ELV recycling legislations, lessons should be culled out from the best and bad practices of ELV recycling in Japan, Korea and even China. This includes an assessment of market principles used in the current system and how it will affect the future of resource recycling network worldwide. Policies should also be region-specific and localized to reflect in recognition of the distinct features of each locality or community.
4. The technological dimension of urban mining should be given attention with respect to local capacities and recovery efficiency. Based on dismantling experiments cited,

manual dismantling is found to be effective in terms of recovering more resource materials compared to machine-based recovery. It is not always necessary that machines are effective since manual recycling in developing countries generates local jobs and increases the value of recovered parts. However, such method should ensure adequate protection of workers from exposure to toxic materials.

5. Engage constructive policy dialogues with exporting countries like Japan and Korea to discuss ways to ensure that used car importation comes with the necessary recovery system in developing countries. This will ensure that developing economies are not inundated with pollutive used cars and ELV recycling is done.

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