LIFE CYCLE COST ANALYSIS OF END-OF-LIFE VEHICLE TO EXAMINE THE ECONOMIC FEASIBILITY AND MANAGEMENT POLICY IN THAILAND

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A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy (Management)
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ABSTRACT

Title of Dissertation	LIFE CYCLE COST ANALYSIS OF END-OF-LIFE VEHICLE TO EXAMINE THE ECONOMIC FEASIBILITY AND MANAGEMENT POLICY IN THAILAND
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A vehicle that is no longer used is called an End-of-Life Vehicle (ELV). ELV management is a crucial issue that is addressed by many countries who are keen to reduce waste and improve the ELV treatment process. In developed countries, regardless of the different policies they chose, ELV management is stable and systematic. In Thailand, there is no direct law or regulation for ELV management. In addition, the current policy promotes the use of old cars because the annual tax registration renewal fee is reduced from year six by ten percent every year to a maximum of fifty percent. Consequently, people tend to use cars for a very long period of time, which leads to ELVs not collected often. Furthermore, the few cars that are collected are not treated appropriately by an ELV management process. When discussing the ELV program, the costs related to ELV management must be mentioned. ELV management, when executed properly, can lead to a win-win situation from both economic and environmental perspectives. To better understand all the mentioned above, this study has 3 main objectives: 1) study ELV management status-quo in Thailand, and to investigate how people manage their unusable cars 2) analyze the life-cycle cost (LCC) of ELV from car owner and steel industry perspectives (not include cost of externality) and 3) propose an appropriate ELV management program for Thailand from costs perspective.

Questionnaires, secondary data, as well as field surveys are used to gain an understanding about how Thai people use cars, the status-quo in Thailand, and about the LCC of ELVs from steel industry and car owner perspective. Secondary data was collected to find the number of ELVs and related information. Life Cycle Cost analysis as well as information from field surveys, questionnaires, and secondary data, allows this study to make informed policy suggestion for ELV management in Thailand. The results show that the estimated number of ELVs in 2016 was approximately 84,000 ELVs with an increasing trend. ELV management status quo is based on market driven factors. There are many stakeholders who are involved in the business because all the car parts have value added. Also, if an ELV is sent for steel recycling, the value added is estimated approximately 16 baht/kg. Thus, instead of discarding an ELV along the street or in a garage, it is better to send it to steel industry. According to lessons learned from other developed countries, there are many steps towards sustainable ELV management with many stakeholders and policies related. ELVs should be promoted for suitable management. For the initial attempt to improve ELV management system in Thailand, this study suggested that car manufactures can contribute a recycling fee to the management fund or related organization to support a car owner and a recycler by applying Extended Producer Responsibility (EPR). The government should also try to frame or enhance standard of practices for dismantler and collectors.

Moreover, Department of Land Transport (DLT) can enforce the annual car registration fee to increase as car ages. A collaboration between DLT and Pollution Control Department (PCD) should standardize an annual inspection to be stricter, so car owners are responsible for maintaining their car to be in good condition during the use phase, thereby reducing particulate matter (PM 2.5). Department of Industrial Works (DIW) and PCD should regulate the stakeholders involved in dealing with ELVs to assure that the environment is not harmed. Policies should also be applied to car owners at use phase. Similarly, policies should be used on car manufacturers and recyclers during the manufacturing and recycling phases of a car to maintain standard of practice in the industries. With this policy change, average age of cars would expect to decrease. Proper collecting and management systems would definitely lead to a win-win situation.

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CHAPTER 1

INTRODUCTION

Over the years, several countries around the world have been working seriously on the environmental topic. Several organizations have been established to collaborate on preventing environmental problem in the world (Biermann, 2001). Waste management is an environmental issue that most countries around the world are seriously concerned about. Currently, world cities generate about 1.3 billion tons of solid waste per year and it will tentatively reach 2.2 billion tons by 2025 (Hoornweg & Bhada-Tata, 2012). Vehicles are perceived to be one source that causes waste. Five percent of the world's industrial waste results from the vehicle sector. This includes not only the waste from discarded vehicle by its owner, but also car manufactures that produce waste throughout production (Simic, 2013).

Discarded vehicles or End-Of-Life vehicles (ELVs) have contributed to an important portion of waste which requires proper management. Regardless of whether it is spacecraft, watercraft or railed vehicles, vehicles as a mobile machine that transports people or cargo play an important role to people's livelihood especially motor vehicle (Halsey, 1979; Krumm, 2012). Focusing on motor vehicles comprised of self-propelled road vehicles and off-road vehicles, and not including vehicles which operate on rail such as trains or trams, there were 1.2 billion vehicles statistically counted as a valid number of vehicles in use around the world in year 2015 (Organisation Internationale des Constructeurs d'Automobiles, 2017). Rapid growth of technology has drastically increased production of vehicles to a very high rate. Several countries are concerned about enforcing laws with regard to the responsibility of managing both usable and ELVs. To achieve this goal, some penalize car owners for illegally disposing ELVs, some pass laws to limit number of vehicles in one's possession. In terms of ELV management technology, recycling is one of the processes that has been posited and applied in several countries to maintain a good environment by reusing parts or manufacturing new cars without using virgin material (Jody, Daniels, Duranceau, Pomykala, & Spangenberger, 2011).

In developed countries, the ELV management system has been continuously evolved in that government can ensure that ELV will be placed into the right process of recycle or reuse. For those countries, what they have been endeavoring at this stage is to reduce waste from the recycling process as much as they can. For example, in Korea, a result of new regulation has been implemented to achieve a goal of disposal reduction by 5 percent, just as the EU have already done (Kim et al., 2004). In developing countries, such as Thailand, on the contrary, ELVs are not well managed. There is no law enforcement to collect or recycle ELVs and also the standard technology of ELV recycling is not available in the country (Dhokhikah & Trihadiningrum, 2016; Fuse & Kashima, 2008). Significant number of vehicles including in-use car and ELVs in Thailand are due to several causes such as the first car possession scheme and no law about car possession limit. As of June 30, 2017, there were 37.8 million vehicles across the country, where 8.4 million were of C1 type, accounting for 22% of the total (Department of Land Transport, 2018b). As vehicles are disposed, some are dismantled and leave the useless part in landfill. Without a systematic ELV management system and no direct ratified laws, the number of ELVs in Thailand would increase year by year (Yano Research Institute, 2014). Inevitably, this could cause environmental as well as health issues, such as toxic chemical leakage from discarded cars, and a source of disease e.g. Mosquito (McMichael, 2000).

When discussing the ELV program, the costs related to ELVs cannot avoid being mentioned. Costs to develop ELV management in Thailand from a car owner and recycling plant perspective need to be considered. To gain an insight of the cost perspective, the LCC concept is applied. The LCC concept is in line with the LCA concept. It is a tool that traces the costs related to a product, system or service from the cradle to grave (Matthews, Hendrickson, & Matthews, 2015). It is used to determine the most cost-effective option among different competing alternatives. An example of this is batteries that have been produced by manufacturer and shipped to a car manufacturer for assembly or install. At the end of its life, the battery is thrown away at one’s convenience, landfilled at a prohibited area, or recycled by recycling plant. In the case of recycling, the outputs generated from the process are delivered back to battery manufacturer as an input material. If all the ELV management stakeholders can gain a profit, then the market can drive the ELV system without subsidy from the government. This issue is still questioned in Thailand since there are no research studies on this issue. With all mentioned above, it leads to three research objectives. Firstly, this research aims to study the ELV management status quo in Thailand, and to investigate how people manage their unusable cars. The second objective is to analyze the LCC of vehicles from the car owner and steel industry (not include externality) in Thailand. This research focuses specially on steel as it is a major part of vehicle. Not only does this paper analyze LCC at the use phase, to understand the perspective of car owners in Thailand and their intention to discard, this paper also focuses on cost of steel of ELVs from the point of discarding to recycling. The third objective aims to propose a suitable ELV management program in Thailand. This is the first attempt to understand ELV flow and management based on cost perspective. The results of this study will benefit both government and public sectors to achieve ELV management program in the future.

Research Objective

1) To study ELV management status quo in Thailand, and to investigate how people manage their unusable cars

2) To analyze the LCC of ELV from car owner and steel industry perspectives.

3) To propose an ELV management program for Thailand (from cost perspective)

CHAPTER 2

LITERATURE REVIEWS

Statistic of vehicle in Thailand was reviewed to obtain an insight information regarding number of vehicles that bring to the figure of ELV. Also, car components and ELV management system in European countries, Japan, China, Taiwan, Korea, and Thailand are discussed. Intriguingly, applying ELV management regulation seems to be impractical for Thais in the way of living. For example, to purchase a new car after discarding the old one is difficult because of high price of vehicle and low income in average of Thai people (Jetin, 2015). Nevertheless, Government policy, financial status and infrastructure are critical factors that help supporting a development of an ELV management in each countries (Fuse & Kashima, 2008). Those factors have been realized as critical factors to determine readiness of country and willingness of people to collaborate in ELV management. (Dhokhikah & Trihadiningrum, 2016; Fuse & Kashima, 2008). Information related to ELV management in global and specifically in Thailand was searched and presented in the following sections.

2.1 Statistics of vehicle in Thailand

According to DLT, vehicles can be classified into 3 main categories: Vehicle under Motor Vehicle Act, Vehicle in accordance with the Land Transport Act, and Vehicle under Non-Motorized Vehicle Act. Bus, Truck, and small rural bus are included in Vehicle under Land Transport Act. According to vehicle under Motor Vehicle Act, C1 to C17 are used to classify vehicles. For example, Sedan which carries no more than 7 passengers is classified in C1. C1 is known as passenger car for carrying not more than 7 people. The width of C1 vehicle is limited to 2.50 meter, and length is no more than 12 meters. Another example is C2 type also known as Microbus and Passenger Van which can carry more than 7 passengers (Department of

Land Transport, 2018b). All types of vehicle under Motor Vehicle Act are presented in Table 2.1.

Table 2.1 Type of Vehicle under Motor Vehicle Act

Type	Description
C1	Sedan (Not more than 7 Pass.)
C2	Microbus & Passenger Van
C3	Van & Pick Up
C4	Motortricycle
C5	Interprovincial Taxi
C6	Urban Taxi
C7	Fixed Route Taxi
C8	Motortricycle Taxi (Tuk Tuk)
C9	Hotel Taxi
C10	Tour Taxi
C11	Car For Hire
C12	Motorcycle
C13	Tractor
C14	Road Roller
C15	Farm Vehicle
C16	Automobile Trailer
C17	Public Motorcycle

Source: Department of Land Transport (2018b)

Over decades, in Thailand, the number of vehicles that were registered to DLT has been rising. As of the first car possession scheme enacted by Thai government started on 1 October 2011 and ended on 31 December 2012, people across the country were encouraged to purchase the first cars. Noticeably, between year 2011 through 2013 (During the policy have been implemented and a year after (2011 through 2013) was the period that new cars have been registered significantly because of the support from that scheme (Thailand Development Research Institute, 2014).

The number of new registered C1 vehicle (C1) from year 2000 to 2017, the number of populations, alongside with the number of C1 vehicles per 10,000 inhabitants. are shown in Table 2.2. Figure 1 shows its trend alongside with the number of C1 vehicles per 10,000 inhabitants. The number of C1 vehicle per capita continued to rise since 2000 until it reached a peak in year 2013 since the first car scheme at that period. It plunged to 93 vehicles per capita in 2014; however, it shows an increasing trend after the year 2015. Those evidences, along with the increasing number of new registered vehicles per capita, reflect an increasing number of vehicles each year at use phase. In other way around, it implies from the figure per capita that, over the past year, passenger car is more important in Thai people's livelihood.

Table 2.2 No. of new registered Vehicles (C1) per Capita

Year	No. of new registered Vehicles (C1)	No of population	No of Vehicles per 10,000 people
2017	638,030	66,188,503	96.39589522
2016	552,947	65,931,550	83.86682855
2015	526,764	65,729,098	80.14167485
2014	603,843	65,124,716	92.72101855
2013	923,899	64,785,909	142.6080168
2012	894,183	64,456,695	138.7261634
2011	541,681	64,076,033	84.53722471
2010	465,738	63,878,267	72.91024348
2009	309,150	63,525,062	48.66583208
2008	329,290	63,389,730	51.94690055
2007	305,696	63,038,247	48.49373429
2006	305,441	62,828,706	48.61487996
2005	314,508	62,418,054	50.38734466
2004	284,813	61,973,621	45.95713392
2003	231,030	63,079,765	36.62505718
2002	180,728	62,799,872	28.77840261
2001	135,625	62,308,887	21.76655796
2000	102,875	61,878,746	16.62525611

From the above table, graph can be drawn to depict trends for both number of new registered vehicles (C1) and number of new registered vehicles (C1) per capita.

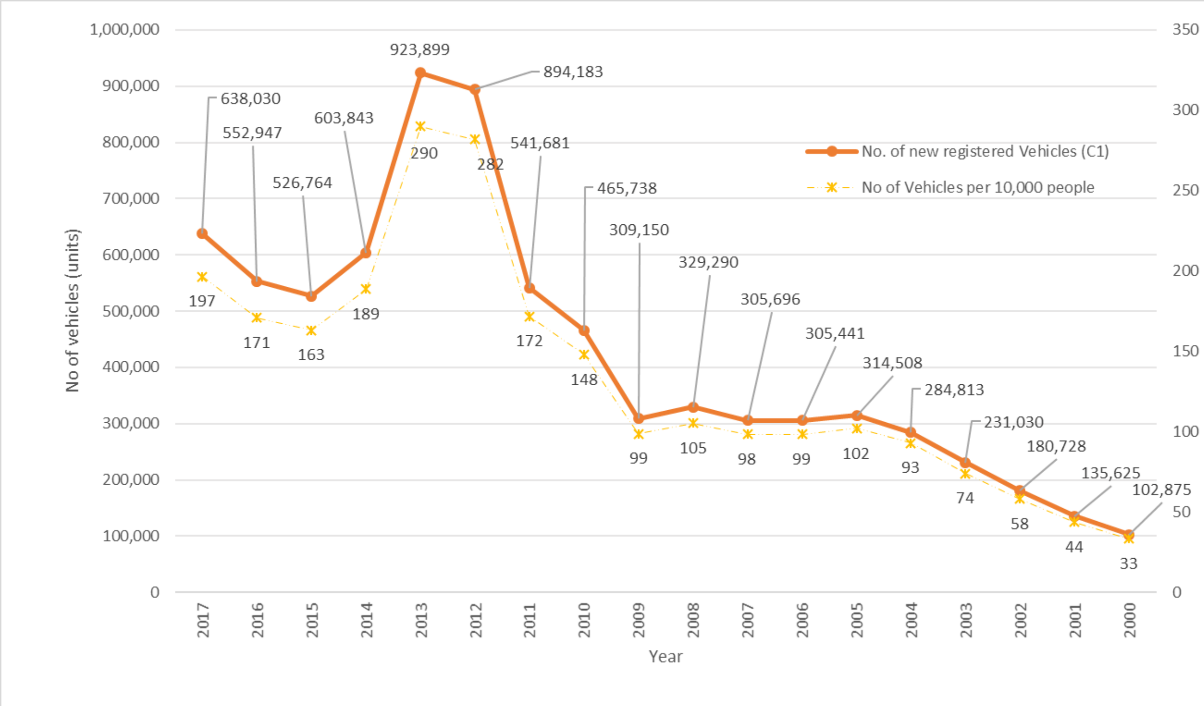

Figure 2.1 New Register C1 Vehicle by Year Chart

From Table 2.3, Cumulative number of vehicles per year is the cumulative number of vehicles registered with DLT, but not include the one with the license suspended (expired for more than 3 years) and licenses deregistered. The cumulative number of vehicles has been increasing year by year. The data in 2015 showed the cumulative number of 36 million which was 38 percent increasing from 2005.

Table 2.3 Cumulative number of Vehicles (all types) Registered in Thailand as of 31 December from 2002 to 2017

Type of Vehicle	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002
Grand Total	***38,308,763***	***37,338,139***	***36,731,017***	***35,835,180***	***34,624,406***	***32,476,977***	***30,194,937***	***28,484,829***	***27,184,577***	***26,417,353***	***25,618,447***	***24,807,297***	***22,571,062***	***20,624,719***	***26,378,862***	***24,517,250***
Total Vehicle under Motor Vehicle Act	*37,059,245*	*36,124,623*	*35,546,514*	*34,681,811*	*33,520,175*	*31,439,643*	*29,204,511*	*27,530,042*	*26,258,235*	*25,511,574*	*24,737,952*	*23,958,454*	*21,729,039*	*19,814,752*	*25,548,694*	*23,674,208*
Sedan (Not more than 7 Pass.)	8,740,890	8,197,012	7,742,434	7,284,259	6,736,562	5,856,454	5,001,442	4,496,828	4,078,547	3,809,082	3,560,222	3,312,941	2,902,980	2,629,377	2,880,893	2,651,399
Microbus & Passenger Van	425,302	422,221	428,403	433,128	430,188	417,529	403,321	392,354	383,684	379,210	381,630	395,318	368,766	363,931	517,870	608,071
Van & Pick Up	6,437,291	6,277,527	6,135,571	5,954,226	5,734,302	5,437,988	5,137,564	4,894,655	4,696,897	4,552,284	4,371,484	4,173,577	3,664,198	3,384,207	3,630,977	3,543,511
Motortricycle	1,592	1,638	1,648	1,611	1,598	1,477	1,435	1,414	1,381	1,326	1,299	1,320	1,193	1,108	2,622	2,984
Interprovincial Taxi	-	2	3	3	3	3	4	4	11	13	654	20	13	15	441	402
Urban Taxi	81,944	95,231	103,881	112,682	114,616	109,281	103,391	97,477	90,999	84,785	79,570	82,930	79,077	69,238	73,792	55,216
Fixed Route Taxi	2,694	2,932	2,998	3,087	3,180	3,293	3,368	3,679	4,834	5,045	4,847	5,823	5,213	5,673	8,586	6,631
Motortricycle Taxi (Tuk Tuk)	20,221	20,389	20,287	20,436	20,602	20,716	21,018	21,310	21,615	21,939	23,696	23,325	24,524	24,693	48,732	46,700
Hotel Taxi	4,374	4,180	3,894	3,411	2,913	1,975	1,792	1,848	1,841	1,873	2,686	1,814	1,532	1,431	2,294	2,174
Tour Taxi	4,878	4,612	4,018	2,924	1,706	1,099	859	787	795	778	611	282	275	279	574	568
Car For Hire	70	57	59	64	77	88	76	74	85	100	110	55	74	96	343	398
Motorcycle	20,501,439	20,276,806	20,308,201	20,141,213	19,853,157	19,023,751	18,018,066	17,156,712	16,549,307	16,264,404	15,961,927	15,650,267	14,548,503	13,206,580	18,210,454	16,581,174

Source: Department of Land Transport (2018b)

Table 2.4 represents the number of Vehicle Registered in Thailand as of 30 June 2018 (Department of Land Transport, 2018b). In Bangkok, total number of vehicles is a lot more significant than any other provinces, accounting for 25 percent of the total number of vehicles in Thailand. Total number of vehicles under Motor Vehicle Act is 37,702,262 and that includes 9,074,573 or 24 percent of total as C1 type. Around 44 percent of total as C1 type in Bangkok. It shows that C1 vehicle is the most popular in Bangkok and whole country regardless of motorcycle. Bangkok, as the capital city, holds a majority in countries.

Table 2.4 Cumulative number of Vehicles Registered in Thailand as of 30 June 2018:
A comparison between Bangkok and other provinces

Type of Vehicle	Whole Kingdom	Bangkok	Regional
Grand Total	***38,969,601***	***10,030,055***	***28,939,546***
Total Vehicle under Motor Vehicle Act	*37,702,262*	*9,844,313*	*27,857,949*
Not more than 7 Pass	9,074,573	4,386,852	4,687,721
Microbus & Passenger Van	425,005	214,600	210,405
Van & Pick Up	6,527,058	1,347,127	5,179,931
Motortricycle	1,572	854	718
Interprovincial Taxi	-	-	-
Urban Taxi	84,005	79,871	4,134
Fixed Route Taxi	2,657	2,140	517
Motortricycle Taxi (Tuk Tuk)	20,117	9,322	10,795
Hotel Taxi	4401	647	3754
Tour Taxi	5,178	1,780	3398
Car For Hire	93	69	24
Motorcycle	20,709,434	3602636	17,106,798
Tractor	532,879	95,907	436,972
Road Roller	14421	3918	10503
Farm Vehicle	107,913	7	107,906
Automobile Trailer	4,785	2,805	1,980
Public Motorcycle	188,171	95,778	92,393
Total Vehicle under Land Transport Act	*1,267,339*	*185,742*	*1,081,597*

Source: Department of Land Transport (2018b)

In this paper, ELV is defined as a vehicle which was discarded by last owner and will not be used anymore. Regarding the number of ELVs, most developing countries with efficient ELV management system are logged and able to present. However, in most countries, the figures are hardly confirmed and easily discovered. For example, in Taiwan, the problem of discarded car without officially deregistration by car owner was one problem to estimate the number of ELVs in the country (Lee, 1997). In this paper, primarily, the number of permanently deregistered was analyzed to determine the number of ELVs.

This paper retrieves the number of vehicles in use from DLT. The number of transactions that owners transact through DLT is recorded each year as shown in Table 2.5.

Table 2.5 Number of vehicles that were extended the licenses, Number of new registered vehicle per year, Number of vehicles that were exempted from registration, Number of vehicles that were deregistered permanently

Year	No. of vehicles that were extended the licenses	No. of new registered vehicle per year	No. of vehicles that were exempted from registration	No. of vehicles that were deregistered permanently
2016	28,815,234	2,875,583	10,050	197,805
2015	28,050,515	2,748,395	9,982	164,894
2014	27,094,719	2,887,583	8,824	145,778
2013	26,720,047	3,894,341	7,301	140,129
2012	24,979,650	3,335,230	5,662	134,581
2011	22,158,178	3,250,736	7,233	156,290
2010	19,944,196	2,776,834	8,355	160,721
2009	18,686,769	2,227,402	9,184	146,761
2008	17,542,517	2,543,227	10,067	131,806
2007	16,520,658	2,468,058	8,388	121,646
2006	14,778,560	2,797,080	8,304	99,932
2005	14,602,671	2,696,827	7,790	65,818
2004	12,829,134	2,544,133	15,669	150,082
2003	11,369,874	2,096,697	9,389	53,482
2002	10,646,564	1,449,821	10,178	44,290

Source: Department of Land Transport (2018b)

Using DLT's fiscal year, 1 October to the end of September in the next year, the table above includes vehicles under Land Transport Act and one under Motor Vehicle Act. The number of new registered vehicles per year includes vehicles that has not been registered before or the ones that renews the license after being suspended. Vehicles that are exempted from registration is the one which is applied for exemption from payment of registration fee and licensing fees for 2 years. The number of vehicles that are deregistered permanently includes vehicles that permanently deregistered with DLT (Department of Land Transport, 2018b). Lastly, the number of vehicles above that were extended the license are the vehicles that extend the license each year. Focusing on C1 vehicle, the number of C1 vehicle in use is summarized in Table 2.6.

Table 2.6 Number of C1 vehicles in use (Cut-off every fiscal year of DLT)

Year	No. of vehicles that were extended the licenses	No. of new registered vehicle per year	No. of vehicles that were exempted from registration	No. of vehicles that were deregistered permanently
2016	7,440,037	566,119	1,828	7,480
2015	7,031,370	511,417	2,157	7,278
2014	6,608,891	649,583	7,058	1,747
2013	6,167,891	1,078,707	1,560	6,384
2012	5,167,461	676,564	1,462	7,507
2011	4,321,123	551,396	1,364	7,156
2010	3,772,372	432,983	1,507	6,568
2009	3,485,829	302,465	1,425	6,741
2008	3,167,546	328,138	1,622	8,088
2007	2,904,413	304,234	1,534	8,575
2006	2,491,798	308,928	1,569	8,154
2005	2,496,390	311,366	1,490	5,806
2004	2,072,517	273,791	1,698	5,969
2003	1,802,441	224,666	1,305	4,420
2002	1,675,334	172,923	1,243	2,999

Source: Department of Land Transport (2018b)

Moreover, another important information provided by Statistic Department of DLT is the number of licenses that was suspended by DLT. The suspended law enacted since 2003 to suspend car that has no extended or renewed the license for 3 years consecutively. For conclusion for C1 vehicle statistics at every end year, the cumulative number of newly registered C1 vehicle, and the suspended one are shown in Table 2.7. From the table, number of suspended C1 vehicles are increasing each year from 2010 through 2016 as the number of cars is increasing year by year. Noticeably, between year 2007 to 2009 does not follow the trend as it should have been decreasing. The reason behind this is 2007 is that year 2003 is the first year that suspended policy starts. For year 2003, all the car without renewal in the past is counted in 2007, 2008 and 2009 respectively.

Table 2.7 Statistics of C1 vehicles: number of vehicles registered, number of newly registered, and number of suspended licenses (Cut-off at end year as of 2017)

Year	No. of C1 vehicles registered	No. of Newly Registered C1 vehicle	No. of Suspended C1 vehicle licenses
2017	8,740,890	638,030	-
2016	8,197,012	552,947	76,763
2015	7,742,434	526,764	56,334
2014	7,284,259	603,843	42,886
2013	6,736,562	923,899	32,779
2012	5,856,454	894,183	30,212
2011	5,001,442	541,681	30,494
2010	4,496,828	465,738	28,024
2009	4,078,547	309,150	32,877
2008	3,809,082	329,290	45,792
2007	3,560,222	305,696	40,279
2006	3,312,941	305,441	-
2005	2,902,980	314,508	-
2004	2,629,377	284,813	-
2003	2,880,893	231,030	-
2002	2,651,399	180,728	-
2001	21,760,467	135,625	-
2000	20,030,220	102,875	-
1999	19,333,726	75,563	-
1998	18,088,478	54,861	-
1997	16,906,589	171,276	-
1996	15,388,669	181,980	-
1995	13,448,359	169,879	-
1994	11,974,342	173,412	-
1993	10,529,400	157,083	-
1992	9,057,741	108,099	-
1991	7,964,969	74,259	-

Source: Department of Land Transport (2018b)

There is no report that shows average age of car in Thailand. To find out the age of vehicles in Thailand from manufacturer until dismantling, there is a statistic from DLT that shows the number of passenger cars using on the road or effective in term of licenses. Table 2.8 illustrates information about number of C1 type vehicle at each age by year (Department of Land Transport, 2018b).

Table 2.8 Statistics of vehicles: Cumulative registered number of C1 vehicles at each age grouped by year 2007 to 2017

Year Age (Year)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
<1	298,057	319,156	299,737	452,137	530,537	881,852	913,568	593,990	516,566	536,903	266,715
1	297,451	297,496	319,021	299,435	451,963	530,160	881,088	912,736	593,248	516,015	585,981
2	313,147	297,118	297,195	318,473	299,309	451,668	529,812	880,379	911,850	592,655	529,581
3	288,008	313,068	296,919	296,523	318,292	299,124	451,376	529,357	879,558	910,969	545,782
4	236,262	285,448	311,155	294,439	294,270	315,783	297,688	448,709	525,904	873,818	734,252
5	184,320	235,619	285,244	310,313	294,065	293,503	315,019	296,830	447,410	523,888	905,240
6	140,552	183,091	235,234	284,702	310,178	293,709	292,870	313,987	295,805	445,574	724,862
7	108,742	138,829	182,492	234,573	284,317	309,393	292,901	291,482	312,195	294,158	486,196
8	77,651	107,096	138,144	181,864	234,342	283,764	308,568	291,829	289,910	310,060	373,182
9	55,805	76,798	106,762	137,695	181,722	234,030	283,090	307,229	291,483	287,903	304,163
10	170,128	55,245	76,529	106,523	137,375	181,490	233,578	282,021	305,641	289,281	301,090
11-15	804,001	851,007	743,226	649,540	590,050	546,050	560,216	739,857	945,009	1,140,256	1,346,106
16-20	275,323	351,509	467,507	576,355	671,232	773,914	827,574	719,447	626,331	565,576	534,796
>20	310,775	297,602	319,382	354,256	403,790	462,014	549,214	676,406	801,524	909,956	1,102,944

Source: Department of Land Transport (2018b)

2.2 Car Components and its material

Car manufacturers are using materials: metal and composites as main components to produce vehicles. To decide what material is suitable for vehicles depends on its properties that meet a requirement of vehicles. Safety and impact on environment which are the major concerns and regulated by law in most countries are the main factor of material selection (Ghassemieh, 2011). Each type of materials is described in the following sections.

2.2.1 Ferrous Metals

1) Definition

Ferrous metals compose of iron which is not found in non-ferrous one. There have been collaborations in research and development regarding ferrous metals. In ferrous metals, iron and steel are the most common casting materials. The good part of cast iron is elasticity, but they are brittle: they tend to be easily broken when bending. For Products with complex shapes or sharp edge, iron is not recommended to be used regarding the process which requires bending. Nevertheless, alloying iron is another ferrous metal generated from the mixing of elements in different ratios.

That can result in removing some of the properties while gaining more advantages in other features.

One of the most well-known ferrous metals is steel which is the combination of carbon, iron, and other elements. High-strength steels, high-strength Low alloy steel, or stainless steel are example of steels innovated from the attempt to create an efficient material for specific requirements. In sum, steel has more strength than cast iron; however, it is traded off with flowability (Romig, 1938).

2) Relevant Industries

Mainly, ferrous metals are used to manufacture vehicles as majority materials. In history, car body or car shell was made almost purely of ferrous material. As it's well-known as the most durable material, vehicle or even gigantic building uses ferrous metal as structure. Car industry, at this period, still use steel as the main part for car shell but some part is replaced by other lightweight material (Gaucher & Guilhot, 1975).

3) Challenges

Focusing on steel, the challenge is that it requires more labor and expertise to cast and produce steel. With high strength, it trades off flowability and, when casting, steel has more extensively shrinkable than cast iron. Still, the high mechanical strength of the final product can make a steel the relatively best choice for many constructions. The innovation of non-ferrous metals or non-metal such as plastic or aluminum in the near future surely at least replace some of the usage of ferrous metal. Especially, the coming of Electric Vehicle requires lightweight material for driving efficiency. That is why ferrous metals needs continuous research to upgrade its properties, such as more flexible, or even easier in production (Nachtman, 1941).

2.2.2 Non-Ferrous Metals

1) Definition

The definition is opposite to ferrous one regarding presenting of iron. Copper, Zinc, Titanium, Lead are examples of non-ferrous metals. Comparing to common ferrous metals, it does not contain alloy or iron. The properties of non-ferrous metals offer less weight against steel. The most commonly known among non-ferrous metal is aluminum which is used in motor-vehicle industry as a light weight material such as battery, BIW, coverage, etc. The common non-ferrous metals are listed below (Darling, 1990):

- Precious metals like silver, platinum, and gold
- Copper and its alloys like bronze and brass
- Nickle, Palladium, Platinum
- Titanium
- Aluminum
- Tin, Lead
- Zinc

2) Relevant Industries

Different purposes of usage generate demands of material with specific property, for examples, the purpose of high resistance to corrosion, non-magnetism, light weight, electrical conductivity, durability, magnetism, recyclability, etc. are required in different industries. Only ferrous metal cannot sufficiently serve those needs for those mentioned properties. Business segment such as car manufacturing requires non-ferrous material for many parts inside and outside the car because of the various functions. Car shell nowadays made from aluminum in more portion comparing to steel because it is lighter in weight. Thus, using aluminum can help save energy and gain more on driving efficiency. Electronic industry requires parts for wiring and for electrical conductivity. Apart from steel, construction companies require material that resistance to corrosion to support its structure. Moreover, energy sector requires related mechanic and electronic parts, and other industries with different requirements (Neikov, Yefimov, & Naboychenko, 2009).

3) Challenges

There are always open questions for the quality of non-ferrous metal. As it is difficult to be created and sometimes the finish goods regarding non-ferrous metal is not widely used. Consequently, the evidences or proofs of usage are not available much for assuring there is no problem arising at use phase. Regardless of how it produces, the price of non-ferrous is relatively high because of trade defense policies in each country. Providing a support for innovation, this should alleviate the pricing issue resulted from the difficulty of production and knowledge about production. Educating all the end-customer as well as the producer itself, this should help to create an understanding of material specification, and customer requirement in various business. Moreover, after-use phase gives some challenges. Sorting or separating non-ferrous is not trivial and requires high technique. It can be done by manual separation by human, through using an expensive method, environmentally deleterious wet processes. The treatment process for non-ferrous material is also required specific technique regarding substance or material composition (Osterberg & Wolanski, 1989).

2.2.3 Non-Metal

1) Definition

Merrian-Webster (2017) provides definition of non-metal as “a chemical element (such as boron, carbon, or nitrogen) that lacks the characteristics of a metal”. Physically, non-metals have low boiling point comparing to steel, so it can easily volatile by heat. They normally have low elasticity, so they would change in its form simply with force. Moreover, one of the most useful properties of non-metal is insulator of electricity. Chemically, they tend to have high ionization energy and electronegativity values, and gain or share electrons when they react with other elements or compounds. Seventeen elements are generally classified as nonmetals; most are gases (hydrogen, helium, nitrogen, oxygen, fluorine, neon, chlorine, argon, krypton, xenon and radon); one is a liquid (bromine), and a few are solids (carbon, phosphorus, sulfur, selenium, and iodine) (Brown & Rogers, 1988).

2) Relevant Industries

Industry segment such as car manufacturer or construction uses non-metal material in several purposes. Internal components such as wheel or seat composes of plastic or wood, for example. Moreover, medical sector also uses non-metal material such as bone support structure. Comparing to construction that use metal as the major components to build structure, it cannot avoid using non-metal as its weight and specific properties (Dorfman, Kushner, Rotolico, DelRe, & Novinski, 1992).

3) Challenges

The composition of non-metal is complex and required more researches to create non-metal materials. On the other way around, it is difficult to subtract all the substances or depollute all of them straightforwardly. Moreover, new non-metal materials with specific properties are continuously created for various purposes because of the competitiveness in industries. Researchers around the world should take its end-of-life process of treatment into account, especially the ASR generated after the process, when starting to create non-metal product (Ferraz & March, 1979).

Regarding vehicles and their components, they consist of approximately 15,000 parts in one vehicle. The main materials: steel, iron, glass, textiles, plastic, and non-ferrous metal account for more than 80 percent of all materials in manufacturing vehicle (Mildenberger & Khare, 2000). Mass reduction through advances in the use of iron and steel is significant (ferrous materials), because they are the dominant material for example, in family vehicle 64% are composed of steel (Funazaki, Taneda, Tahara, & Inaba, 2003; Sharma, Sharma, Sharma, & Srivastava, 2016). The breakdown information of material of a passenger vehicle is presented in Table 2.9 (Funazaki et al., 2003; Zorpas & Inglezakis, 2012).

Table 2.9 Material components of passenger vehicle

Material	Percent from total weight
Ferrous metal	68.30%
Plastics	9.10%
Light non-Ferrous metal	6.30%
Tyres	3.50%
Glass	2.90%
Fluids	2.10%
Rubber	1.60%
Heavy non-Ferrous metal	1.50%
Other	1.50%
Battery	1.10%
Process polymers	1.10%
Electrical/electronics	0.70%
Carpet	0.40%

Source: Department of Land Transport (2018b)

As one of a widely used ferrous material, Steel is the mixture mainly between iron and carbon. This combination makes it harder and stronger than pure iron and other metal. Steel is cheaper than most of the metals. It can easily be folded to form different shapes without breaking. This property facilitates the making of the curved parts of car bodies. Apart from making the car bodies, other uses of steel include making the rods of concrete buildings, domestic appliances, nails, engines and construction of bridges (Prawoto, 2013).

There are a lot of collaboration around the world to increase the use of light-weight material to reduce energy consumption, which are fuel consumption, greenhouse gas emission, in use phase of vehicle (Ghassemieh, 2011). Despite high cost comparing to steel, attempting to use aluminum instead of steel are example. Aluminum as non-ferrous material was claimed to be a material that is efficient to be reused and recycled than steel. There was a research that showed the advantages of aluminum structure over the steel one. Aluminum structure offsets the steel structure in term of CO_2 emission and investment after a period (Ashby, 2009).

However, from American Iron and Steel Institute perspective, there are a lot of researches and supportive article that backing the usage of steel. The organization that supports steel usage addressed that as new regulations focusing on cleaner economy fail to recognize all the life cycle phase. They also claimed that LCA should analyze one material from the pre-manufacturing, manufacturing, use, and post-use to make sure that it is worth for using steel over other trendy materials (Steel Market Development Insitute, 2017). For instance, iron is not commonly used in making car bodies because it cannot be bent to form the curved parts of the car body. Aluminum, though durable and not easily corroded, it is expensive due to its scarcity (BBC, 2017). As the most abundant of all commercial metals, alloys of iron and steel continue to cover a broad range of structural applications.

The LCA process shows that steel, which currently makes up about 60 percent of the average North American vehicle, generates fewer emissions than other automotive body materials and therefore steel-intensive automobiles will continue to be the lowest emitting vehicles on the road (Steel Recycling Institute, 2017).

Apart from metal material, plastic is one of the materials used in several parts of vehicle. However, some companies have been initiating the way to reduce using plastic material. Studying of use of plastics derived from plants is one challenge for Toyota motor corporation. Using re-use part is one approach for car manufacturer to supply alternative way for customer who agrees to use a used part for a maintenance. Moreover, Toyota brand established technology to use recycled and eco-plastic up to 20% of all plastic component (Vehicle Recycling, 2014).

Moreover, Battery is also the important component that people replace it frequently. In EU, it reports that battery has a good collection rate and percentage of recycling more than one of other materials (Zorpas & Inglezakis, 2012). Battery for vehicle is rechargeable. It is mainly used for starting engine. A typical lead-acid battery, regularly used in vehicles, mainly contains of lead that is a mixture of water and acid (Linden & Reddy, 2002). End-of-life battery causes a huge concern in environment. Regulation or law enforcement were issued regarding how people manage after life of battery such as returning battery to producer for recycle (Kusibab, 2014)

2.2.4 Automotive Shredding Residue (ASR)

Focusing on ELV management process, the output left during the process of recycling: from depolluting chemical, to shredding are composed of material above called Automotive Shredding Residue (ASR).

ASR in definition is residue which is important to select a right technique in recycling and recovery system. The portion of ASR in vehicle is around 15-25 percent after passing the process: de-pollution, dismantling, shredding, and removing metals from the output of shredding. Some research defines ASR as the residue after shredding without metal removal. ASR consists of residue ferrous and non-ferrous metals, plastics, rubber, textile and fiber material, wood, and glass They mixed each material to each other, so it is difficult to eradicate so it is challenging for those developed countries to decrease ASR from recycling process. Over the years, ASR has become diversified as materials has been newly created by using various substances regarding the requirement of lightweight product or some specific requirements (Vermeulen, Caneghem, Block, Baeyens, & Vandecasteele, 2011).

An exhaustive collection of material is significant in order to reduce the amount of ASR and to avoid hazardous substance contamination in ASR. Figure 2 represents the percentage of ASR composition (Economic and Industrial Research Department Development Bank of Japan, 2003).

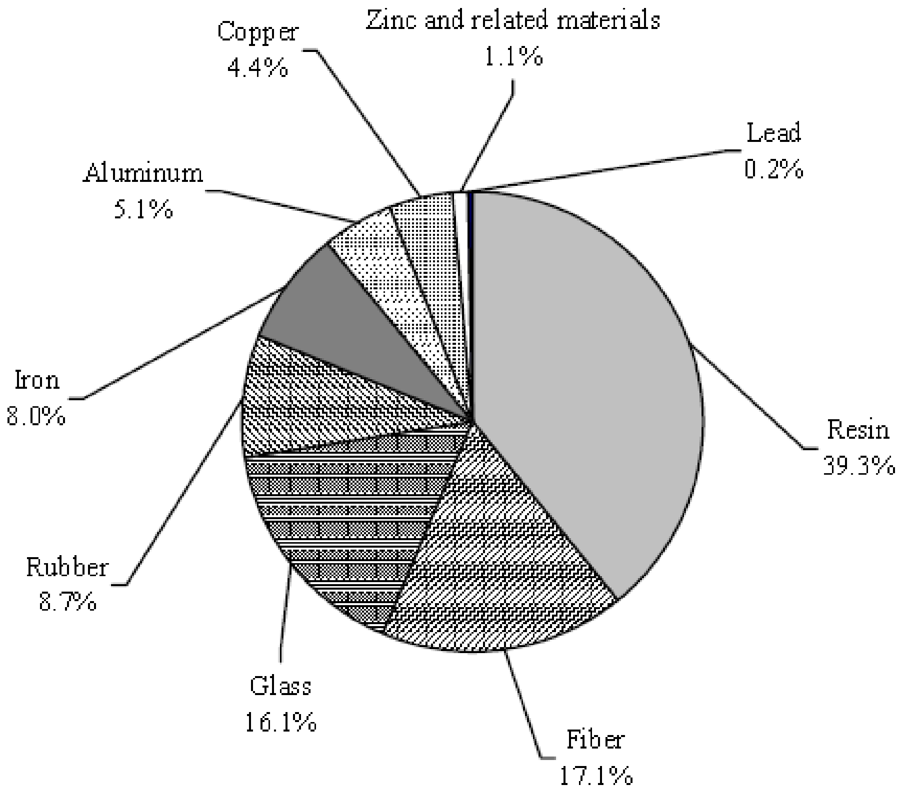

Figure 2.2 Composition of ASR (%)

2.3 ELV management status worldwide

From consumer’s perspective, starting from purchasing, people use car in their everyday life. Gas is an important factor to drive their vehicles. Parts maintaining is also crucial so that vehicles are in good condition and to pass an inspection. Registration fee as well as annual license fee are required for legal use. Sending vehicle to ELV management process might require paying a license fee (Yoshida & Hiratsuka, 2012). On the other hand, handing vehicle to ELV management in some countries such as Taiwan offers a reward to car’s owner (Lee, 1997). There are several expenditures car’s owners have responsibility for paying: Car Price, Annual tax registration renewal fee, Car Maintenance, Car Insurance, etc. Starting from purchasing a car, buyer invests some money to buy a car. At this step, car owner is required to pay for registration fees including Compulsory Motor Insurance, License Plate fee, Document fee, and other costs regarding the process of registration.

Moreover, every year car owner is to pay for annual tax registration renewal fee. Next, Car in the first 3 years normally does not appear to be malfunctional or even many of car companies offer warranty for years after selling. During car usage, apart from Registration fee, owner requires to pay inspection fee each year to test for car health. Maintenance is what car owner must do to maintain car in good condition (Department of Land Transport, 2018a; Zahedi, Cremades, & Lázaro, 2012). This includes gas, battery or engine oil which are required to change periodically. After the use phase, car in some countries are sold to second-hand car shop to be reused or sending to an ELV treatment process as car wrecks (Pholphirul, 2007). Finally, car wrecks are sent to collector, dismantler, and until recycler for scrapping and recycling (Sakai et al., 2014).

To compare among the countries worldwide, ELV management in EU, Japan, Korea, China, and US are explained to gain a clear picture of alternative method and background that motivate development of ELV in each country. The above countries are perceived as developed countries with efficient ELV management system and technologies. They are attempting to develop their process such as mitigating ASR to lessen the impact on environment.

ELV management in each country can be described based on the precedent researches which compiled all information categorized in each country.

There are 2 types of ELV categorized by considering how vehicle becomes an ELV. The first one is Premature ELV and the second one is 'Natural ELV'. The first one is when vehicle has not reached its life time, but it is ended by accident or disaster such as flooding or firing. The second one is vehicles which reach their life time naturally (Lashlem, Wahab, Abdullah, & Haron, 2013).

While most developing countries are at the beginning stage of ELV management project, in developed countries, such as those in Europe, USA, Korea or Japan, they are obviously known as the countries with efficient ELV management. Over the last 15 years, average age of cars decreases to about 10 - 12 years in the EU. As a result, ELV recycling is a matter of country's attitude towards supporting the environment preservation and it is emerged as a novel area of scientific research. (Simic, 2013). In Korea, government has been attempting to reduce disposal amount to less than 5 percent of car as done in Europe and Japan (Kim et al., 2004). To understand the condition of ELV management, ELV management process should be primarily addressed.

There are various definitions of ELVs regarding how we interpret vehicles that reach its life cycle. ELV, in some researches, means vehicles that has been discarded and went to the right process of ELVs management. However, ELVs in some researches refer to discarded vehicles by last owners regardless ELVs management process they may get. In this paper defines ELVs as vehicles which has been discarded by last owners which may optionally go to a management process below (V. Kumar et al., 2005; Zussman, Kriwet, & Seliger, 1994).

1) Disassembling process and remanufacturing parts
2) Remanufacturing vehicles
3) Recycling process
4) Landfill legally or illegally by last owner

For Natural ELV, it does not mean all the parts are broken or malfunction. Although it cannot be operated, it may be disassembled to get healthy parts. The car maker is perceived to be a place of remanufacturing part. Remanufacturing process is about to transform used or end-of-life vehicle part into an as-new part. For premature ELV, it may be passed to the remanufacturing process to make it as good as new. Nevertheless, a remanufacturing process requires processes which are disassembling, recovering, re-assembling, or even cleaning.

Next, recycling process is about to recycle ELV part to gain recycled material. The other option is to landfill vehicle. However, vehicle's owner sometimes might sell to others to use (Ghassemieh, 2011). This means vehicle life is not ended and it is not ELV by definition of this study.

Fundamentally, to achieve waste reduction, 3Rs is the keys in mitigating environmental impact from waste reduction. 3Rs – Reduce, Reuse, and Recycle- are ordered according to its importance and priority. Reduce is the direct way in that as long as we can reduce using car, we do not have to face the vast amount of disposal. However, to reduce using or purchasing car is difficult in practice unless people can stop travelling by car or buying new car to serve their needs. For reuse, even it does not interest manufacturer much, but it is valuable to design a vehicle to be durable against corrosion and facilitate dismantling and maintaining processes. In other words, Reuse is about extending lifetime of vehicle and its components. Some might criticize that Reduce and Reuse are efficient than Recycle; however, all processes, 3Rs, are to support each other. Eventually, reused material requires recycle to recover the value of material (Gesing, 2004). Similarly, research done by Spielmann and Althaus (2007) criticized on exhaust emission reductions by comparing 2 options: increasing in specific car manufacturing expenditure, and prolong use of the car. From the research, it is still an open-question and not officially conclude about which approach gives more advantages.

Altschuller (1997) defined that Recycling is a process by which used materials are remade to form a new product.". Figure 3 shows the hierarchies of recycling which start from reuse process. Reuse process is about to consider if the product or part can be reuse as second-hand. If not but it could fix, remanufacture or reconditioning process are placed in this process. Next, recycling as a second level in this hierarchy is to process parts to be raw material which can be categorized into grades: high and low material. The recovery phase is about energy recovering or road surfacing by using waste. Finally, waste is disposed to landfill site. Regarding steel making, by The Basic Oxygen Furnace process (BOF), steel is produced using raw material inputs. On the contrary, The Electric Arc Furnace process (EAF) is a more advanced method of steel production that mainly use scrap recycled steel. The benefit results from scrap usage by EAF process is a reduction of energy which saves around 64 percent comparing to BOF process (Yellishetty, Mudd, Ranjith, & Tharumarajah, 2011).

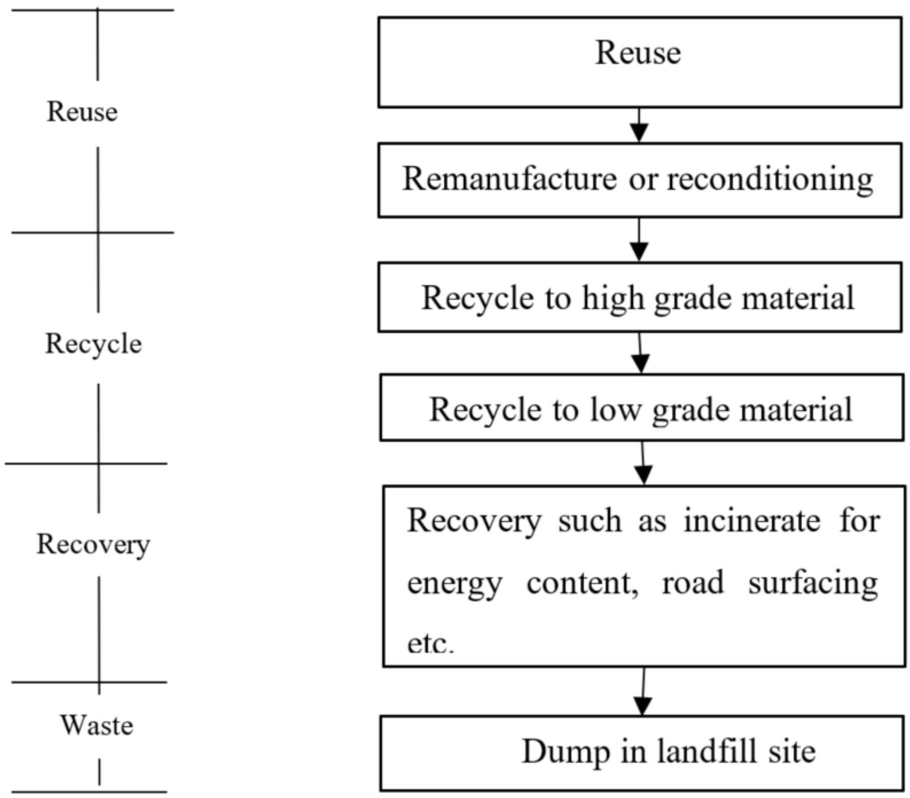

Figure 2.3 Hierarchy of recycling
Source: Blount (2006)

Apart from 3R, the concept 6R was proposed as a concept that concerns more in detail in post-use phase. It helps improve efficiency in sustainability gaining more value (Joshi, Venkatachalam, & Jawahir, 2006). Figure 2.4 shows Product value gained from 6R.

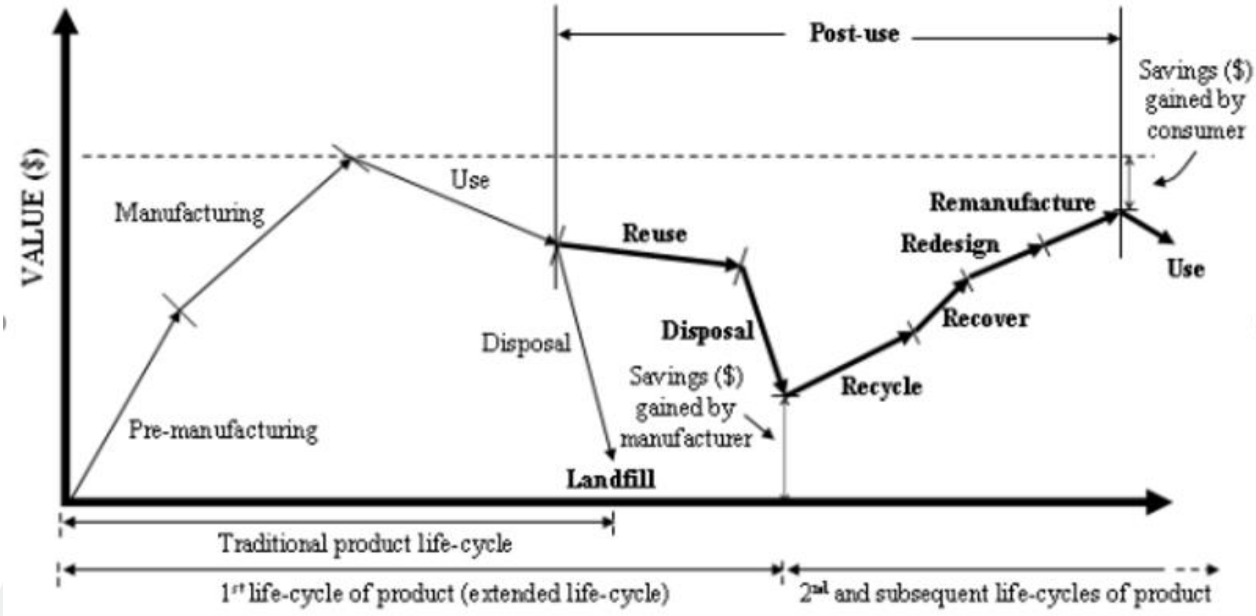

Figure 2.4 Product value gained from 6R
Source: Joshi et al. (2006)

For the concept of 6R, reduce method is about reducing use of resource in pre-manufacturing and reducing energy in manufacturing and waste during the use phase. Reuse method is important to reuse the product instead of sending to recycling process that might produce or consume more energy. Recover method is to make sure, at the end of usage stage of product, it must be collected, disassembled, and sorting cleaned. Redesign to make it easily for recycling or durable for reusing in the future helps a lot in sustainability. Remanufacture is required at some points to make the product become brand new so that it could save more energy than producing it from zero. The recycling system are still crucial to transform waste to raw material again. All to processes is to help protect environment from waste and consuming of resources including material and energy.

To sum up, a product value gained from 6R can be explained by 6R methodology shown in Table 2.10.

Table 2.10 6R methodology in sustainability

6R Methodology	Explanation
Reduce	Reduced use of resources in pre-manufacturing Reduced use of energy and material in manufacturing Reduce the waste during the use stage
Reuse	Reuse of the product or its component in order to use as the raw material for producing the new product
Recover	Collecting, disassembling, sorting cleaning at the end of usage stage of product
Redesign	Simplifying future post-use processes
Remanufacture	Re-processing of already used product
Recycle	Converting the waste material or product to new material and product

Source: Troschinetz and Mihelcic (2009)

Apart from recycling process, another important part of ELV management is collection and treatment. It requires last owners to deliver ELV to the authorized or licensed collectors and to reduce hazardous resulted from ELV treatment (Lucas, 2001).

2.3.1 ELV management in EU

1) Law and Regulation

In EU, law and regulation that push government and automobile industry in EU to comply regarding ELV management system is the directive of European Parliament And of the Council of 18 September 2000 on end-of-life vehicles enforced in 2000. Motivation of the directive is to measure of increasing ASR, to measure environment for the dismantling site, and measure abandoned automobiles.

The Directive states that vehicle manufacturers and material and equipment manufacturers must meet the following objectives:

1) attempt to reduce the use of hazardous substances from the design stage;
2) design and produce vehicles which facilitate the dismantling, re-use, recovery and recycling of ELVs;
3) increase the use of recycled materials in vehicle manufacture;

4) ensure that components of vehicles placed on the market after 1 July 2003 do not contain mercury, hexavalent chromium, cadmium or lead

In EU, most of the cost on recycling are responsible or subsidized by car manufacturers. However, to assure the target of recycling would carry out. The Commission of European Communities has proposed a new target for future vehicle to be liable on the vehicle's ability to be 95% reusable or recoverable. This procedure will apply to vehicles put on the market 3 years after the new Directive enters into force. The target is that reuse and recovery shall be increased to at least 95% by an average weight per vehicle and year, while reuse and recycling shall be increased to at least 85% by an average weight per vehicle per year. The characteristic of management is based on the subsidiarity principle and the principle of EPR to prohibit inclusion of heavy metals: mercury, cadmium, hexavalent chromium, and lead (Gerrard & Kandlikar, 2007). Figure 2.5 represents the history of law and regulation in EU.

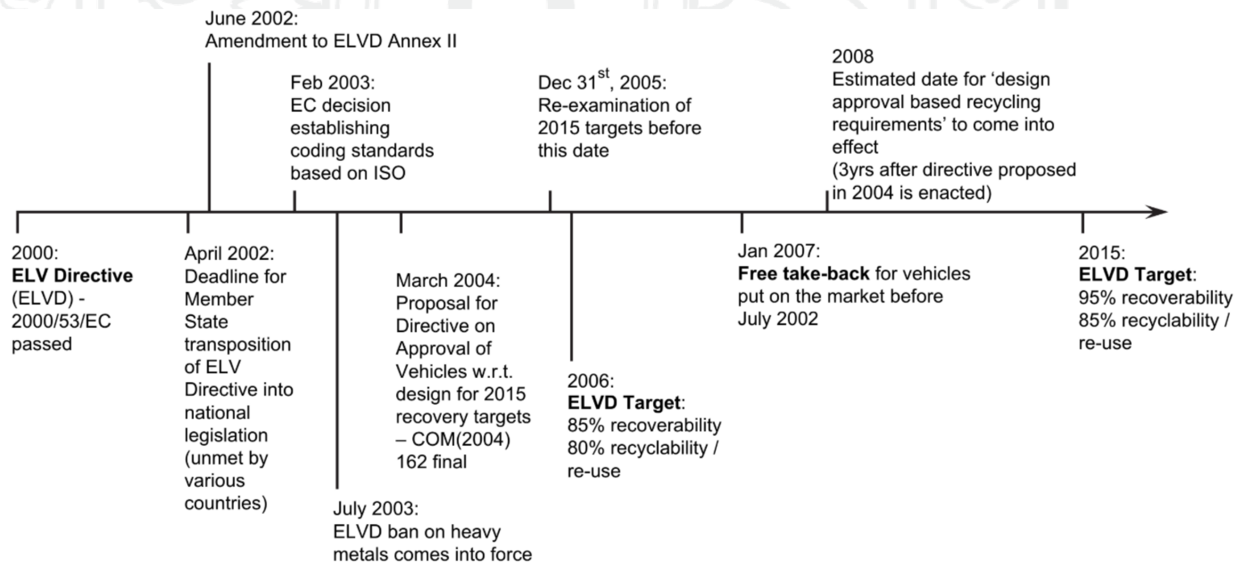

Figure 2.5 ELV legislation timeline of EU
Source Gerrard and Kandlikar (2007)

2) Recycling Process

To understand how ELV processes work in detail regarding each stakeholder, Figure 2.6 explains a practical ELV management by using EU process as a good practice. ELVs, after deregistered, are recycled via appropriate recycling process. The process begins with incoming vehicles collected by certified collector and passed to certified dismantler. Dismantler job description are removing reusable components along with avoiding any environmental problem per ELV directive. The wheels and tires, battery and catalytic converter are removed. Fluids, such as engine coolant, oil, air conditioning refrigerant, and gasoline, are also drained and removed. Certain high value parts such as electronic modules, alternators, starter motors are removed to sell either in "as-is" used condition or to a refurbish one. Next, the remainders are hulked to make it easier for shredding. Ferrous and non-ferrous material are still mixed and waiting to be separated. The outputs from hulking are sent to shredding station afterwards. Shredding process are about to make the parts smaller. Sorting technique are required at this step. It extracts non-ferrous out of ferrous material so that only ferrous materials are sent to steel industry. However, one major problem is waste from shredder which is called “Automobile Shredding Residue”. EU is one of the countries that has been seriously attempting to reduce (ASR) as much as possible (Kanari, Pineau, & Shallari, 2003).

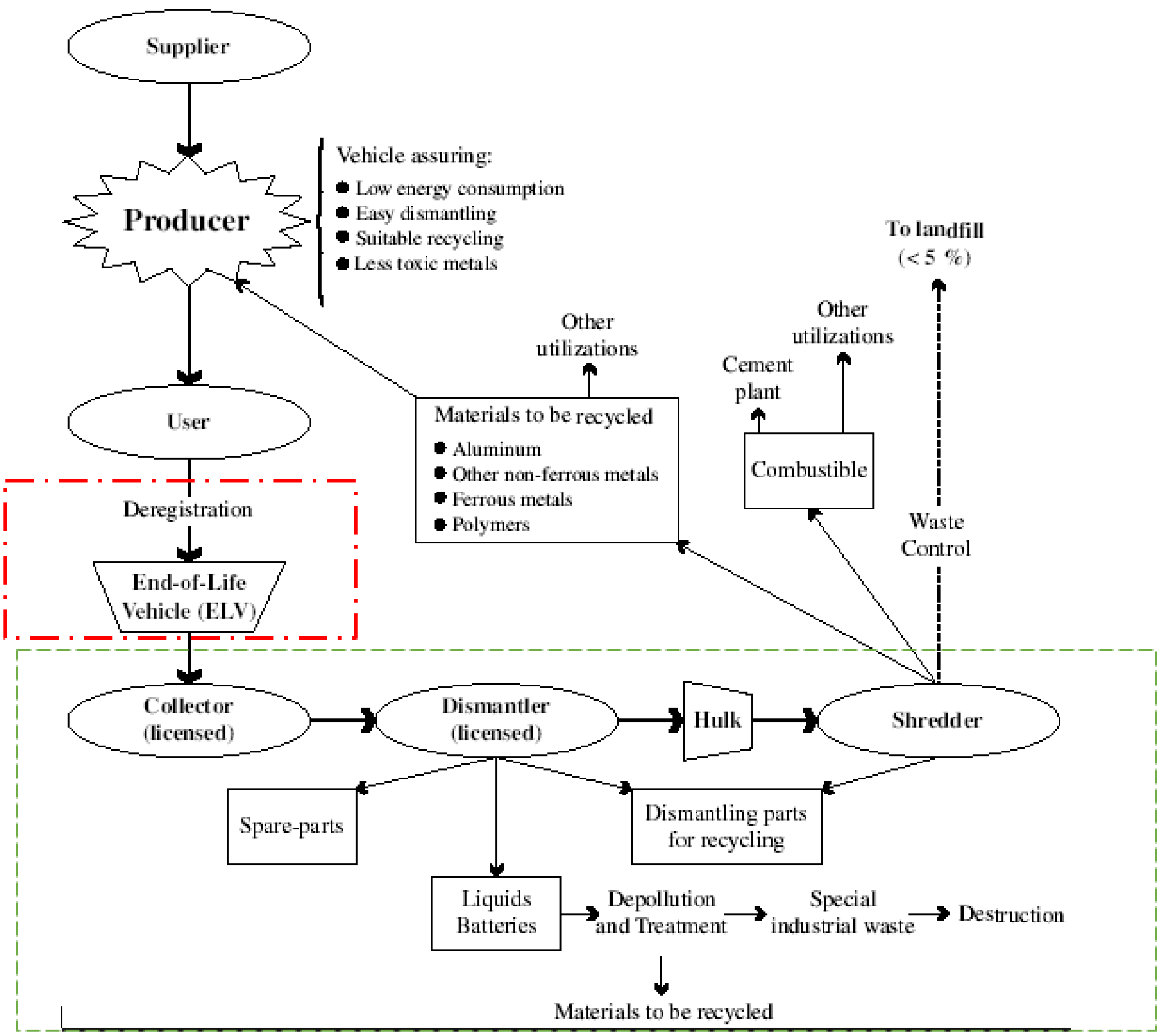

Figure 2.6 ELV process in EU

Source: Kanari et al. (2003)

Defining ELV as the deregistered vehicle brought to the process of recycling system. Automobile ownership worldwide and the estimated generation of ELV in year 2010 are shown in Table 2.11. Around 50% of vehicles worldwide are from EU and USA. In newly industrialized countries such as China and India, the number of vehicles is increasing rapidly year by year. Noticeably, the number of ELV per year is less than the number of deregistered vehicles per year. The differences result from vehicles might be exported, or reused in private site, or landfilled illegally (Sakai et al., 2014). It is very essential for countries around the world to closely monitor along with improving ELV management in order to prevent a problem of waste disposal from discarded vehicles.

Table 2.11 Estimated number of automobile ownership and ELVs, only a country with automobile ownership of more than 10,000,000 units of and a positive in Year 2010

Country/State	Automobile ownership (units)[a]	Deregistered automobiles (units/year)	Number of ELVs (units/year)
European Union	271,319,000	14,077,000	7,823,211
USA	239,811,984	20,419,898	12,000,000
Canada	21,053,994	1,321,658	1,200,000
Brazil	32,100,000	1,058,064	1,000,000
Japan	75,361,876	4,080,000	2,960,000
China	78,020,000	6,000,000	3,506,000
Korea	17,941,356	849,280	684,000
Australia	15,352,487	600,311	500,000

Source: Sakai et al. (2014)

2.3.2 ELV management in Japan

1) Law and Regulation

Over the years, Japan has been faced insufficient of landfill site for ELVs and illegal disposal of ASR. Only managed landfills with certified water treatment infrastructure could be used. Since the strict law of landfill site causes the number of landfill site decreases. The price of landfill was higher. From these mentioned situation, illegal dumping has been increasing and treatment of ELV were ignored by some operators. Moreover, there have been a many ELVs exported from Japan to other countries.

To solve the problem regarding small number of landfill sites and illegal dumping, ELV recycling law in 2005 has been enforced after it was passed in 2002. Automobile manufacturers and importers take responsibility for the recycling in order to properly treat ELVs and efficiently use of resource. Unlike in the past, people paying for used car to car owner, consumers or car owners are solely responsible for the cost in ELV management at the time they purchased. There is no such law for the age of car to be able to use in Japan. As long as car can pass the inspection, they can legally run on the road. However, the maintenance cost to pass the inspection increases as car is getting older. From economic perspective, car owner at the end select to hand them to registered collectors as ELVs (Zhao & Chen, 2011).

2) Recycling Process

ELV handed by car owner to registered collectors are first passed through Fluorocarbon collection process as Fluorocarbon is substance which harms ozone and causes global warming. Next, Depollution is required to leaking off the toxic or hazardous fluid, Batteries, Air Bag, as well as fluorescent lamp. In the case of Japan, the collection of refrigerant gases and air bags are legally mandated.

Then remainders are sent to the main process, which is dismantling. Engine, tyres, motors, and other components are taken off from car shell. Car hulk is the next step to prepare for shredder. Sorting process, as in other developed countries, is important to classified metal and non-ferrous metal material. This uses Air classifier and Magnetic drum technique. For non-ferrous metal, heavy media or eddy is involved to separate non-ferrous metal. More importantly, recovery rate is one of the achievements of Japan ELV management. Material and Thermal Recovery technique is used to recovery energy back. The environmental concern also gives Japan encourage operator to lessen ASR as much as possible. Educating and incentive strategies are blended so that operators can apply. Figure 2.7 illustrate the ELV recycling flow under legislative management systems in Japan.

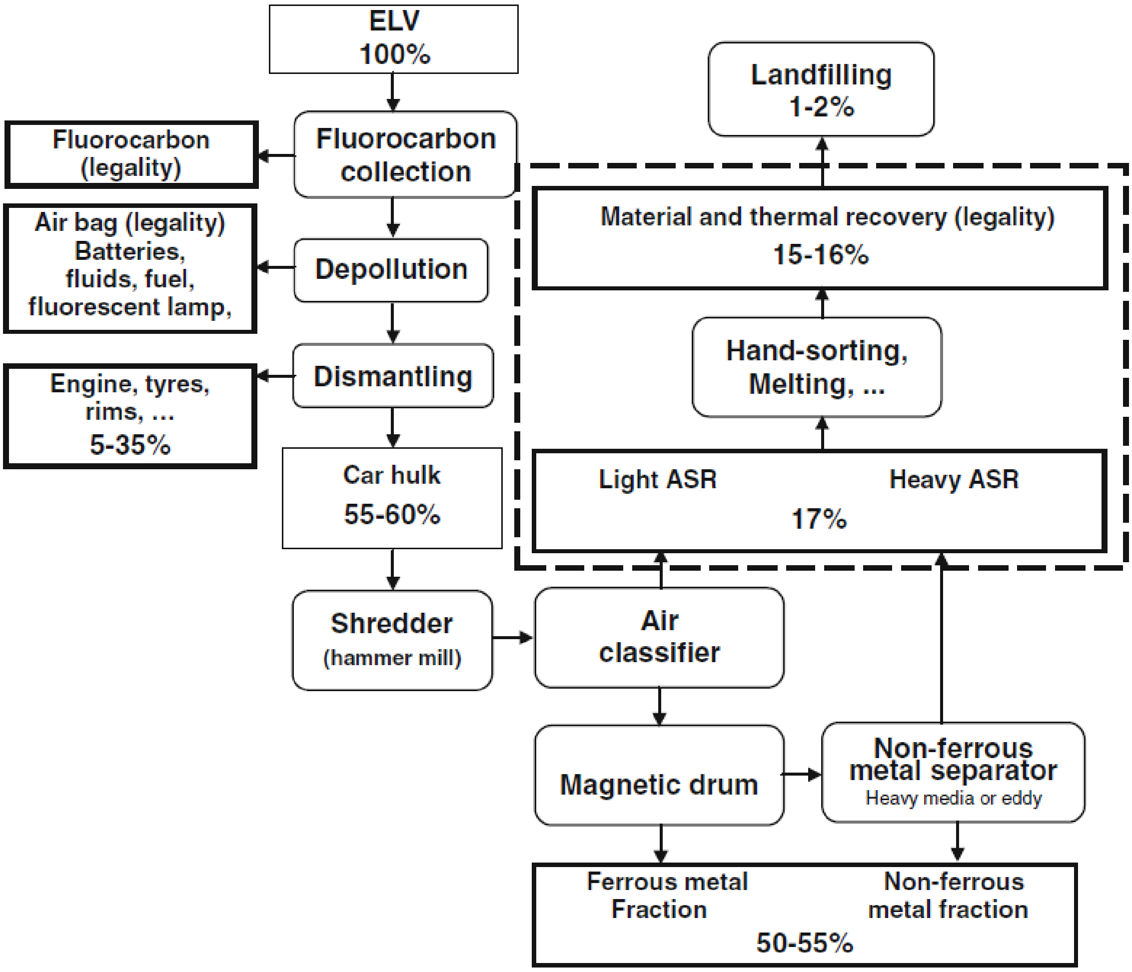

Figure 2.7 ELV recycling flow under legislative management systems in Japan

Source: Vermeulen et al. (2011); Yoshida and Hiratsuka (2012)

2.3.3 ELV management in US

1) Law and Regulation

No direct law is enforced regarding ELV management in US. Originally, Automotive Recyclers Association (ASR) promoted ELV recycling. The ELV management is driven by environmentally sound management. It does not use integrated management to lead or regulate directly. However, it seriously controls hazardous substances such as chromium and mercury or brominated flame retardants and phthalate compounds. Those are monitored closely to prevent environmental impact. Unlike other countries that applied the same law and regulation across countries, US allow state government to manage and enacted their own regulations.

However, the Resource Conservation Recovery ACT (RCRA) Laws and Regulations is related and used to regulate ELV management. RCRA is a public law that creates the framework for the proper management of hazardous and non-hazardous solid waste. Clean Air Act (CAA), and Clean Water Act (CWA) are also the regulation that helps control ELV management in US as well. As No party requires to be responsible for ELV and no target is set, management of ELVs is automatically driven by value and demand of secondary resource (Sakai et al., 2014).

2) Recycling Process

The recycling process is controlled under the environmental protection regulations. It is assumed that the level of ELV processing is at the same one as of EU because the price of ELV is relatively high comparing to cost of ELV operation. Currently in most states, ASR is classified as non-hazardous substance that can be landfilled. However, the high concern of ASR has been increasing so government starts to support the treatment process in a variety of ways.

2.3.4 ELV management in Korea

1) Law and Regulation

The beginning of attempt of Korea regarding ELV management started from applying EPR to the Waste management policy. Consequently, Act for Resource Recycling of Electrical/Electronic Equipment and Vehicles was enforced in 2008 regarding ELV related law. This act enhanced the EPR policy, which further published the Integrated Product Policy until the introduction of the Eco-assurance System (see Figure 2.8).

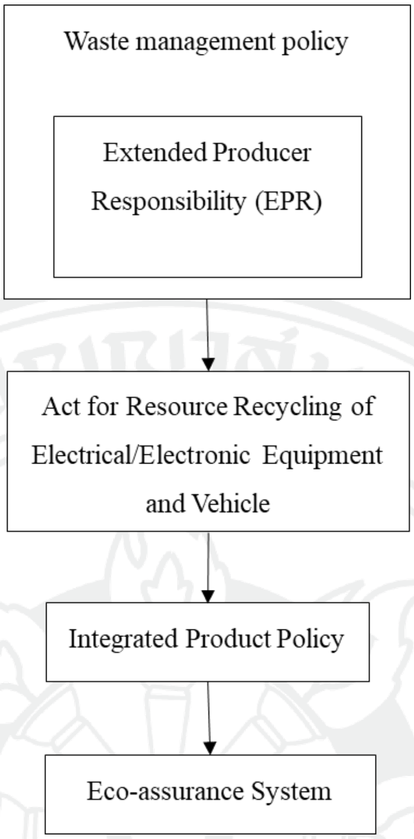

Figure 2.8 Development of Law and Regulation in Korea

The Eco-Assurance System assures the ELV management process with both preventive and follow-up management. Preventive focused on the design phase to assure the environmental friendly of finish goods. Whereas the follow-up one is to conduct environmentally sound management of wastes. About this act, the responsible for ELV recycling is on all stakeholders including importers, manufactures, dismantlers, shredders, ASR recyclers and refrigerant gas processors. The recycling and recovery rate are set to be at least 95% in 2015. Prior to the current policy, waste management act has been issued with the objective to control ELV regarding ELVs measuring and management of information (Kim et al., 2004).

Unlike Japan, car owners receive money from handing car to collectors. Mostly via agency, ELVs are sent to dismantlers while some are handed directly to dismantlers. Collector receiving ELVs from car owns could make profit from output after dismantling or recycling. Some ELVs are handed to agency but some goes directly to dismantlers. However, this was supervised and audited by Korea Environment Corporation (KECO).

2) Recycling Process

Regarding recycling process, similar to the other developed countries, fluid and hazardous substance such as gasoline, engine oil, anti-freezing solution must be taken off and treated appropriately before dismantling process. Figure 2.9 shows in summary about ELV treatment process step by step. Starting from ELV is brought to an operator. Fluid, engine oil, hazardous substances, Anti-freezing solution are removed at the first stage. Then, they was sent to recycling process for recycle or treatment.

The next step is Dismantling. It can be divided into 3 stages. The first one is about disassembling parts so that some reusable parts can be reused right away, and some are required a refurbishing or remanufacturing to make it as new. Those will go to second-hand market for sell. Eventually, the remainders go to the next dismantling step.

The second step of dismantling is to take off battery wire, seat, synthetic resin. Some of reusable battery wires are sent to recycler to remanufacture again. Recyclable parts of seat and synthetic resin are recycled, while non-recyclable parts are required an incineration at site to eliminate. Those outputs from incineration, at the end, are landfilled. However, some of the portion of nonrecyclable material are required to be sent for chemical Recycling.

The third step of dismantling is to take off engine, transmission, and spring. While spring goes to recycling system, engine and transmission must be cut to gain ferrous and non-ferrous material for further recycling.

The remaining output from the previous step are car shell required a compressing and cutting into small pieces so that the further step, shredding can be done efficiently. Additionally, an efficient sorting technique are important before the shredding step since it determines the quality of collecting and recycling.

Next, the output from shredding finally are separated into ferrous and non-ferrous material. By magnetic operation, the ferrous materials are collected apart from non-ferrous. The non-ferrous finally requires manually process by hand to pick the ferrous material and send to the next recycling process.

It is necessary to establish a policy for an optimal management system of ASR and to develop the related technologies in Korea, as other advanced countries have already set reduction targets for ASR.

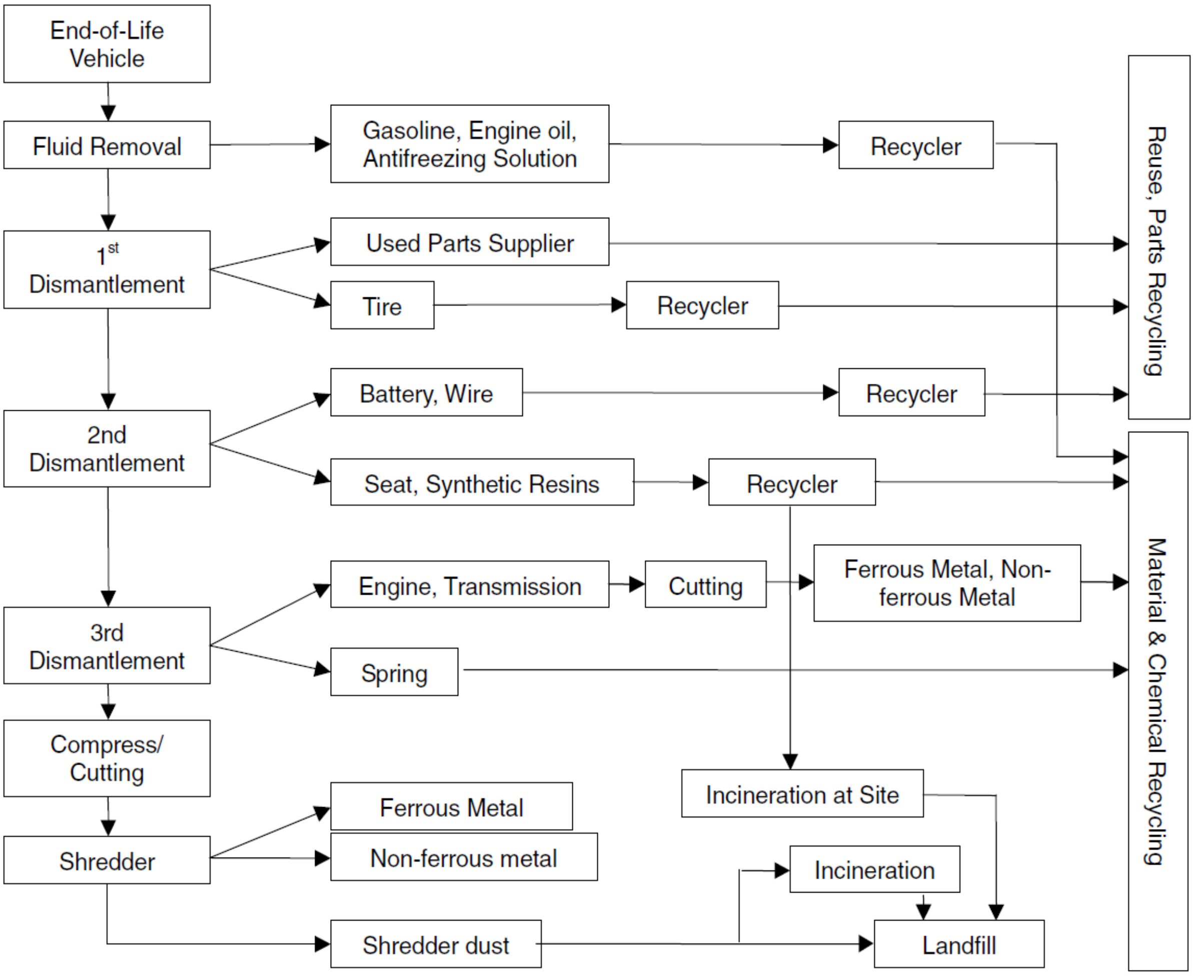

Figure 2.9 Summarized flow sheet of end-of-life vehicle treatment system

Source: Kim et al. (2004)

2.3.5 ELV management in China

1) Law and Regulation

To strengthen ELV management and road traffic order as well as recycling activities, End-of-Life Vehicle Recycling Regulation was enforced in 2001. The regulation mainly focuses on Scrap automobile recycling industries access conditions.

Participant should have capital at least 500,000 Yuan. The area of factory or work should be not less than 5000 m^2. The number of dismantled vehicles should be more than 500 per year and number of staffs should be more than 20. The enterprise must meet national environment protection standards with no illegal dismantling activities. Later in 2006, Automotive Products Recycling Technology Policy was enacted by the National Development and Reform Commission (NDRC). It aimed to improve resource utilization and was a guide to drive the establishment of the ELV recycling system. Moreover, it helps the ELV related companies to engage, and supports a recycled automotive product market. It focuses on each stages to responsible for its own tasks to achieve objectives including car manufacturers and importers, environmental protection, restricted in hazardous substance generated by vehicles activities, incentives to stakeholders (Wang & Chen, 2013).

ELV management in China seems to be properly improved; however, there are some hindered factors which slower the evolution of ELV management system in China. In 2011, there were 356 qualified ELV dismantlers collected by the state administrative department and more than 800 collectors across country. Approximately 4.8 million vehicles were scrapped in 2010. In general, the number of scrap vehicles rises with the increase in vehicle sales. However, the volume of the scrap vehicles in recent years is far less than the number of the estimate of the experts, moreover, gradually reducing. Regarding scrap steel, the number of scrap steel was increasing together with the number of car registered. To drill down into the ratio of scrap steel, it was mitigating over the year 2002 to 2008 (see Figure 2.10).

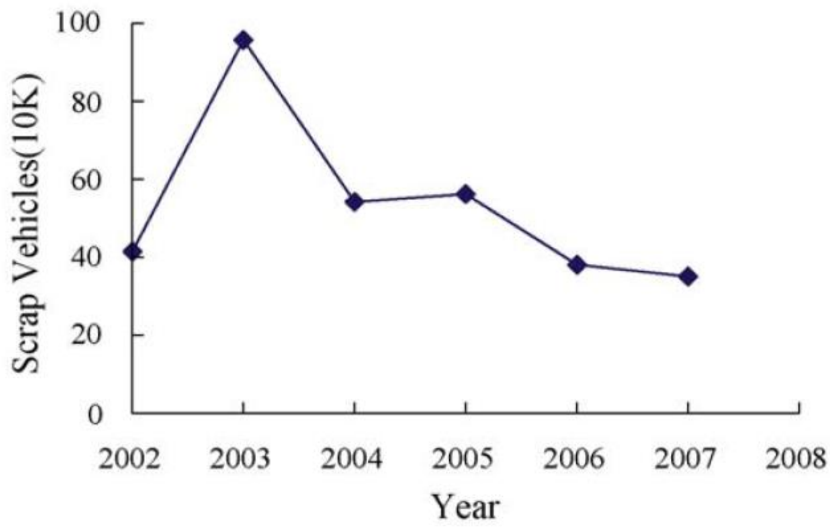

Figure 2.10 The number of the scrap vehicles in China
Source: China Automotive Technology and Research Center

The main reason was explained that the second-hand market in China had high demand on used car. Used car were remanufactured or even sold as second-hand car instead of sending it to the treatment process. Most of the second-hand car shop purchased car from car owner with satisfied price. That results in that cars were running illegally on the road. Most importantly, ELVs did not go to the right process of treatment because there were a lot of dismantler running illegally. Acting as a central collector, dismantler gained a second-hand car in several ways: direct purchase from car owner, purchase from dealer or service garage, or auction. The process of recycling including dismantling could harm the environment because the process emits or produces waste that was never treated well before landfilling. Leaking toxic fluid during the dismantling process or burned wire to gain copper are the example of environmental risks.

However, environmental protection parallelly works seriously to restrict inappropriate activities during recycling process. Banning a dismantler which does not abide by the regulation or without certification, China government expected the number of scrapped vehicles to increase.

2) Recycling Process

For recycling process in China over the years, car owner sells EVL to dismantler in China. Scrap car recovery certificate was issued for car owner by certified dismantler company. While ELV, by car owner, are required to be deregistered officially, car owner with scrap car recovery certificate sends car for dismantling. The process of dismantling starts with cleaning and take off toxic or hazardous substances: oil, gasoline, power steering fluid, windshield washer fluid, brake fluid, antifreeze substance, oil transmission fluid, and batteries. However, the above toxic substances do not all go for treatment process to assure it is harmless to environment. Next, usable parts such as plastic glass, other material, are separated from ELV by hand. Wheels, fenders, radios, horns, or engine are sold without any inspection.

After using manual process by human for separation of reusable parts, the remainders were cut into smaller pieces, called scrap, for convenience in transportation. The scrap is delivered to shredder for shredding process before going to steel manufacturer for making steel product. Figure 2.11 illustrates the status quo of ELV process in China.

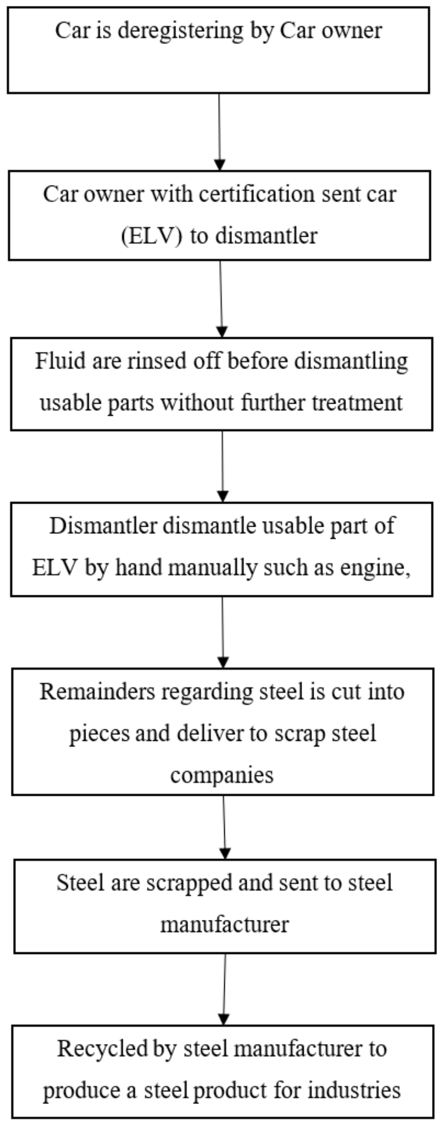

Figure 2.11 Status quo of ELV process in China

2.3.6 ELV management in Taiwan

1) Law and Regulation

Starting from Waste Disposal Act (WDA), ELV management in Taiwan has been evolving a lot over the past 20 years to become one of the world most efficient ELV management. The history behind the success of ELV management in Taiwan can be explained into 4 stages. The first stage is called Free market operating stage. At this stage, no specific organization regulates how recycler should be operated. Cost of recycling or recycled products were based upon market-driven. Used vehicles or parts were traded in second-hand marketplace so the recycler mostly focused on dismantling. Moreover, there was no regulation regarding environmental pollution at this stage, so waste from recycling processes impacts significantly on environment. It could be formally classified the environmental problem from recycling process at this period of term below.

1. Unable to efficiently clear or dispose wastes or residue from recycling process
2. contain components that do not readily decompose over a long period
3. contain hazardous substances

The second is General Waste Recycling, Clearance and Disposal Fund (GWCF) operating stage. GWCF founded at this stage and it funded to publish “ELV Recycling and Disposal Rules” in 19994, which is under the WDA regulation by Environmental Protection Administration (EPA). The establishing of GWCF effects the manufacturer and importers which were enforced to pay for recycling fee. GWCF not only guided recycler to efficiently improve their workplace and showed the appropriate way to dismantle, it planned to construct the first shredding plat to improve the sorting process that is done after shredding.

Next, ELV Recycling Fund Management Board (ERFMB) operating stage was in a period of Year 1997 to 1998. The remaining money in the recycling fund from the second stage was transferred to the mutual fund, called “Recycling Management Fund” (RRMF) and the old associations were forbidden to work on recycling business. The Recycling of Specific Waste Items and Container Rules was enacted for taking over the recycling system. ELV Recycling and Disposal Rules was abolished. Finally, ‘‘Recycling Fund Management Board” (RFMB), established in July 1998, became the management authority of mandatory recycling items.

The present stage is called RFMB operating. RFMB works to provide recycling channels for people and organizations. It is responsible for planning and supervising all the process regarding ELVs: disposal, and recycling. Moreover, Auditing and Certification Regulations for Mandatory Recycling Items was also established to investigate the process to assure it runs correctly and comply the rules (Chen, Huang, & Lian, 2010). Figure 2.12 illustrates ELV recycling and processing system in Taiwan.

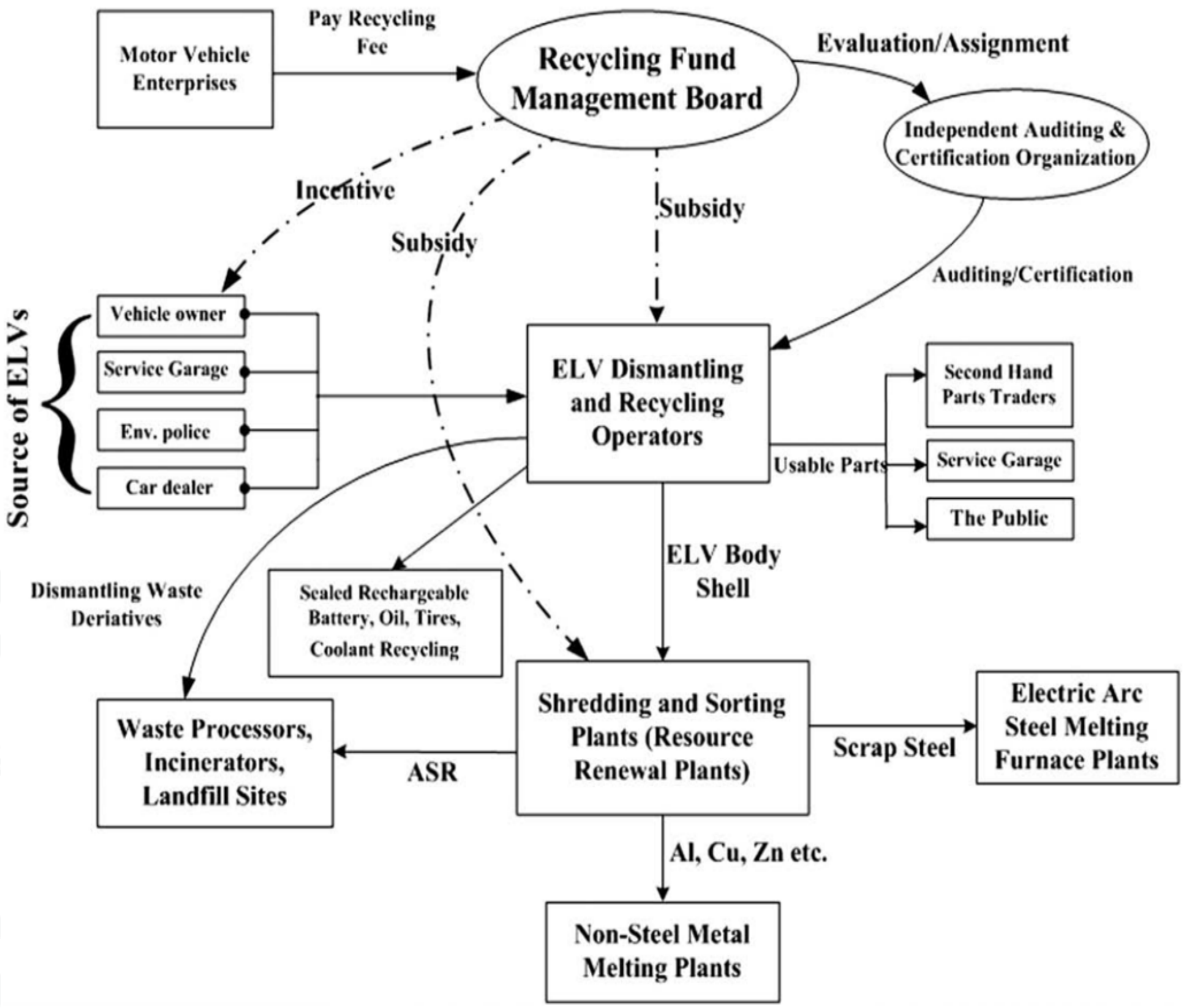

Figure 2.12 End-of-life vehicle recycling and processing system

Source: Chen et al. (2010)

(1) Recycling fees, rewards, subsidies

Recycling fees, rewards to the public, and subsidies for recycling_operators are the keys to encourage and subsidize stakeholders in order to sustainably bring them to the recycling system. A recycling fee is paid by the enterprises: importers, manufacturers to the Recycling Management Fund to be responsible for recycling cost of vehicles manufactured or imported by them. Recycling rewards was for encourage people to legally bring their vehicles to treatment operators. Auditing and certification supervises and investigates operators who performed recycling process. As a result, subsidies are used to cradle them to maximize their recycling outputs (Chen et al., 2010).

(2) Rewards

Besides, to encourage car owners to engage the recycling system. Car owners are given award by turning in ELVs after deregistration. Apart from car owner, people such as car dealer, service garage, environmental police are encouraged to this incentive plan too. Car dealer or service garage who owned an unusable car can turn in them to claim for the fee. Environmental polices normally collects unusable cars from roadside. The car will be announced to find an owner. Unless car owner come to be identified him/herself as owner, it is disposed of as a waste and then auctioned off. Finally, it is turned in to claim for the fee. Table 2.12 below shows the historical ELVs recycling reward paid to car owner (Chen et al., 2010).

From the middle of 1999 to the end of 2003, the EPA provided increased subsidies for owners who voluntarily surrendered ELVs with funding from the Air Pollution Control Fund (APCF) to diminish air pollution and to accelerate the replacement and recycling of old vehicles. The rewards increased periodically until the end of 2003. The results of this incentive resulted in the increasing number of recycled ELVs while the subsidy peaked at 10,000 NTD per vehicle. However, as of the mature of recycling system and the concerns of environmental, the government reduced rewards in 2007. The adjustment regarding amount of rewards were still ongoing as the policy adjustment (1 USD equals to 31 NTD approximately).

Table 2.12 Historical ELV recycling rewards (Unit: NTD/vehicle)

Date	Automobile	Motorcycle
1/1/99–30/6/99	1800	400
1/7/99–31/12/00	3000	1000[a]
1/1/01–31/12/01	13,000[b]	3000[b]
1/1/02–31/12/03	3000	4000[c]
1/1/04–31/12/06	3000	1000
1/1/07–30/6/07	3000[d]	1000[d]
1/7/07	1000[d]	300[d]

[a] Vehicles older than (and including) 7 years are subsidized with $350 NTD/vehicle from the Air Pollution Control Fund (APCF).

[b] Cars older than (and including) 10 years and motorcycles older than (and including) 7 years are subsidized with $10,000 and $2000 NTD/vehicle from the APCF.

[c] Motorcycles manufactured prior to the end of 1997 are subsidized with $3000 NTD/vehicle from the APCF.

[d] Only motor cars older than (and including) 10 years and motorcycles older than (and including) 7 years may apply for rewards.

Source: Chen et al. (2010)

(3) Recycling fees

As RFMB is given a payment for Motor Vehicle Enterprises and importers to be able to support whenever the operators or recycler requires more investment to operate. The calculation of payment from Motor Vehicle Enterprises and importers is based on the volume of car produced in a period of time and the volume of imported car respectively. Table 2.13 below shows the rate RFMB received a payment from Motor Vehicle Enterprises and importers.

Note: 1 USD equals to 31 NTD, approximately

Table 2.13 Historical rates paid by motor vehicle enterprises (Unit: NTD/vehicle)

Date	Automobiles	Motorcycles
01/97–10/97	3000	700
11/97–12/97	2000	500
01/98–06/99	1000	250
07/99–12/00	983	264
01/01–12/04	643	96
01/05–12/06	965	144
01/07–12/07	2050	683
01/08–12/09	3500	700
01/10	3800[a]; 2700[b]	800[a]; 650[b]

[a] General design.
[b] Design complies with Green Mark.

Source: Chen et al. (2010)

(4) Subsidies

The subsidy will be sent via RFMB to those ELV Dismantling and Recycling operator as well as Shredding and Sorting Plants. The payment method of subsidy has been evolving step by step to improve the efficiency and quantity in recycling system.

At the first place, the payment was based on where (the distance) the residues were sent. This were subsidized to alleviate cost of travelling. Next, the payment was based on the investment of the recycling operation including clearance and the treatment of ASR. However, this payment method was not effective since there is no motives for operator to maximize the ratio of recycled product or the ASR treatment quality. Consequently, government decided to adjust the calculation method based on the techniques using in recycling system. Table 2.14 shows the payment figure from RFMB to operators based on performance of recycle dismantling (1 USD equals to 31 NTD approximately).

Table 2.14 Subsidies for recycling operators performing recycle dismantling and for responsible enterprises (Unit: NTD/vehicle)

Item	Subsidy rules		Year 2002–2004	Year 2005–2008
Administration subsidized cost	Motorcycles	Surrendered by people and notified by the environmental police	250	185
		Market independent recycling	150	
	Automobiles	Surrendered by people and notified by the environmental police	850	770
		Market independent recycling	450	

Source: Chen et al. (2010)

Similarly, the payment also went to shredding and sorting operators based on the performance of recycling. The number of ELV shells recycled was calculated together with the volume of ASR disposal which could be reduced. The renewal resource ratio was another factor to determine subsidies. Table 2.15 shows Subsidies for operators performing shredding and sorting and for responsible enterprises (1 USD equals to 31 NTD approximately).

Table 2.15 Subsidies for operators performing shredding and sorting and for responsible enterprises.

Year	Subsidy item	Subsidy amount (NTD/ton)			
2002	Processing fee for ELV shell[a]	$1712 (commissioning public major metropolitan incinerator for processing)		$3028 (commissioning private incinerator for processing)	
2003–2004	ASR disposal and processing cost	$2402 (for $3000 and under)	$2708 (for $3000–$3800 Inc.)	$3028 (for over $3800)	
2005–2006	ASR disposal and processing cost [b]	$2400 (for $3000 and under)	$2700 (for 3000–3800 Inc.)	$3000 (for over $3800)	
2006	Renewed resource ratio[c,d]	Nil (for under 65%)	$3000 (for 65% Inc.–70% exc.)	$3400 (for 70% Inc. ~75% exc.)	$3800 (for over 75% Inc.)

[a] Applicable until 6/2/2003.
[b] Applicable until 31/10/2006.
[c] Applicable between 1/11/2006–30/6/2007. When the scrap steel generated exceeds 75% of the raw vehicle shell amount entering the plant for the period, the excess is excluded from the certified amount.
[d] Applicable from 1/7/2007. When the scrap steel generated exceeds 70% of the raw vehicle shell amount entering the plant for the period, the excess is excluded from the

Source: Chen et al. (2010)

1) Recycling Process

The statistics provided by RFMB shows that 303 ELV recycling operators in Taiwan. Five shredding and sorting plants are located in northern, central, and southern part of Taiwan. There are no operators in the offshore islands. The Figure 2.13 shows in detail about the recycling and dismantling process in Taiwan.

"Environmentally friendly dismantling" is defined as the efficient process on dismantle battery, hazardous fluid, toxic substances, waste oil, coolant, tires, and other components which have an impact on environment. High technologies or tools using in dismantling process should be specific and appropriate for each procedure. There have been attempts to develop efficient process of EVL management, or even higher the ratio of renewable substances in the future. Most importantly, the objective is to assure that treatment of waste disposal in EVL dismantling process are done properly.

After dismantling, the plastic, glass, rubber, and seats are sent to the shredding and sorting operator with the ELV shell. Usable materials are sent directly for refurbishing to be reused as second-hand. The ELV shell are shredded while plastic, glass, and rubber are separated using specific technique. ELV shell after shredded are delivered to electric arc steel melting furnaces plant. There can be categorized into 3 sub-methods in shredding process: Shredding, Sorting, and Mobile machine.

1) The Shredding system includes the pre-shredder and main shredder.
2) The Sorting system consists of cyclone dust collector, a water cleaning tower, magnetic sorter, an eddy current separator.
3) The Mobile machine includes bobcats, forklifts, and tow trucks.

Aluminum, copper, plastic, glass, or fiber are the output of sorting. Iron and cooper can separately sell to recycling operators. Parts that cannot be recycled or not worth to be recycled become ASR which mainly impacts environment as ASR would lower the efficiency of incineration which causes air pollution.

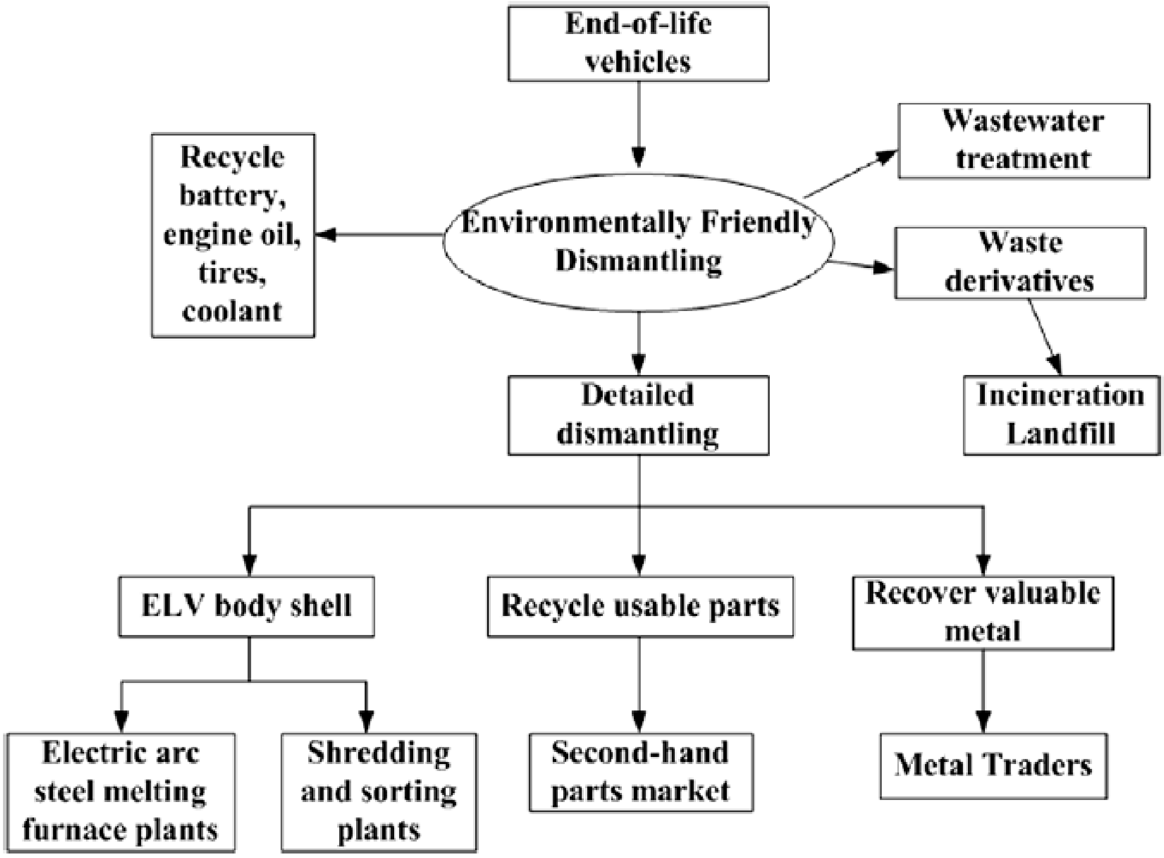

Figure 2.13 End-of-life vehicles dismantling procedure
Source: Chen et al. (2010)

2.3.7 ELV management in Thailand

1) Law and Regulation

There is not direct law or regulation regarding ELV management in Thailand.

2) Recycling Process

Wreck or unused car are sold by insurance company to auction company that are dismantled and scrapped. Eventually, recyclers take those scrap or part such as battery to recycle. There is no government or certified organization to directly manage ELVs such as collecting or recycling. Regardless of car manufacturer and steel producer, stakeholders mentioned above are sources of demand and supply of ELVs in Thailand market (Aroonsrimorakot & Akaraj, 2010).

The recycling flow of ELVs turned out to be almost identical in many countries, regardless of the existence of a legislative management system. The process of ELV recycling starts with dismantling. At this point, components containing hazardous substances such as lead batteries, mechanical oils and refrigerant gases are collected first, and then recyclables and valuable materials for secondary use, including engines, tires and bumpers are collected. In the US, voluntary collection of components containing mercury, such as switches, is operated during the dismantling stage. In China, components collected at the dismantlers are very often re-sold or recycled as secondary products. The weights of ELV after dismantling are reduced to 55–70 % of the original weights in the EU and Japan.

To compare among the countries worldwide, Table 2.16 shows a comparison of ELV management systems in several countries. The ELV management systems shown here are categorized into two parts. One is the direct management system based on legislation which includes EU, Japan, Korea, and China. The second part is the indirect management system based on market mechanisms and environmental regulations used in the US.

Table 2.16 A comparison of the ELV management methods in various countries and regions

(M1, 4-wheeled vehicles with seating capacity of nine or less, including passenger vehicles; M2, seating capacity of nine or more, vehicle weight under 5,000 kg; M3, vehicle with seating capacity of nine or more, vehicle weight over 5,000 kg; N1, freight vehicle with maximum load capacity under 3,500 kg; N2, maximum load capacity of 3,500 kg or more, freight vehicle weight under 12,000 kg; N3, freight vehicle with maximum load capacity of 12,000 kg or more)

	EU	Japan	Korea	China	US
Law enforcement	Law Directive 2000/53/EC/Of The European Parliament And Of The Council of 18 September 2000 on end-of-life vehicles (enforced in 2000)	Law Law for the Recycling of End-of End-of-Life Vehicles (enforced in 2005)	Law Act for Resource Recycling of Electrical/Electronic Equipment and Vehicles (enforced in 2008)	Law End-of-Life Vehicle Recycling Regulation (enforced in 2001) Automotive Products Recycling Technology Policy (declared in February 2006)	Related law Resource Conservation Recovery Act, Clean Air Act, etc.
Background of ELV management	Measures for increasing ASR Measures for abandoned automobiles Environmental measures of dismantling sites	Lack of final disposal sites Illegal dumping of ASR Effective use of resources	Measures for ELVs Effective use of resources Management of information on ELVs	Measures for illegal assembly Effective use of resources Measures for recycling economy	Strict implementation of regulations Environmental conservation measures associated with ELV recycling
Party responsible for recycling costs	Automobile manufacturers and importers (if the recycling incurs cost), finally users	Users	Automobile manufacturers and importer (if the recycling incurs cost), finally users	No regulation (traded as a valuable secondary resource)	No regulation (traded as a valuable secondary resource)
Target automobile	M1, N1	All vehicles (including buses, trucks, etc.), with the exception of two-wheeled vehicles	M1, N1	M1, M2, M3, N1, N2, N3	No regulation
Recycle target	Until 2006: Reuse and Recovery: 85 % Reuse and Recycle: 80 % Until 2015: Reuse and Recovery: 95 % Reuse and Recycle: 85 %	Airbag: 85 % ASR: 70 % (from 2015 onwards) 50 % (2010 to 2014) 30% (2005–2009)	Until 2014: Material and energy recovery: 85 % (of which energy recovery rate is within 5 %) After 2015: Material and energy recovery: 95 % (of which energy recovery rate is within 10 %)	Possibility of recycling: 2010: about 85 % (material recycling of 80 % or more) 2012: about 90 % (material recycling of 80 % or more) 2017: about 95 % (material recycling of 85 % or more)	No specific goals (95 % of ELVs enter the recycling route, of which 80 % of the materials are recycled)

Source: Sakai et al. (2014)

Additionally, one key factor that brings countries to ELVs issue are imported used vehicle or parts. The impacts of importing used vehicles or parts on environment are researched and investigated for several countries as it might harm environment. Efficient monitoring or appropriate policy in countries on exporting used vehicles are essential to prevent those impacts on environment. Importing used vehicles has benefits in cost perspective. People can gain parts with low cost comparing to the new; however, it results in the environmental and health problem. With imperfect parts, it causes traffic accidents and generates bad pollution (S. Kumar & Yamaoka, 2007) For example, Japan annually produces more than 10 million new vehicles and generates more than 5 million ELVs. Many of these ELVs are exported globally and utilized as used vehicles and as sources of used automobile parts and materials especially in developing countries, mainly in Asia. Thus, in Asian countries with inappropriate recycling systems, ELVs from Japan have caused serious environmental problems such as soil pollution and resource dissipation due to inadequately treated batteries and uncollected rare metals. In addition, both the export of ELVs from Japan and the generation of ELVs in Asia are anticipated to increase with future economic growth and the accompanying motorization of Asia. Therefore, not only from the local viewpoint but also from the global viewpoint, it is necessary to design an appropriate automobile recycling system before problems arising from ELVs intensify in Asia. Thailand is an important outlet of Japanese automakers in ASEAN and has imported many used vehicles and parts from Japan in the past. Although Thailand has basically prohibited the imports of used vehicles and parts to protect and promote its own motor industries, as have other developing countries, such a strict restriction does not function satisfactorily in real situation (Fuse & Kashima, 2008).

2.4 Law and Regulation related to ELV management in Thailand

ELV management in Thailand has been raised by government over the years to reduce waste (Aroonsrimorakot & Akaraj, 2010). One factor is the import in ELVs from other countries especially the ones who own vehicle productions. However, there is an attempt from Thai government to prohibit the imports of used vehicles and parts to protect and promote its own motor industries, as have other developing countries. In practical, such a strict restriction does not function satisfactorily because of consumer and producer responsibility, limited budget allocation, or weak organization (Dhokhikah & Trihadiningrum, 2016; International Business Publications & Washington DC, 2011; Pelletiere & Reinert, 2002, 2004; Udomsri, Petrov, Martin, & Fransson, 2011).

In Thailand, automobile repair shops are ranked top regarding sources that produce hazardous substances (Pollution Control Department, 2017). The Act that regulates how hazardous should be managed is Hazardous Substance Act (Office of the Council of State, 1992c). Still, there are several related law and regulation that associate to the ELV and its life cycle; however, there is no direct law or regulation about ELV management in Thailand. In manufacturing process, DIW are the main stakeholder to control an operational process as well as regulate factories. Managing along with Industrial Estate Authority of Thailand (I-EA-T) Operation Center, DIW monitors all the factories in Thailand to ascertain that they have a qualified operational process and efficient management of environmental and safety issues and integration of all information. The main act took charge by minister of industries are Factory Act (Office of the Council of State, 1992b). Apart from the effects of maintaining or producing car, discarded cars sometimes are dumped or landfilled illegally. There are some related laws about waste management such as act on The Maintenance of The Cleanliness and Orderliness of the country, but it is not directly regulation about ELV management of how car should be landfilled or registered after used. Regarding act on The Maintenance of The Cleanliness and Orderliness of the country, it defines “Car wreckage” means car, motorbike, machine, ship, wheeled vehicle, other vehicles that is so old that it can no longer be used and shall include parts of a car, machine or vehicle (Office of the Council of State, 1992a). Moreover, a related act that is always applied to those mentioned act is Public Health Act (Office of the Council of State, 1992d). Whenever any hazardous or cleanliness posing the health problems or related to them, this act will help in to control.

According to Vehicle Act and DLT regulation, car owners are enforced to bring their vehicles for inspection annually. For inspection process, car owners are required to pay inspection fee. For car which weight is less than 1,600 Kg, the fee costs 150 baht, and for over 1,600 Kg costs 250 baht. Once vehicle passes the inspection test, car owners are issued a certificate to show to the Land Transport Office, the blue book, and receipt of annual tax registration fee for Compulsory Motor Insurance. Regarding annual tax registration renewal fee, it is based on vehicle’s engine displacement as shown in Table 2.17. The annual tax registration renewal fee is the same for the first five years. It is reduced from year six by ten percent every year to a maximum of fifty percent. Less than five years, vehicle is not required for inspection process so car owner can only paid for annual tax registration renewal fee for the year to come. (Department of Land Transport, 2018a, 2018b). Regarding inspection process, there’s an evidence that it does not seriously follow the required standard and also not every parts are inspected completely (Taneerananon et al., 2005).

Table 2.17 Rate for Annual Tax Registration Renewal Fee

C1 Type (Passenger or less than 7 seats car), Engine (CC)	Rate for Annual Tax Registration Renewal Fee
600 CC	0.5 Baht per CC
601-1,800 CC	1.50 Baht per CC
More than 1,800 CC	4.00 Baht per CC

Regardless of ELV management in Thailand, law and regulation in Thailand as well as policy seems to encourage most people to extend car usage without maintaining it in good condition. This depends upon factors such as decrement of annual tax registration renewal fee each year after five years, the value of vehicle at the time of discarding, availability of second-hand car shop marketplace, standard and policy of inspection and Gross National Income situation (Faiz, Weaver, Walsh, Gautam, & Chan, 1997; Pholphirul, 2007). To use old car with poor condition, this may cause bad pollution and high energy consumption during car usage such as carbon dioxide, carbon monoxide, waste from oil, and fuel consumption (Beaton et al., 1995; Bin, 2003). Unlike Thailand that annual tax registration renewal fee is based on engine displacement, in most of developed country, the way to calculate annual tax registration renewal fee depends on actual condition of vehicle , such as carbon dioxide emission (Hayashi, Kato, & Teodoro, 2001; Zahedi et al., 2012)Life cycle cost (LCC)

2.4.1 Life Cycle Assessment (LCA)

Life cycle assessment (LCA) is a framework for examined and determine material or product from the cradle to the grave. It is also defined as a systematic process to measure an environment impact from using products throughout its lifecycle. The environment impact are resulted from functioning or using of product such as energy consumption, service or maintenance, disposal, repair, reuse, or recycle (Matthews et al., 2015).

Poboon (2017) defined the meaning of LCA, “the process of analysis and assessment of impacts of products on environment throughout the product life cycle.

Starting with creating or acquiring of raw materials, production process, logistic or product distribution, product use, reuse, remanufacture, recycle, and waste management after use. These could mean considering product from Cradle to Grave together with measuring energy and material used as well as wastes disposed to environment. Consequently, this is to find the way to improve products to minimize the impact on environment."

The methodology of LCA of product consists of:

1) To identify and determine Environmental Loads in every activity which relates or happens throughout its life time. For example, energy and materials used, waste disposal and disseminate of pollution to environment.
2) To assess and find possibility of Environmental Impacts by considering from environmental impact level and figure.
3) To assess an opportunity in improving environment and apply information regarding environmental impact from activities as key determination.

The steps of LCA includes:

1) Goal and Scope

This consists of setting goal and Product Function, Functional Unit, System Boundary, and Product System.

2) Life Cycle Inventory

This is about collecting and calculating data acquired from the processes in Goal and Scope.

3) Life Cycle Impact Assessment

This is to assess an impact of product system regarding environmental perspective from resource usage information and waste disposal. It includes input and output from Life Cycle Impact Assessment regarding environment.

4) Interpretation

This is to analyze results in order to conclude, find limitation, provide recommendation regarding LCA, and generate reports.

The research also explicated that LCA also used in industries to minimize production cost and environmental impact. However, the limitation of LCA are time consuming since it takes a long time to collect all the data from cradle to grave. The budget is another main obstacle which is relatively high for data collecting process. Nevertheless, to apply result and analysis to create a new product does not meet the consumer's requirement. As producer concerns on business confidentiality, analysis data or results is limited on knowledge sharing.

The research regarding LCA which associates to vehicle were done by (Poboon, Phoochinda, Chompunth, & Mangmeechai, 2015). This research was applied LCA concept to assess energy usage and Greenhouse gas (GHG) emission in transportation perspective in order to recommend policy. This is to help reduce energy usage. The research focused on passenger car (C1) in various types: Eco-car, Flex fuel vehicles: FFV, Hybrid electric vehicles: HEV, Electric vehicles: EV, Fuel cell vehicles, and common passenger car. The research was conducted by applying ISO 14044: LCA-Requirement and guideline. The results regarding energy usage and GHG emission each phases of lifecycle of vehicle are concluded as follows:

1) Production process ranks second regarding energy usage and GHG emission
2) Transportation process does not consume much energy and GHG emission is relatively low comparing to other phases in life cycle.
3) Selling and Maintenance process does not use much energy and GHG emission regarding information from Car Service Dealer across countries.
4) Use phase ranks first in energy usage and GHG emission. From the research, Hybrid electric vehicles consume energy and emit GHG the least. However, focusing only on GHG emission, electric vehicles emit smallest amount of GHG.
5) ELV management phase consumes small number of energy since there is no large machine operating in Thailand. However, the environmental problem still incurs. Toxic or hazardous substance leakage from the inappropriate ELV treatment process impacts on environment.

2.4.2 Life Cycle Cost (LCC)

Expanding LCA concept, tracking cost over the life cycle of products or projects can be achieved by using economic performance. There are various methods and applications to perform life cycle cost analysis (LCCA) in support of decisions for basic products, choices, and for infrastructure systems. Depending on the complexity of the project, we may want to adjust for the time value of money by using discounting methods that normalize all economic flows as if they occurred in the present. A benefit of using such methods is that they allow incorporation of costs by both the owner as well as other users. Beyond deterministic methods, LCCA can support probabilistic methods to ensure we can make robust decisions that incorporate risk and uncertainty (Matthews et al., 2015).

There are some prior researches that studied about vehicle cost using LCC concept. Only a few researches on LCC has been conducted in Thailand. Studies by Goedecke, Therdthianwong, and Gheewala (2007) examined cost and benefit of vehicle in different technologies and fuels in Thailand. Societal life cycle costs, consumer life cycle costs and taxes are studied based on parameters, vehicle initial cost, vehicle operational cost, environmental damage cost in order to find cost and benefit of these technologies for society. Results showed that the lower fuel price of natural gas is the main reason that makes societal life cycle cost of vehicle using compressed natural gas as fuel to be lower than other technologies. On the other hand, apart from small pollution damage costs, hybrid vehicle gives a high societal life cycle cost since its high production cost. Moreover, the result shows that Thai vehicle taxation scheme gives huge incentives for consumers and producers to invest in alternative vehicle technologies.

Another research by Jeong and Oh (2002) also studied on LCC of a fuel cell hybrid vehicle. The study of advantages of using pure fuel cell and fuel cell hybrid vehicles as energy sources are analyzed with life-cycle cost analysis technique. It shows that LCC depends largely on fuel cell size, and cost as well as hydrogen cost. To select the most effective fuel depends on those factors. It is worth to choose pure fuel cell when the cost of fuel cell is low. On the other hand, when the cost of fuel cell is high, the hybrid one is more profitable.

Hellgren (2007) applied LCC technique to determine which alternative powertrain is cost effective regarding each application in various scenarios: a car, a city bus and an intercity bus operated in Sweden. This research focuses on the influences of fossil fuel price on choosing of powertrain. Researchers concluded that it is not clear which powertrain concept is the best choice and the most cost-effective alternative will depend on the application.

Many researches about fuel consumption related to efficiency of vehicle were focused on use phase to see their cost effectiveness, while others focus more on other phases such as pre-manufacture phase or the phase of recycle. Saman, Zakuan, and Blount (2012) published the study on initial design phase of vehicle. Using related concept of LCC analysis, the research investigated on the current situation, Recycling Function Deployment analysis for value and cost, characteristics selection and decision for detail design. The paper concluded that the Framework for Design for ELV value helps designer to identify the performance of the current design towards cost and revenue at the end of life. The developed framework is a tool to increase interaction between the automotive designers and the recycling industries and as a groundwork for the business strategy.

Another study that applied LCC technique to compare different materials regarding cost and environment impact and enable the best tradeoff between cost and environment was conducted by Witik, Payet, Michaud, Ludwig, and Månson (2011). To support material selection, this research also aimed to find the best trade-off between cost and environment by calculating them both in use and end of life phase. The study mentioned that high weight savings materials such as carbon fibers and magnesium can lead to negative environmental benefits because of increased environmental burdens associated with their production. Despite not being recycled, materials such as sheet molding compound were found to be effective from life cycle perspective. However, lighter weight vehicle is normally costly, but it helps consumer to reduce cost of fuel.

Pholphirul (2007) studied on the second-hand car trading. Apart from economic and social wellbeing issues that this paper aims to study, environmental impact and regulation and law imposed by the Thai government are discussed. The results showed that despite the impossible to measure sale of second-hand cars with the exact figure, it has a strong relationship to overall economy.

Aroonsrimorakot and Akaraj (2010) studied the potential of ELV directive implementation in Thai Automotive Industry in Thailand by using interview and questionnaire. This study aimed to examine factors that affect automotive industries toward ELV directive implementation. The researcher concluded that the most influential decision factor to implement ELV directive is customer's request. Environmental management system had an influence on the ELVs management. Government and private sectors depended on foreigners' technology and knowledge.

The research also mentioned that, without a direct law to regulate ELVs, management of ELVs in Thailand is driven by DIW.

Related research that supports ELV study by Nilbai and Sriduang (2018) is important to find value of used car. The research illustrates how to find price of car by defining parameters such as age of car, engine displacement, brand, etc. Used car price depreciate after the car has been used from the first day. Specification such as color, engine, brand and model of vehicle are the main factors that affect the original car price. Each model has its own depreciation rate according to the markets and popularity. For example, in some model, price of car with white color reduced significantly comparing to the black one. How far the car has been run determines the price too. The more the distance they run, the more the budget tends to be used for maintenance. Also, the age of the car determines price depreciation rate. The older the car is, the lower the price would be. Price of second-hand car comparing to the price of brand-new one can determine how the second-hand car market goes in Thailand.

In sum, regarding reviewing of literature in Thailand, most researches about vehicle pinpoint on the operating cost or management cost at use phase. The LCC in Thailand regarding ELV has not been specifically studied.

CHAPTER 3

METHODOLOGY

There are 3 objectives in this study and each objective requires different methods to acquire the answers.

3.1 To study ELV management status quo in Thailand, and to investigate how car owners manage their unusable cars

3.1.1 To understand life cycle of passenger car and ELV management status quo

To understand the ELV management status quo in Thailand, this was investigated by using a field survey done with participants: insurance company, auction company, second-hand car shop, automobile repair shop, dismantler or collector, recycler, car manufacturer.

At first, all the name of companies in the sector were listed and more than three companies were selected based on size and notability. Letters asking for interview were sent but not all companies that were selected was willing to provide information due to confidentiality concern.

A survey is undertaken step by step to investigate how people manage their unusable cars and also ELV management status quo in Thailand such as the number of ELVs and how the vehicles flows in the cycle.

The insurance company provided the information staring from sending a car to maintenance car shops, until manage wreck such as selling or remanufacturing.

Next, the survey has been done with auction company (Second Cars and ELVs). The auction company provided information about wreck cars they gain. The standard bidding price and where it goes after bidding. The survey was done on second-hand car shop to acquire information about demand, supply related to price of second-hand car.

The automobile repair shop also plays an important role in ELV management in Thailand. Doing field survey by interviewing the owner of automobile repair shop, useful information regarding refurbishing car and vehicle parts in the market were collected.

Collector or dismantler was the stakeholder which was studied to gain knowledge about how they collected ELV and how to pass to steel industry. In Thailand, most of collectors are also dismantler themselves.

Steel Mills are the stakeholders on which the research seriously focuses to investigate how steel are recycled and sources of steel. It also focused on other materials such as plastic that plastic recycler gave us information about the process. Interviewing car manufacturer, we could understand the responsibility and perspective of producer in term of material recycling used in production and also how to trace car after selling.

More importantly, the organization especially government sector has been interviewed. To gain information from the government perspective on ELV Management, PCD and DIW were visited to gain information, including responsibility and role of those organization regarding law and regulation enforcement.

Moreover, the statistical data of vehicles from DLT were used to analyze with information from the mentioned stakeholders. The relationship of each stakeholder brings us to understand a flow process in term of business and its lifecycle. To gain more information regarding statistics of vehicle in various perspective, and to understand how DLT works on inspection process, DLT has been interviewed to provide such information. Table 3.1 shows the stakeholders in this research which provided the information by field survey study.

Table 3.1 Number of organization/shop/industries visited

Visited Place	Number of organizations/shops/industries
Department of Land Transport	1
Auction company	1
Automobile repair shop	2
Insurance Company (association)	2
Second-hand car shop	2
Collector (Dismantler)	2
Steel Industries	2
Car Manufacturer	1
Pollution Control Department	1
Department of Industrial Works	1

3.1.2 Questionnaire and Secondary Data to understand car owner behavior and estimated average age of car

This research conducted questionnaire for Thai car owners to depict how Thai people manage and also value their cars. Approximately 118 people who owns car in Thailand responded to the questionnaire. These are factors that could determine the status quo of ELV in Thailand. The questionnaire was designed mainly to gain the knowledge of how old cars normally be until it is going to be discarded by an owner, the way owners maintain their car, and their knowledge about car management. Apart from questionnaire, secondary data, the number of car versus age range, were also used to determine the age of car.

3.1.3 Secondary data to estimate number of ELV

From the statistics reported by DLT, the number of deregistration is very low comparing to the number of new registrations over the years. The figure can imply that some of vehicles in Thailand that have been discarded for any reasons did not appear to be deregistered. The methodology to find the number of permanently discarded vehicles as an ELVs is relatively difficult as there is no records or direct evidence regarding the number of discarded vehicles. In other countries with effective ELV management, the number of vehicles admitted the recycling process will be recorded alongside the tickets issued to make sure the exact number of discarded vehicles (Sakai et al., 2014).

To achieve the number of ELVs, two approaches are developed to estimate the number of permanently discarded vehicles. The former approach is estimated from the number of first registration of brand-new vehicle in the past. The former is to use statistics of the number of suspended and deregistered vehicles. The latter is to use statistics of cumulative and newly registers number of vehicles.

The number of ELVs can be calculated from the vehicles that did not pay license tax. This number could lead to the figure of ELVs. Regarding information from DLT, there are several vehicles which are behind in payment. Thanks to statistics collected by DLT, the number of cars that has not been extended license for 3 years in a row are forced to be suspended. Those cars include both in-use car but avoiding payment and the car which was discarded but did not deregister. Consequently, the number of ELVs of said year can be achieved from the number of vehicles that was suspended the licenses plus the number of vehicles that were deregistered permanently. Below is the formula for the first approach. The formula can alternatively be defined as equation (1) below.

No. of discarded C1 vehicle of said year = No. of C1 vehicle that are suspended of said year + No. of vehicles that were deregistered permanently of said year (1)

Another formula proposed in this study is to use a difference of cumulative number of vehicles of said year and the next year. The cumulative number of vehicle registered is defined as the number of registered vehicle from the past excluding the one suspended and deregistered (Department of Land Transport, 2018b). However, the increasing number of registered vehicles each year is from the newly registered. Consequently, the number of discarded C1 vehicle of said year is the subtracting of Cumulative number of vehicles in the present year from the cumulative number of vehicles in the previous year plus the number of newly registered C1 vehicle of said year. The below equation (2) illustrates the described formula.

No. of discarded C1 Vehicle of said year= Cumulative no of vehicle in the previous year + no of Newly Registered C1 Vehicle of said year – Cumulative no of vehicle of said year; (2)

This approach is expected to yield the nearly result as the first one. Since, the cumulative number of vehicles does not include the vehicles that is suspended and deregistered, this formula yields the number of suspended and deregistered vehicles of that year. However, that the year suspended is 3 years after consecutively not extending licenses may not exactly imply the number of discarded vehicles. It may be discarded 3 years before suspended. However, the result from second approach in said year is rather the one in the last 3 years because the suspended is effective due to ignorance of extending happening 3 years earlier.

Studying about lifetime of car in Thailand, the comparison between number of C1 type vehicle in the past and present year is analyzed to find the decreasing number in ages. Table 2.8 are the information this research uses to estimate or find an implication of lifetime of cars.

From the status-quo information together with information regarding LCC of ELV from consumer perspective, this would reach to the understanding of how car owners manage their unusable car.

3.2 To analyze the LCC of ELV from car owner and steel industry perspectives

To obtain the life cycle costs of ELV, each stakeholder in life cycle flow process were investigated by field survey and secondary data. The system boundary of LCC can be seen in Figure 3.1. The functional unit of LCC is baht/ELV. To analyze how steel from ELV could be used or recycled, interviewing with steel industry are done to find weight of steel per ELV.

3.2.1 To understand LCC of ELV from car owner perspective

More importantly, intention to discard and perspective of using car are investigated by studying factors and condition that results in discarding. Information regarding cost of buying car, energy consuming to operate car, maintenance cost including gas, registration or renewal fee, as well as money gained from selling car are examined to determine how long people discard car. Information are studied and provided in scenarios: Status quo and newly proposed policy. To understand the status quo, set of variables in Table 3.2 were configured to see cost in one life cycle regarding car owner perspective.

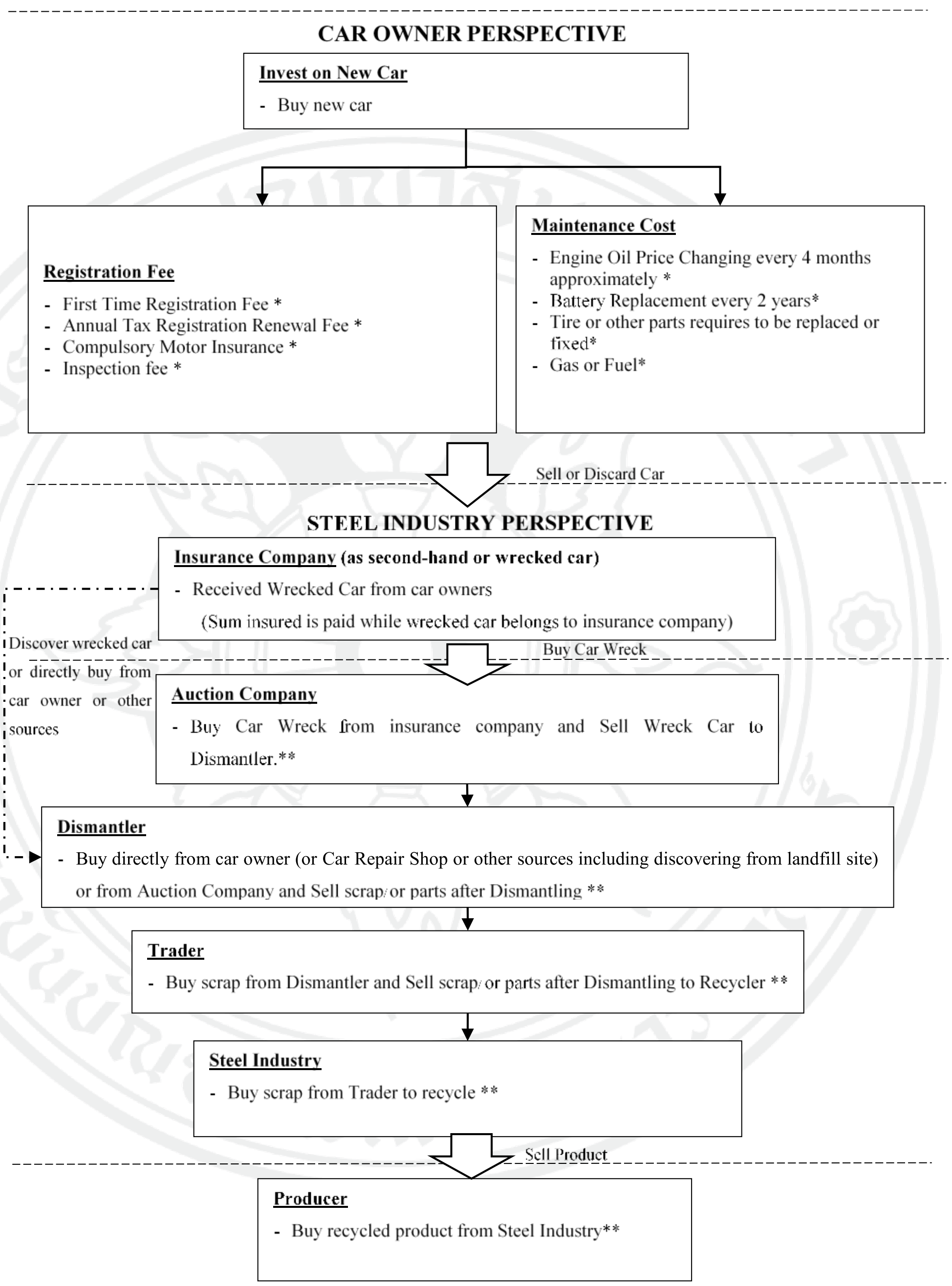

Figure 3.1 System Boundary of LCC from owner and steel industry perspectives

Note: (*) presents costs from Consumer perspective; (**) presents cost and benefits from steel industry perspective

Again, the questionnaire for Thai car owners helped to depict how costs go in car owner perspective. The questionnaire is not only to gain the car owner management method, but it also helps imply the relationship of cost and the way people manage car. Cost in any transaction regarding market's demand could reflect the way people manage their car.

This paper referred to cost of maintenance regarding remuneration compensation guideline of Bureau of the Budget (Budget Bureau, 2018). This paper referred to Toyota Yaris ATIV (J ECO) since it's the best seller model regarding DLT statistics (Department of Land Transport, 2018b). Table 3.2 illustrates Cost of Components and Activities with Data source.

Table 3.2 Cost of Components and Activities with Data source

Cost of Component and Activities	**Data source**
Costs of new car	Toyota Motors Thailand
Costs of gasoline	Bureau of the Budget
Cost of Registration	Department of Land Transport
Cost of Compulsory Motor Insurance	Department of Land Transport
Cost of Maintenance	Bureau of the Budget, 2018
Cost of license renewal	Department of Land Transport
Cost of Inspection	Department of Land Transport
Cost of used car	Formula

Note: Assuming average mileage is 20,000 km per year and there is not maintenance cost for the first 3 years since a warranty is covered.

3.2.2 To understand LCC of ELV from steel industry perspectives

From the perspective of steel industry, starting from discarded vehicle, each stakeholder has expense and income from buying and selling vehicles' parts. Supply of steels and price per steel in weight are investigated and calculated to gain profits. At the end, steel industry transforms steel as raw material to steel product. To analyze the cost of steel, selling price, operating cost, and buying price are collected from stakeholder to see the margin of stakeholder. This paper used life cycle cost technique to determine cost of steel at each state. However, a financial perspective alone will not capture the gains to society at large and a quantitative assessment of economic costs and benefits is necessary.

Starting from auction company, unusable car is sold to dismantler. Sometimes, however, unusable car is discovered by dismantler itself. After the process of dismantling, dismantler sells scrap car to trader. Trader sell scrap to steel industry and finally the product from steel industry is sold to producer, such as construction company. Figure 3.1 represents System Boundary of LCC which describes each stakeholder's perspective from purchasing a car by car owner until it is returned as raw material to manufacturer. Moreover, Table 3.3 shows stakeholders and their activities from steel industry perspective.

Table 3.3 Stakeholders and their activities from steel industry perspective

Step	Stakeholder	Activity	Stakeholder	Data source
1	Auction Company	Purchase from	Insurance or Car Owner	Auction Company, Insurance and Car Owner
2	Dismantler	Purchase from	Auction	Dismantler and Auction
3	Trader	Purchase from	Dismantler	Trader and Dismantler
4	Steel Industry	Purchase from	Trader	Steel Industry and Trader
5	Producer	Purchase from	Steel Industry	Steel Industry and Trader

3.2.3 Scenario analysis for ELV management systems

In this study, two scenarios were developed to understand the costs related to the current situation of car owner behavior in Thailand and the ones related to new proposed policy.

The first scenario was developed to understand the costs related to the current situation of car owner behavior. As C1 type are focused in this paper and 1,200 CC engine car are mostly used by Thai people, car price, in this paper, has been assumed by using car price of Toyota Yaris 1.2J produced in year 2013-2015 (Department of Land Transport, 2018b). The maintenance costs are referred from the report of Bureau of The Budget. Annual tax registration renewal fee is referred from DLT and used to test regarding as-is policy. Moreover, a frequency of changing car, as control variable, was used to determine its price at the end. Table 3.4 illustrates set of parameters this research has set up for each scenario in order to understand a life cycle cost and perspective of car owner regarding policy. Using discount rate of 1 percent as the core and headline inflation rate from Bank of Thailand fluctuate in a narrow frame, 0.7-1.1 percent in 2018 and 0.9-1.1 in 2019 (Bank of Thailand, 2018), parameters in scenario one are given to generate the situation that inspection is not strictly performed. That means people do not have to maintain car in good condition. The registration fee and other expenditure parameters are given with real information.

Table 3.4 Parameter and Values for each scenario

Scenario	Description	Parameters	Values	Data sources
Status-quo	Based on age of car people use it in one life cycle, Maintenance cost paid to be able to pass inspection policy, Car price after used, and no government subsidy for handed ELVs	Initial Car Price	479,000 baht	Toyota Motor (Thailand)
		Maintenance	0 baht from Year 1 to 3 11,900 baht from year 4	Field Survey
		Fuel (Gas) and Lubricant	45,800 baht per year	Bureau of the Budget
		Registration Tax & Fee	21,570 baht at the first place of registration	Bureau of the Budget
		Frequency of Changing car	20 years	Department of Land Transport
		Compulsory Motor Insurance	600 baht	Department of Land Transport
		Annual Tax Registration Renewal Fee	1,200 baht per year and applying discount after year 6 for 10 percent until reaching 50%	Department of Land Transport
		Inspection Fee	200 baht	Department of Land Transport
Propose new policy	Car is required to pass a high standard inspection. annual tax registration renewal fee does not decrease when car is getting older.	Initial Car Price	479,000 baht	Toyota Motor (Thailand)
		Maintenance	0 baht from Year 1 to 3 11,900 baht from year 4 to 6 69,900 baht from year 6	Bureau of the Budget
		Fuel (Gas) and Lubricant	45,800 baht per year	Bureau of the Budget
		Registration Tax & Fee	21,570 baht at the first place of registration	Bureau of the Budget
		Frequency of Changing car	20 years	Department of Land Transport
		Compulsory Motor Insurance	600 baht per year	Department of Land Transport
		Annual Tax Registration Renewal Fee	1,200 baht per year and remains the same throughout the life time	Department of Land Transport
		Inspection Fee	200 baht per year	Department of Land Transport

According to literature review of ELV management in developed countries, developing high standard of inspection and increasing annual tax are the fundamental towards ELV sustainable management. For second scenario, the proposed new policy, the parameter and costs related were also summarized in Table 3.4, by not decreasing registration fee as car is getting older, applying strict inspection policy so that car should emits lower Carbon and stay in very good condition to pass inspection criteria. With this new policy, car owners seriously maintain car to be in high standard. This could mean more money spent in maintaining. Note that the average age of car in EU was approximately 12 years (Simic, 2013)**.** The increasing annual fee and maintenance costs are added to make the total costs spent in year 20 equals to year 12.

3.3 To propose an ELV management policy in Thailand (from cost perspective)

The results from objectives 1 and 2 together with literature reviews of ELV management system of other countries are drawn to the answer of objective 3.

For the first objective, it is important to know number of ELVs discarded each year as well as understand ELV management status quo in Thailand which has never been reported. By understanding those situations, ELV management policy can be proposed.

For the second objective, LCC of ELV from the perspective of car owners and steel industries led to the practical and economically feasible policy. After the LCC is quantified, the scenario analysis is discussed to understand how the ELV management system (e.g. add disposal fee or annual tax, inspection regulation) could affect car owner. This is also to understand what policy could work for Thailand situation regarding ELV management.

CHAPTER 4

RESULTS AND DISCUSSIONS

The results and discussions present the value gained from the data collecting and calculated using the methodology mentioned in the previous chapter.

4.1 To study the ELV management status quo in Thailand, and to investigate how people manage their unusable cars

4.1.1 To understand the life cycle of passenger car and ELV management Status quo

By working on field surveys and interview stakeholders, the life cycle of a vehicle is illustrated, as in Figure 4.1, that car owners stop using cars with or without deregistering. After a car is discarded, it is sent to a second-hand car shop, car dealership service center, automobile repair shop, vehicle spare part shop after being dismantled by automobile repair shop or dismantler, or landfill site. Most car owners sell their used car by posting to media or friends, by selling to a second-hand car shop, or by selling to a car dealership service center. Wrecked cars from accidents go to the automobile repair shop usually prescribed by the insurance company. In some cases, is not worth repairing a car from an accident. Some money from insurance will be paid to the car owner, while the wrecked car becomes the property of the insurance company. The insurance company sells wrecked cars to an auction company or leaves it at the automobile repair shop. Sometimes the second-hand car shop or the insurance company sells a used car to the automobile repair shop, which restores it as new. In turn, the automobile repair shop sells these restored cars back to the second-hand car shop. A vehicle spare part shop is a place for selling and buying automobile parts. The automobile repair shop buys parts from the vehicle spare part shop as brand new or second-hand. Above all, Landfilling is the way people might discard their cars for convenience; however, it is only a small number since most of the cars are valuable through sale. The study regarding second-hand market car by (Pholphirul, 2007) supports our analysis about second-hand cars and the car parts market in Thailand. This shows us that unused cars can be sold for a relatively good price in Thailand. Some cars, in the end, are in too poor of a condition to be sold as second-hand car. The quality of parts is sometimes not good enough to be reused. It eventually becomes a wrecked car.

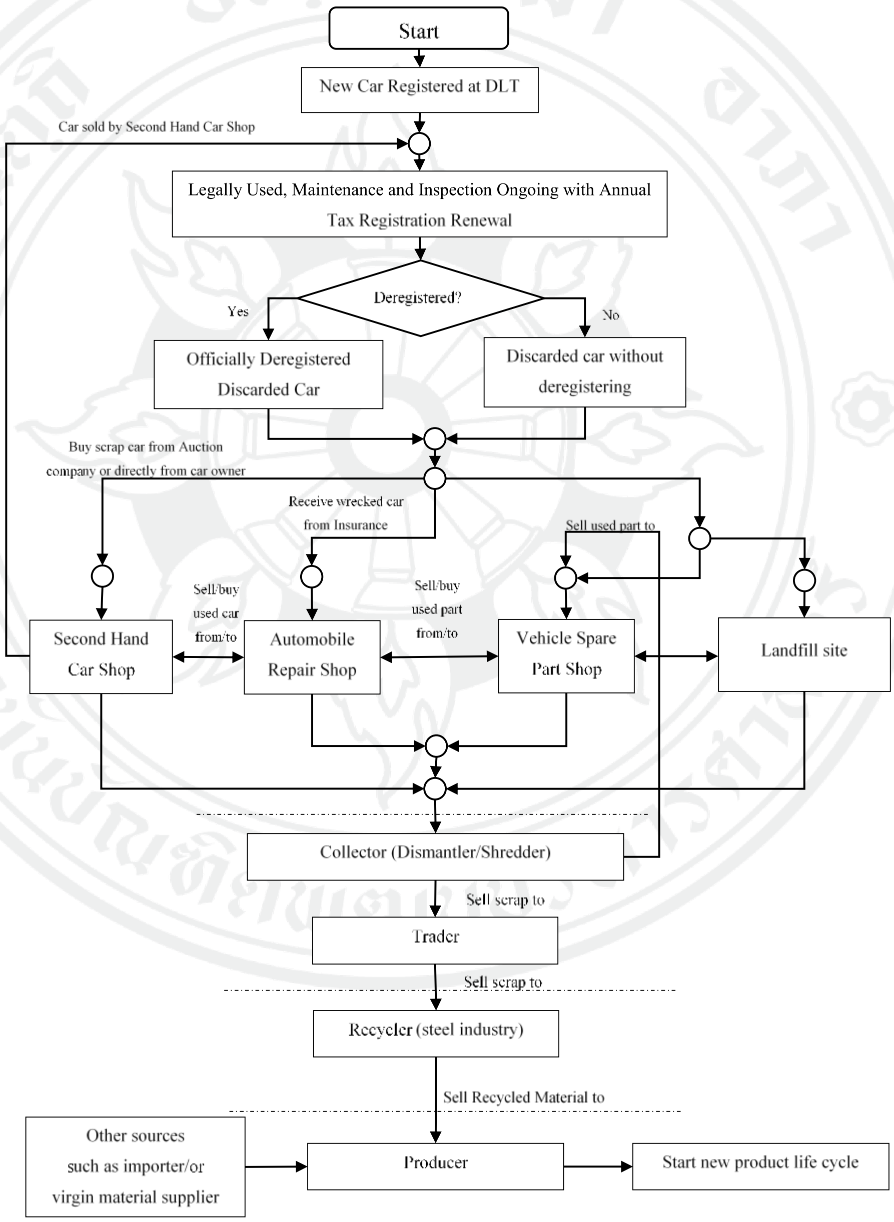

Figure 4.1 Flow Process for each stakeholder in ELV Value Chain

A collector, which is a dismantler or shredder, is another stakeholder in ELV lifecycle. The activities of collectors are to collect ELVs and dismantle them after that. After dismantling, the parts that are in good condition are sold to be reused or refurbished. Outputs such as ferrous materials are sent to a shredder where they are scrapped and then sold to traders. Traders resell to a steel industry as supply material. However, the source of ELVs regarding prior studies is not found because most ELVs are illegally collected and operated.

For steel material, using a process such as inductive furnace yields brand-new steel for construction. The product for construction is, for example, I-beam steel. As discovered through interview with the Recycling Industry and a collector, steel from ELV is relatively difficult to be dismantled and requires many processes to filter out contaminants. Steel from other sources, such as household, is easier to recycle. Material in good condition is chosen to be reused or remanufactured for a vehicle than to be recycled. Still, regarding the interview with recycler, steel manufacturer, there's not enough input of steel so it partially requires imports from overseas. The high demand of scrap steel is supported by the statistics provided by Thai Customs Department (also called the Thai Customs), which show that imported steel in Thailand is increasing. Information from the Thai Customs shows a substantial increase of ferrous scrap imports by Thailand in the Year 2017 compared to the previous year. Moreover, the ferrous scrap imports by Thailand totaled 108,019 metric tons in April 2017. When compared with March 2017, which is 69,972 metric tons, the imports are higher by 54.4%. When compared with the same month in year 2016, the imports during the month are higher by almost 97.3%.

In 2017, the monthly ferrous scrap imports by Thailand averaged at 113,000 tons per month. Also, going by the current rate, the cumulative imports by the country are likely to total around 1.370 million tons during the entire year 2017 (Thai Customs Department, 2018)

PCD, from a field survey, is mainly responsible for controlling pollution by providing information as a consultant to related departments. There is no task regarding regulations or law enforcement. For example, PCD gives information to the DIW to set the severity of risk and hazard. Collaborating with PCD, the DIW regulates car manufacturers and related producers, maintenance car shops, and dismantlers regarding to the manufacturing process to ensure quality of treatment and restrict pollution emission.

Additionally, from an interview with the car manufacturer, TOYOTA DAIHATSU ENGINEERING & MANUFACTURING (TDEM), the status of legislation for Car-Recycling-law is not ready for the countries in ASEAN except Vietnam which will be operative from 2018. EU, EFTA (4-member states of Switzerland, Norway, Iceland, and Liechtenstein), Japan, Taiwan, Korea, Turkey are the countries in which Car-Recycling-law is enacted. However, Russia, India, China, Mexico, and Vietnam are still studying the process. The difficulty is how to find and trace a vehicle through its end of life. Regardless of the status quo in Thailand, from the principles of ELV proper treatment, TDEM found that treating hazardous materials properly is not difficult and is affordable because the equipment is simple: gas recovery equipment, manual recovery air bag inflator, suction discharge device (oil, fluid), furnace air clean processor. However, the step of recycling should be applied with high technology to gain high quality of outputs and more on recovery. It is challenge and is complicated. Some parts must be sent back to Japan to continue the recycling process. Because Toyota is concerned about the increasing number of ELV expected to reach 200,000 to 300,000 in 2020's, Toyota plans to establish a recycling-based-society. The full society is set to be completed in 2050.

4.1.2 Questionnaire and Secondary data to understand car owner behavior and estimated average age of car

From the questionnaire, 118 respondents, car owners, who responded to the survey are mostly at the age of 27 to 37 years old, accounting for (MEANS = 34.3 and SD = 9.943). 57.6 percent are females while 42.4 percent are males. Salaries are mostly in the range of 15,000 – 30,000 baht per month, accounting for 28.8%. Most of the respondents are living in Bangkok, so the licenses of vehicles are registered in Bangkok. The most popular brand is Honda and Toyota, accounting for 30.5 and 22 percent respectively. Age of car they are using is approximately 1-5 years old. Around half of respondents rate their knowledge of maintaining and using skills at moderate with the mean 3.1 out of 5. The displacement of vehicles used by most respondents are less than 1,900 CC, accounting for 69.5 percent. Most of the car owners use their car every day (65.3%). Driving distance (Mileage) ranges, for most car owners, between 10,001- 20,000 kilometers per year, accounting for 33.9 percent. Most of them bring their car in for inspection when it reaches approximately 5,001 to 10,000 Kilometers. Approximately 60 percent of them intend to use car until it is 6-10 years old before discarded. More importantly, most of them sell a car at second-hand car shop, sell by posting via website or social media, or exchange for a new car at a car dealer, accounting for 32.2, 32.9, 27.1 percent respectively. Some choose to sell to an automobile repair shop (3.4%) and some sell to a Vehicle spare part shop (1.7%). Noticeably, only 1.7 percent of respondents discard their car by ignoring such as disposing at landfill site or along the street. From the response, it reflects that cars no longer used by their owners do not always become ELVs, since they are sold to be reused as second-hand car. With regard to the interview with second-hand car shops and automobile repair shops, cars might be sold to continue its life or dismantled to obtain parts depending on its condition.

In addition, from the survey, discarded cars, or even wrecked cars, can be restored and sold to make profits, or even sold as parts after dismantling. These are reasons why selling a car, after car owners stops using it, is easy. Another factor is from the previous evidence that inspections in Thailand are easy to pass, and older cars are charged a lower fee. This implies that old cars with below standard condition can legally drive on the road. This encourages the second-hand car marketplace to be popular, because a used car still valuable with high demand. The paper researched by Taneerananon et al. (2005) explicated the inspection effectiveness in Thailand. The inspection process and criterion are below standard compared to developed countries, which also leads to traffic accidents. Table 4.1 shows the information from questionnaire.

To estimate how long the car has been used until discarded, this paper also used secondary data for analysis. It requires the number of cars at each specific age in each year in order to imply some facts about how people use their car and when they discard it. Table 4.2 shows the year and age of car we focused upon. In year 2007, the total number of 1 to 5 years old cars is 552,878 units. As cars from 2007 at age 1 to 5 years old became the 11-16 years old car in 2017, the number of cars is compared. 1,319,188 is the number of cars in 2007.

However, in 2017, it became 1,346,106 units. It can be implied that most of the cars are still been used until year 10-15. In the same way, the number of cars at age 6 to 10 is 552,878. In 2017, the car at age 16 to 20 became 534,796 units. The changes in the number of cars are 18,082, which is the number of cars discarded at year 16 to 20. There is only 10 years worth of data, so looking out 20 years is analyzed using trends.

Table 4.1 Demographic Characteristics of Respondents

Demographic Characteristics of Respondents

Characteristics(i)	Frequency	Percentage(ii)	Mean	S.D.
Age				
	-	-	34.3	9.943
Below 20 years old	7	5.9%		
20 - 40 years old	87	73.7%	-	-
41 - 60 years old	21	17.8%		
61 years old and above	3	2.5%		
Gender:				
Male	50	42.4%	-	-
Female	68	57.6%		
Income level (Per month) :				
Below 15,000 THB	7	5.9%		
15,000 – 30,000 THB	34	28.8%		
30,001 – 45,000 THB	25	21.2%		
45,001 – 60,000 THB	15	12.7%	-	-
60,001 – 75,000 THB	12	10.2%		
75,001 – 90,000 THB	6	5.1%		
90,001 – 105,000 THB	2	1.7%		
105,001 THB or above	17	14.4%		
Car brands :				
Honda	36	30.5%		
Toyata	26	22.0%		
BMW	8	6.8%		
Nissan	15	12.7%		
Mazda	6	5.1%		
Isuzu	3	2.5%	-	-
Mercedes-Benz	9	7.6%		
Mitsubishi	4	3.4%		
Ford	6	5.1%		
MG	1	0.8%		
Suzuki	2	1.7%		
Chevrolet	2	1.7%		
Origin of car registration :				
Bangkok Metropolitan Region	102	86.4%	-	-
Provincial	16	13.6%		
Vehicle age :				
1 - 5 year(s)	72	61.0%		
6 - 10 years	31	26.3%		
11 - 15 years	5	4.2%		
16 - 20 years	5	4.2%	-	-
21 - 25 years	2	1.7%		
25 - 30 years	1	0.8%		
31 years or above	2	1.7%		

(i) All characteristics are self-reported.

(ii) n = 118

Demographic Characteristics of Respondents (Cont.)

Characteristics(i)	Frequency	Percentage(ii)	Mean	S.D.
Number of car(s) in possession :				
1	59	50.0%		
2	34	28.8%		
3	9	7.6%	-	-
4	8	6.8%		
5 or above	8	6.8%		
Experience of car usage and car maintenance (1 = Beginner & 5 = Expert) :	-	-	3.1	0.958
Vehicle displacement :				
1,100 - 1,300 CC	12	10.2%		
1,301 - 1,500 CC	31	26.3%		
1,501 - 1,700 CC	15	12.7%	-	-
1,701 - 1,900 CC	24	20.3%		
More than 1,901 CC	36	30.5%		
Frequency of car usage				
Everyday	77	65.3%		
4 - 6 times per week	12	10.2%		
2 - 3 times per week	19	16.1%		
1 time per week	3	2.5%	-	-
1 time per month	1	0.8%		
2 -3 times per month	5	4.2%		
Never	1	0.8%		
Average mileage per year (Each car)				
Below 10,000 Kilometres	33	28.0%		
10,001 - 20,000 Kilometres	40	33.9%		
20,001 - 30,000 Kilometres	23	19.5%	-	-
30,001 - 40,000 Kilometres	8	6.8%		
40,001 - 50,000 Kilometres	4	3.4%		
50,001 Kilometres or above	10	8.5%		
Frequency of vehicle inspection				
1 - 5,000 Kilometres	14	11.9%		
5,001 - 10,000 Kilometres	49	41.5%		
10,001 - 15,000 Kilometres	42	35.6%		
15,001 Kilometre or aboves	5	4.2%		
Only when disfunctional	8	6.8%		
Appropriate age of car at use phase				
1 - 5 year (s)	13	11.0%		
6 - 10 years	69	58.5%		
11 -15 years	28	23.7%		
16 - 20 years	7	5.9%	-	-
21 - 25 years	1	0.8%		
25 - 30 years	-	-		
31 years or above	-	-		
How to discarded car				
Exchange for a new car at Car Dealer	32	27.1%		
Sell at second-hand car shop	38	32.2%		
Sell to Automobile Repair shop	4	3.4%		
Sell to Vehicle Spare Part shop (Junk Yard)	2	1.7%		
Annouce for sell via media (e.g. post to web or social media)	40	33.9%		
Dispose at landfill site or along the street	2	1.7%		
(i) All characteristics are self-reported.	118			

(ii) n = 118

In conclusion, this can imply some people are still using cars for more than 20 years. While in the questionnaire, respondents report that a car has been used for not over 10 years. With both pieces of information, this can imply that people might purchase and use cars as second-hand.

Table 4.2 Statistics of vehicles: Cumulative registered number of C1 vehicles at each age grouped by year 2007 to 2017 by focusing on specific year and age (Currency Unit: baht)

Year Age (Year)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2007
<1	298,057	319,156	299,737	452,137	530,537	881,852	913,568	593,990	516,566	536,903	266,715
1	297,451	297,496	319,021	299,435	451,963	530,160	881,088	912,736	593,248	516,015	585,981
2	313,147	297,118	297,195	318,473	299,309	451,668	529,812	880,379	911,850	592,655	529,581
3	288,008	313,068	296,919	296,523	318,292	299,124	451,376	529,357	879,558	910,969	545,782
4	236,262	285,448	311,155	294,439	294,270	315,783	297,688	448,709	525,904	873,818	734,252
5	184,320	235,619	285,244	310,313	294,065	293,503	315,019	296,830	447,410	523,888	905,240
6	140,552	183,091	235,234	284,702	310,178	293,709	292,870	313,987	295,805	445,574	724,862
7	108,742	138,829	182,492	234,573	284,317	309,393	292,901	291,482	312,195	294,158	486,196
8	77,651	107,096	138,144	181,864	234,342	283,764	308,568	291,829	289,910	310,060	373,182
9	55,805	76,798	106,762	137,695	181,722	234,030	283,090	307,229	291,483	287,903	304,163
10	170,128	55,245	76,529	106,523	137,375	181,490	233,578	282,021	305,641	289,281	301,090
11-15	804,001	851,007	743,226	649,540	590,050	546,050	560,216	739,857	945,009	1,140,256	1,346,106
16-20	275,323	351,509	467,507	576,355	671,232	773,914	827,574	719,447	626,331	565,576	534,796
>20	310,775	297,602	319,382	354,256	403,790	462,014	549,214	676,406	801,524	909,956	1,102,944

4.1.3 Secondary data to estimate number of ELV

In most developed countries, the number of deregistered vehicles practically should be more than number of ELVs with appropriate management/treatment because the deregistered vehicle normally includes used cars for export, unregistered cars used within private sites, or cars illegally dumped as waste (Sakai et al., 2014). However, only the number of vehicles that were deregistered permanently cannot imply the number of ELVs in Thailand. Instead, the number of vehicles that did not extend the license appropriately helps us estimate the number of ELVs.

Applied by the formula in the previous section, these yields estimate the number of ELVs. However, because of the suspended law enacted in 2003, this study focused from the year 2007 for accuracy (Department of Land Transport, 2018b). These two approaches resulted in a result that is close to each other almost every year as the assumption from the previous section. The significant difference of the results of the two approaches (in some years) may be because of the error from the collecting method in the year after the suspended law was enacted. Moreover, the different cut-off period of licenses may be another reason (see Table 4.3).

From the in-depth interview with the staff from the Statistics Department at DLT, by law, cars with legal licenses that are discarded are required to be deregistered. In reality, license plates and chassis numbers does not match to each other. Consequently, the license of that car may be, in the future, reused for another new car. However, without extending or deregistering licenses for more than 3 years, those cars will be suspended by DLT (Land Transport Act, 2003). The act has been enforced since 2003; however, DLT has begun to collect data since year 2007. The activities that may affect the number of ELVs are an illegal subrogation of discarded vehicle license. That makes the number of ELVs greater than it should be regarding the statistics. However, the case of renewing after suspension does not affect the result of the calculation or make it inaccurate since every license suspended requires a new registration instead of renewing. The results from both approaches are very close to each other. This validates the logic that suspended or deregistered cars results in a decrement of cumulative number of registered cars. Regarding statistics, the number of suspended and deregistered cars is generally increasing. That means the number of ELVs has been increasing over the years.

Table 4.3 Estimated number of ELVs calculated using first and second approaches

Year	Estimated no. of Discarded C1 Vehicle (Using 1st Approach)	Estimated no. of Discarded C1 Vehicle (Using 2nd Aprroach)
2017	-	94,152
2016	84,243	98,369
2015	63,612	68,589
2014	44,633	56,146
2013	39,163	43,791
2012	37,719	39,171
2011	37,650	37,067
2010	34,592	47,457
2009	39,618	39,685
2008	53,880	80,430
2007	48,854	58,415
2006	-	-

4.2 To analyze the LCC of ELV from car owner and steel industry perspectives

4.2.1 To understand LCC of ELV from car owner perspective

To understand LCC of ELV from car owner perspective, the cost during use phase is investigated. From initial car price, registration fee, gas and maintenance cost incurred each year for car owner. The registration fee, however, is decreasing regarding DLT regulation (Department of Land Transport, 2018b). The maintenance is increasing each year starting from 0 baht for the first three years. The maintenance for 4th to 6th years increases to 11,900 baht per year. After year 6, the maintenance cost estimated to be 69,900 baht per year. The gas cost is steady for each year. After using a car for 20 years, it can be sold for 50,000 baht according to interviews at second-hand car shops. This is an estimation of used car price as it varies depending on car condition and market demands of wrecked cars. Table 4.4 illustrates the cost of each activity from a car owner perspective.

Table 4.4 Estimated number of ELVs calculated using first and second approaches

Cost of Component and Activities	Value (Baht)	Data source
Costs of car	479,000	Toyota Motors Thailand
Costs of gasoline	42,900 baht per year	Bureau of the Budget
Cost of Registration	21,570 baht at the first year	Department of Land Transport
Cost of Compulsory Motor Insurance	600 baht per year	Department of Land Transport
Cost of Maintenance	0 baht per year from year 1 to 3 11,900 baht per year from year 4 to 6 69,900 baht per year from year 6	Bureau of the Budget, 2018
Cost of license renewal	Per year = 1,800 baht	Department of Land Transport
Cost of Inspection	200 baht per year after year 6	Department of Land Transport

When applying all data in Table 4.4 and developed the cash flow for 20 years, the NPV at year 20 is -1.4 million baht (see Table 4.5).

Table 4.5 Scenario 1 (Status Quo) (Currency Unit: baht)

Year	Capital costs	Registration	Maintenance	Gas	Net Cost	Net Revenue	PV	NPV
0	479,000		0	0	479,000	0	0	0
1	0	21,570	0	42,900	64,470	0	-63,832	-542,832
2	0	1,800	0	42,900	44,700	0	-43,819	-586,651
3	0	1,800	0	42,900	44,700	0	-43,385	-630,036
4	0	1,800	11,900	42,900	56,600	0	-54,391	-684,428
5	0	1,800	11,900	42,900	56,600	0	-53,853	-738,281
6	0	1,680	11,900	42,900	56,480	0	-53,207	-791,487
7	0	1,760	11,900	42,900	56,560	0	-52,755	-844,242
8	0	1,760	11,900	42,900	56,560	0	-52,232	-896,474
9	0	1,760	11,900	42,900	56,560	0	-51,715	-948,189
10	0	1,760	11,900	42,900	56,560	0	-51,203	-999,392
11	0	1,760	11,900	42,900	56,560	0	-50,696	-1,050,088
12	0	1,760	11,900	42,900	56,560	0	-50,194	-1,100,282
13	0	1,760	11,900	42,900	56,560	0	-49,697	-1,149,980
14	0	1,760	11,900	42,900	56,560	0	-49,205	-1,199,185
15	0	1,760	11,900	42,900	56,560	0	-48,718	-1,247,903
16	0	1,760	11,900	42,900	56,560	0	-48,236	-1,296,138
17	0	1,760	11,900	42,900	56,560	0	-47,758	-1,343,896
18	0	1,760	11,900	42,900	56,560	0	-47,285	-1,391,181
19	0	1,760	11,900	42,900	56,560	0	-46,817	-1,437,998
20	0	1,760	11,900	42,900	56,560	0	-46,353	-1,484,352

4.2.2 To understand LCC of ELV from steel industry perspective

Steel from ELVs are relatively difficult to be found or traced. A life cycle of car could be very long until it is dismantled for use in other cars. The recycling process or policy does not encourage people to put their own vehicles into the treatment process. Instead, a used car ready to be discarded is normally sold as second-hand car. We calculate backward from the data collected from the steel industries. Per interviewing with steel industries, 600kgs is the weight of steel recycled from an ELV. Steel industries normally purchase steel from trader around 9 baht per kg. The cost per ELV of steel industries will be 5,400 baht. Moreover, from the field survey, the cost per ELV of auction company is 3,000 baht. The cost that a dismantler could purchase from the auction company normally is 3,300 baht per ELV. Traders eventually purchase more than 3,300 baht per ELV and should not purchase more than 5,400 baht per ELV as a highest price. Finally, the producer, such as construction company, purchases steel from steel industry approximately 15,000 baht per ELV (Department of Internal Trade, 2018). Table 4.6 shows each step of buying and selling steel after an owner discards a car. From the above information, the market-driven aspect is important to support stakeholders of steel industry perspective to survive in business. The price of an ELV depends on demand of scrap steel and supply sources.

Table 4.6 Estimated price of purchasing and operation cost (Currency Unit: baht)

Step	Stakeholder	Activity	Stakeholder	Estimated Price of Purchasing (Capital cost) per ELV (baht)	Estimated Operation Cost per ELV (baht)
1	Auction Company	Purchase from	Insurance or Owner	3,000	
2	Dismantler	Purchase from	Auction	3,300	<900
3	Trader	Purchase from	Dismantler	>3,300 and <5,400	<1,200
4	Steel Industry	Purchase from	Trader	5,400	<5,400
5	Producer	Purchase from	Steel Industry	15,000	

System Boundary of LCC from owner and steel industry perspectives with cost are summarized in Figure 4.2.

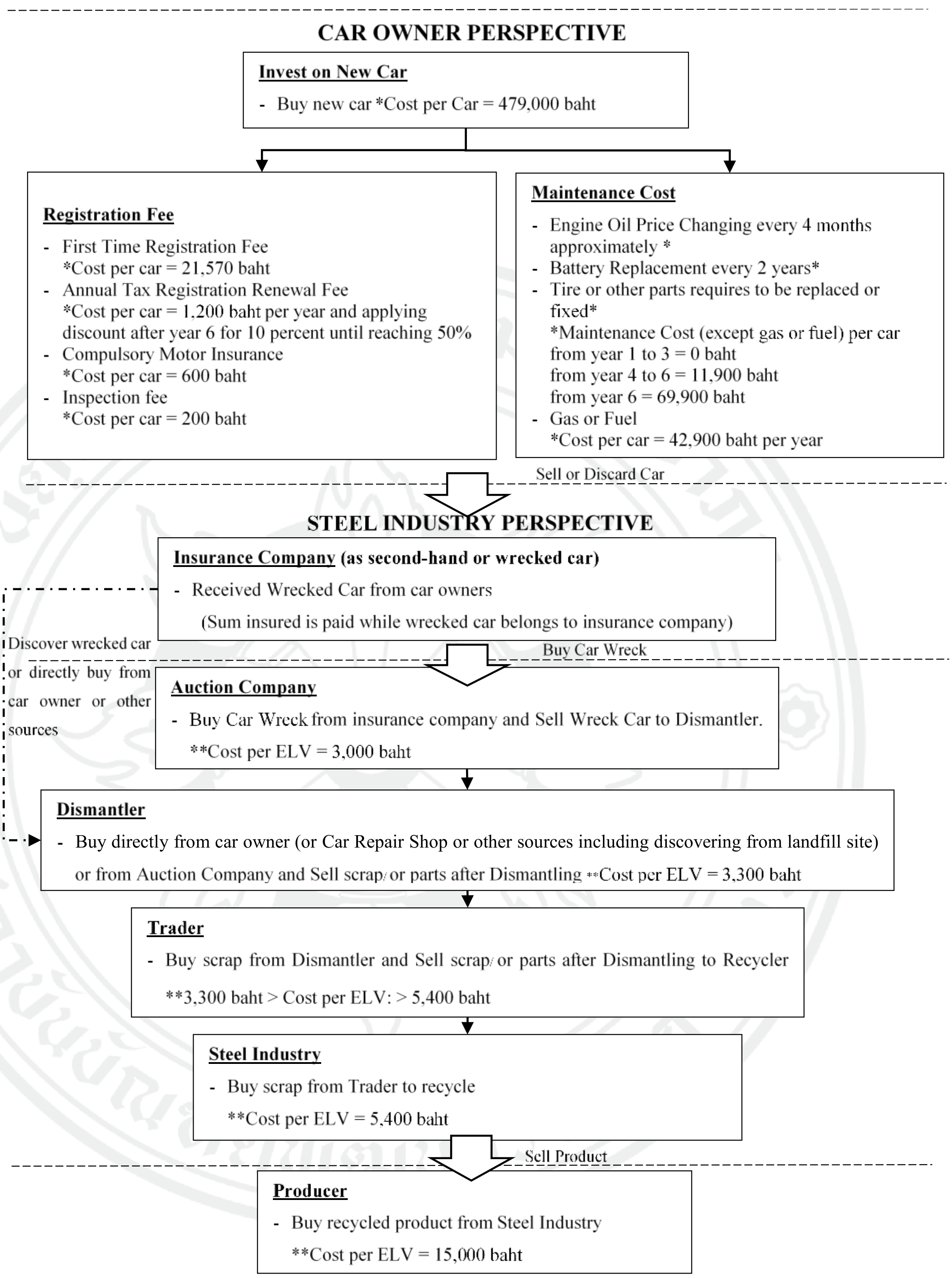

Figure 4.2 System Boundary of LCC from owner and steel industry perspectives (cost)

Note: (*) presents costs from Consumer perspective; (**) presents cost and benefits from steel industry perspective

4.2.3 Scenario analysis for ELV management systems

From the information that age of car is increasing each year as well as the estimated age of car analyzed above, using 20 years as status quo for car usage lifespan, and with the new policy applied, below are the results of cost that people spends in both scenarios.

The first scenario applies parameters to create the situation similar and close to the status quo in Thailand.

From the data presented in the earlier section, the annual tax registration renewal fee for car registration decreases after year 6 to a maximum of fifty percent so people with older car tends to pay less. This is also one of the important factors that discourage people to buy a new car. With regards to the field survey with Car Inspection Division at DLT, it shows that the inspection process in Thailand is not intensively strict, and that it is easy to pass an inspection each year regarding standard of inspection. If the car owner use car for 20 years, the NPV was approximately 1.4 million baht as shown in Table 4.5.

Regarding the second scenario, law and regulation is applied so that people are required to fix serious maintenance issues to pass an inspection. The renewal fee is applied so that people have to pay more for an older car. With the proposed policy, if the car owners keep using for 20 years, the total cost is estimated to be 2.19 million baht which is far higher than the status quo (scenario 1). The expenditure gets higher as the car ages in the second scenario (see Table 4.7).

Table 4.7 Scenario 2 (Extended Responsibility with Changing in Policy) (Currency unit: baht)

Year	Capital costs	Registration	Maintenance	Gas	Net Cost	PV	NPV
0	479,000		0	0	479,000	0	0
1	0.00	21,570	0	42,900	64,470	-63,832	-542,832
2	0.00	1,800	0	42,900	44,700	-43,819	-586,651
3	0.00	1,800	0	42,900	44,700	-43,385	-630,036
4	0.00	1,800	11,900	42,900	56,600	-54,391	-684,428
5	0.00	1,800	11,900	42,900	56,600	-53,853	-738,281
6	0.00	1,800	11,900	42,900	56,600	-53,320	-791,601
7	0.00	2,000	69,900	42,900	114,800	-107,076	-898,677
8	0.00	2,000	69,900	42,900	114,800	-106,016	-1,004,692
9	0.00	2,000	69,900	42,900	114,800	-104,966	-1,109,659
10	0.00	2,000	69,900	42,900	114,800	-103,927	-1,213,586
11	0.00	2,000	69,900	42,900	114,800	-102,898	-1,316,484
12	0.00	2,000	69,900	42,900	114,800	-101,879	-1,418,363
13	0.00	2,000	69,900	42,900	114,800	-100,870	-1,519,233
14	0.00	2,000	69,900	42,900	114,800	-99,872	-1,619,105
15	0.00	2,000	69,900	42,900	114,800	-98,883	-1,717,988
16	0.00	2,000	69,900	42,900	114,800	-97,904	-1,815,892
17	0.00	2,000	69,900	42,900	114,800	-96,935	-1,912,826
18	0.00	2,000	69,900	42,900	114,800	-95,975	-2,008,801
19	0.00	2,000	69,900	42,900	114,800	-95,025	-2,103,826
20	0.00	2,000	69,900	42,900	114,800	-94,084	-2,197,909

From the first scenario, at year 20 the cost was 1.4 million baht, which is equal to the cost in year 12 of the second scenario. This can imply that people tentatively change cars approximately a year 12. The above analysis regarding different scenarios are compared as shown in Table 4.8 and chart in Figure 4.3.

Table 4.8 A Comparison between Scenario 1-2 (Currency Unit: baht)

Year	Status Quo	Policy Change	Cost Increase by Policy Change
1	-542,832	-542,832	0
2	-586,651	-586,651	0
3	-630,036	-630,036	0
4	-684,428	-684,428	0
5	-738,281	-738,281	0
6	-791,487	-791,601	113
7	-844,242	-898,677	54,435
8	-896,474	-1,004,692	108,218
9	-948,189	-1,109,659	161,469
10	-999,392	-1,213,586	214,193
11	-1,050,088	-1,316,484	266,395
12	-1,100,282	-1,418,363	318,080
13	-1,149,980	-1,519,233	369,254
14	-1,199,185	-1,619,105	419,920
15	-1,247,903	-1,717,988	470,085
16	-1,296,138	-1,815,892	519,753
17	-1,343,896	-1,912,826	568,930
18	-1,391,181	-2,008,801	617,620
19	-1,437,998	-2,103,826	665,827
20	-1,484,352	-2,197,909	713,558

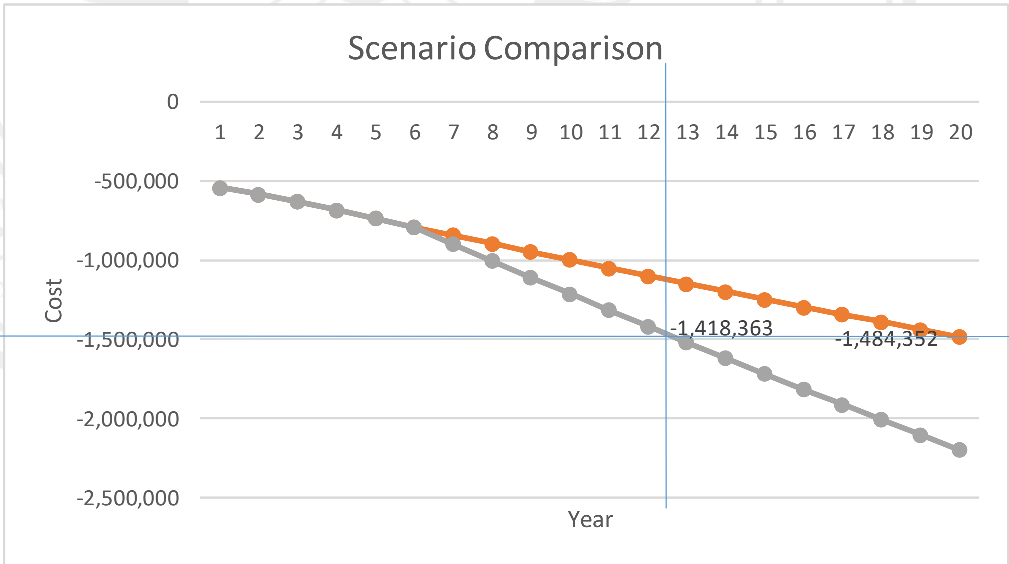

Figure 4.3 Comparison of Scenario 1 and 2 in Chart

4.3 To propose an ELV management policy in Thailand (from cost perspective)

From the estimated number of ELVs in Thailand, there are 84,000 vehicles discarded in 2016. In Thailand, as ELV management is not in place, collectors are not centralized. Dismantlers can be found across country; however, most of them are illegal and some are not professionally operated in terms of environmental issues. Because the ELV management system is not efficient, it generates a variety of environmental problems.

In summary, there is no direct law enforcement to regulate ELV management system. Indirect ones such as the act on the maintenance of the cleanliness and orderliness of the country, and the Factory Act are enacted to help manage discarded cars. No party is responsible for recycling costs. Parties who gain the profit in recycling have willingness to pay for wrecked cars to resell, so costs are determined by market forces. There is neither regulation for automobile target regarding quantity nor recycle targets. Table 4.9 summarizes ELV management status quo information in Thailand.

Table 4.9 ELV management methods in Thailand

Topic	Thailand
Law enforcement	Indirect law enforcement e.g. as act on The Maintenance of The Cleanliness and Orderliness of the country, and Factory Act
Background of ELV management	No ELV management program.
Party responsible for recycling costs	Market driven based. Stakeholders are responsible for the costs.
Target automobile	No regulation
Recycle target	No target

Two major keys can help improve the ELV management process in Thailand, in the terms of car owner, recycling industries, car manufacturers and environmental perspectives.

1. Change in Policy

From the policy of increasing the annual tax registration renewal fee as well as taking more serious on car inspection by government, two policy changes are suggested. First, the annual tax registration renewal fee should be increased. Secondly, car inspections performed by the government should be stricter. These changes in policy would discourage people to keep using car for too long without maintaining car in good condition.

Moreover, the result of this policy will automatically decrease second-hand car markets since there is no demand of second-hand part that might not be cheap and in good condition. Regarding changes in policy, using a second-hand car or parts is not worth it compared to purchasing new one. However, other countries purchase second-hand cars and parts. This might create another problem regarding environment. Selling second-hand parts or exporting them to other countries gains more money than sending them to treatment process. Consequently, it might harm the environment of that country and the world. This was agreed by Fuse and Kashima (2008) which analyzed used vehicle parts in Japan exported to developing countries. This results in problems regarding environment as it does not send cars and parts to the appropriate recycling process.

2. Government Support

With new policy, owners are responsible for maintaining their car to be in good condition during use phase. From the above analysis, car owners have more expenditure to maintain their car. Government support is essential to alleviate a difficulty of how people can afford to maintain a car. How much support given should depend on the increasing of expenditure in maintenance after policy is changed. The supportive policy was agreed by the research by Poboon (2017). The recommendations in the research are to support car owners who exchange an ELV for a new electric car or to subsidize recycling operators who partake in the ELV management system.

People can change the way they use their car from the above explanation. Also, the export policy could ensure that ELVs go to the right process of recycling instead of selling to other countries. The research of Amemiya (2018) strengthened the essentials of exporting policy. In Japan, as mentioned in the research, ELVs are being transferred abroad as second-hand car. In the worst case, those are becoming 'Hi-Tech trash' which eventually impacts the environment of destination countries. While the exporting policy helps mitigate the number of exported ELVs, it increases the number of recycled ELVs locally. In conclusion, these policies and results improve the environment because cars in better condition emit less pollution and ELVs are sent to the right treatment process. Not only does ELV management help the country to mitigate environmental problems, but also it helps reduce the number of car accidents. Substandard cars are discarded for the recycling system, and only cars in good condition that function safely are allowed to be driven on the road. This eventually helps reduce car accident rates.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The number of vehicles in Thailand has been increasing over the years. DLT reports that the total number of vehicles in 2017 is approximately 38 million units, which includes more than 8 million units of C1 type. Apart from the traffic problem and pollution produced at use phase, a vehicle after its lifetime also generates serious problem in many aspects. Without efficient ELV management policy or inspection on environmental protection, vehicles have been disposed as waste across country. Some are sent to a dismantler to dismantle usable part without appropriate methods. Those ELVs certainly cause improper disposal of hazardous substances that severely impact the environment.

The objective of ELV management process is to benefit the environment, society, and related businesses who are in alignment with sustainable development. ELVs that pass through an efficient treatment process will help decrease environmental contamination from improper dismantling process, as well as reduce landfill space.

DLT has not officially reported the number of ELVs generated each year. By compiling all related data, this research found that approximately more than 84,000 units were estimated as ELV in year 2016. However, Thai people and their government are not yet seriously concerned with an ELV management system because there are no government mandates for this matter or even direct laws regarding ELV management. For example, the Act on the Maintenance of The Cleanliness and Orderliness of The Country is the policy that relates to ELV as it prohibits disposal of waste and hazardous substances in appropriately. However, it does not prescribe specific enforcement for ELV related activities. While our challenge regarding ELV management system is to help country become environmentally friendly, it should be implemented step by step to make sure it does not affect livelihood of Thai people.

One of the objectives of this study is to understand ELV management system in Thailand. The results show that the status quo of ELV management in Thailand is driven by market forces in which all stakeholders (e.g. collector, dismantler, steel industry) aim to minimize costs and maximize profits without taking the environment or societal aspects into account. Most car owners in Thailand choose to discard their cars by selling them to second-hand car shop or dealers as it is the most profitable way.

After dismantling, some car parts that are in good condition are sold for reuse or refurbished. Steel from ELVs could be recycled. In an ELV, there is approximately 600 Kg of steel component. Due to high demand, steel mills in Thailand receive steel scraps (from local and import) mostly from demolished buildings or houses. They consider steel from ELVs as an important source. However, steel scrap from an ELV is difficult to obtain because it cannot be traced back on where this ELV comes from and how it was obtained. It may come from a stolen car or an illegally imported car. Thus, steel mills are afraid to purchase ELVs from unauthorized trader. ELV has its values. If it was sent to steel recycling, the value added is estimated approximately 9 Baht/kg. Thus, instead of discarding ELVs along street or garage, it is better to send it for recycling. At a rough estimate, the valued added from steel recycling ELV is approximately 450 million Baht (84000*600*9).

Implementing an effective ELV management system in Thailand requires collaboration among public and private sectors. Also, there are many steps towards that achievement for the initial attempt to improve ELV management system in Thailand. This study suggests that the government should try to frame or enhance standard practices for dismantlers and collectors. Also, the annual car registration fee should increase as car ages. The annual inspection should be stricter, so car owners are responsible for keeping their car in good condition during the use phase.

With these policy changes, there is an increased expense for car owners e.g. increasing annual fee and maintenance costs. To alleviate this burden, sources of funding or supports from the government could be discussed in future study. For example, sources of fund could possibly come from car manufacturers, recyclers or government by implementing regulation using Extended Producer Responsibility (EPR).

An incentive could be estimated based on the status quo of the cost car owner spent on car maintenance per year. According to literature reviewed, the average lifespan of a car in developed countries is shorter than that in Thailand due to strict inspections and fees for old car. The life time of a vehicle in EU is 12 years (Simic, 2013). To understand the total costs of using car for 20 years (status quo) and the costs of using car for 12 years and discarded (new strict policy), the costs of using car over its life time (12 and 20 years) were estimated. The added costs that make car owners to discard their cars at year 12, instead of discarding their car at year 20 was calculated (Total costs at year 12 = total costs at year 20). Comparing the cost between the status quo and the new policy situation in year 12, people spends around 300,000 baht more with new the policy (Table 4.8). In the same way, if people use car for 20 years, the maintenance cost at year 20 of new policy is approximately 500,000 baht more than the one of status-quo. This difference cost may be used to calculate an incentive for people to send car to a certified collector.

Finding the suitable age of car before discarding is also important in order for people to gain the most profit in one life cycle of a car. Policies about an annual tax registration renewal fee should be based on the condition of car instead of its engine displacement or age. Carbon dioxide emission can also be a factor when calculating the annual tax registration renewal fee.

5.2 RECOMMENDATIONS

Recommendations for improving ELVs management in Thailand in related segments are explicated below:

5.2.1 Government Agency

1) DLT

Relating to vehicle information collected by DLT, the process should be more accurate, informative, and consistent. The deregistration process should be enforced more seriously to keep track ELVs. In developed countries, since vehicle statistics have been done appropriately, data analysis and prediction can be done effectively and precisely (Chatani, Morikawa, Nakatsuka, Matsunaga, & Minoura, 2011; Chung & Lee, 2002; Ko, Chang, Kim, Holt, & Seong, 2011). As a result, studying of ELVs can be done with ease in terms of vehicle tracking, current situation investigation, decision support information and prediction (Bener, Abu-Zidan, Bensiali, Al-Mulla, & Jadaan, 2003; Chatani et al., 2011; Prevedouros & An, 1998). DLT, collaborating with PCD regarding technical knowledge, should also reorganize the inspection policy and practices. It would help the environment tremendously when an inspection policy is implemented with high standards. Cars in poor condition would not be allowed to pass inspection process; as a result, it lessens second-hand car shop and increases of supplies of scrap steel from ELVs (Beaton et al., 1995; Johnstone & Karousakis, 1999; Nakajima, Yokoyama, Matsuno, & Nagasaka, 2007).

2) PCD and DIW

Organizations such as, DIW, and PCD, should enact or enforce ACT for the steel industry (recycler), related producer, and its owner to assure that the recycling or manufacturing process will not harm the environment. The technique of pollution detection should be trained so that steel industry (recycler) could efficiently evaluate severity or risk (Busch & Sterling, 2000). DIW should develop guidelines for automobile repair shops, and dismantlers on how they manage discarded car parts, and ELVs to make sure that their management process does not harm the environment e.g. toxic chemical, oil leakage, etc.

5.2.2 People

Incentives can help encourage people send their car to a certified or appropriate treatment process. For example, rewards can distribute to anyone who brings a car to certified operator, or a discount can be given to anyone who buys new electric car (Poboon, 2017). Apart from an incentive to car owners, the government should provide knowledge of how to maintain a car to reduce the impact on environment (Flamm, 2009). People should be educated that discarding ELVs along the street or left in a garage could cause environmental problem such as water pollution. Instead, as ELVs can provide added value, they should send ELVs to a proper treatment process. This would lead to win-win solution and sustainable management.

5.2.3 Private Company

The related ACT of ELVs should be feasibly enacted by related government sectors to be able to enforce car manufacturer to trace a car and bring them back for an appropriate treatment process. EPR would be applied so that car manufactures are responsible for contributing a recycling fee to the management fund or related organization. Otherwise, the offender would be subjected to a heavy penalty (Forslind, 2005; Wilts, Bringezu, Bleischwitz, Lucas, & Wittmer, 2011; Xiang & Ming, 2011).

More importantly, to achieve sustainability of ELV management, it is better that every stakeholders have a self-conscious and social responsibility (McWilliams, Siegel, & Wright, 2006).

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APPENDICES

APPENDIX A

QUESTIONNAIRE IN ENGLISH VERSION

Survey – How Thai People Manage their car

Car Usage Behavior Survey created to study Behavior of Thai car owner including purchasing, maintenance car, until ELV management.

Please complete the following details by ticking (✓) in the box for the details that is appropriate for you.

1. Age

   [ ] years

2. Gender
   - Male
   - Female

3. Salary per month
   - Below 15,000 baht
   - 15,000 - 30,000 baht
   - 30,001 - 45,000 baht
   - 45,001 - 60,000 baht
   - 60,001 - 75,000 baht
   - 75,001 - 90,000 baht
   - 90,001 - 105,000 baht
   - 105,001 baht or above

4. What brand is your car?

   [ ]

5. What province is your license plate?
   - Bangkok
   - Provincial

6. How old is your cars? (counted from the begin of its life)
   - 1-5 year(s)

- 6-10 years
- 11-15 years
- 16-20 years
- 21-25 years
- 25-30 years
- 31 years or above

7. How many cars do you own?
   - 1
   - 2
   - 3
   - 4
   - 5 or above

8. What size (CC) is your car displacement?
   - 1,100 - 1,300 CC
   - 1,301 - 1,500 CC
   - 1,501 - 1,700 CC
   - 1,701 - 1,900 CC
   - 1,901 CC or above

9. How frequently do you use your car?
   - Never
   - Every 2 or 3 months
   - Every month
   - Every week
   - 2-3 times per week
   - 4-6 times per week
   - Everyday

10. What is the average mileage per year, for one car?
    - Below 10,000 Kilometre(s)
    - 1 - 10,000 Kilometres
    - 10,001 - 20,000 Kilometres
    - 20,001 -30,000 Kilometres
    - 30,001 - 40,000 Kilometres
    - 40,001 - 50,000 Kilometres
    - 50,001 Kilometres or above

11. How frequently do you bring a car for inspection?
    - 1 - 5,000 Kilometre(s)
    - 5,001 - 10,000 Kilometres
    - 10,001 - 15,000 Kilometres
    - 15,000 Kilometres or above
    - Only when difunctional

12. What is the appropriate age of car at use phase? (Your expectation to use from the beginning of its life until discarded)

- 1-5 year(s)
- 6-10 years
- 11-15 years
- 16-20 years
- 21-25 years
- 25-30 years
- 31 years or above

13. How do you discard your car?
    - Exchange for a new car at Car Dealer
    - Sell at second-hand car shop
    - Sell to Automobile Repair shop
    - Sell to Vehicle Spare Part shop (Junk Yard)
    - Announce for sell via media (e.g. post to web or social media)
    - Dispose at landfill site or along the street

APPENDIX B

QUESTIONNAIRE IN THAI VERSION

แบบสำรวจการใช้งานรถยนต์ส่วนตัวของคนไทย

แบบสำรวจการใช้งานรถยนต์ส่วนตัวของไทยนั้นจัดทำขึ้นเพื่อศึกษาพฤติกรรมและวิธีการของคนไทยในการใช้รถซึ่งรวมถึงการซื้อ การบำรุงรักษา จนกระทั่งการจัดการรถยนต์และอะไหล่หลังจากเลิกใช้แล้ว

โปรดตอบคำถามต่อไปนี้ โดยการทำเครื่องหมาย (✓) ในช่องวงกลมที่ตรงกับรายละเอียดของท่าน หรือกรอกรายละเอียดในช่องว่าง

1. อายุ

   [ ] ปี

2. เพศ

   ○ ชาย
   ○ หญิง

3. รายได้ของท่านต่อเดือน

   ○ ต่ำกว่า 15,000 บาท
   ○ 15,000 - 30,000 บาท
   ○ 30,001 - 45,000 บาท
   ○ 45,001 - 60,000 บาท
   ○ 60,001 - 75,000 บาท
   ○ 75,001 - 90,000 บาท
   ○ 90,001 - 105,000 บาท
   ○ 105,001 บาท หรือสูงกว่า

4. ท่านใช้รถยี่ห้อ / รุ่น อะไร

   [ ]

5. ทะเบียนรถของท่านเป็นทะเบียนของจังหวัดอะไร
   - ○ กรุงเทพฯ
   - ○ ต่างจังหวัด

6. รถยนต์ที่ท่านใช้อยู่มีอายุกี่ปี
   - ○ 1-5 ปี
   - ○ 6-10 ปี
   - ○ 11-15 ปี
   - ○ 16-20 ปี
   - ○ 21-25 ปี
   - ○ 25-30 ปี
   - ○ 31 ปี หรือมากกว่า

7. ท่านมีรถในครอบครองกี่คัน
   - ○ 1 คัน
   - ○ 2 คัน
   - ○ คัน
   - ○ คัน
   - ○ คัน หรือมากกว่า

8. รถของท่านมีขนาดเครื่องยนต์เท่าไหร่
   - ○ 1,100 - 1,300 CC
   - ○ 1,301 - 1,500 CC
   - ○ 1,501 - 1,700 CC
   - ○ 1,701 - 1,900 CC
   - ○ 1,901 CC หรือมากกว่า

9. ท่านใช้รถยนต์เป็นประจำหรือไม่
   - ○ ไม่เคยใช้
   - ○ 2-3 เดือนต่อครั้ง
   - ○ เดือนละครั้ง
   - ○ อาทิตย์ละครั้ง

- อาทิตย์ละ 2 - 3 ครั้ง
- อาทิตย์ละ 4 - 6 ครั้ง
- ใช้ทุกวัน

10. จำนวนระยะทางเฉลี่ยที่ใช้ต่อปีสำหรับรถ 1 คันของท่าน เป็นเท่าไหร่
    - ต่ำกว่า 10,000 กิโลเมตร
    - 1 - 10,000 กิโลเมตร
    - 10,001 - 20,000 กิโลเมตร
    - 20,001 -30,000 กิโลเมตร
    - 30,001 - 40,000 กิโลเมตร
    - 40,001 - 50,000 กิโลเมตร
    - 50,001 กิโลเมตร หรือมากกว่า

11. ท่านนำรถเข้าตรวจเชคสภาพทั่วไป โดยเฉลี่ยที่ทุก ๆ ระยะทางเท่าใด
    - 1 - 5,000 กิโลเมตร
    - 5,001 - 10,000 กิโลเมตร
    - 10,001 - 15,000 กิโลเมตร
    - มากกว่า 15,000 กิโลเมตร
    - จะนำเข้าไปตรวจเชคเมื่อมีอาการผิดปรกติเท่านั้น

12. ท่านคิดว่าอายุการใช้งานรถยนต์ที่เหมาะสมนั้นมีอายุทั้งสิ้นกี่ปี
    - 1-5 ปี
    - 6-10 ปี
    - 11-15 ปี
    - 16-20 ปี
    - 21-25 ปี
    - 25-30 ปี
    - 31 ปี หรือมากกว่า

13. ท่านทำอย่างไรกับรถของท่านเมื่อหมดอายุการใช้งาน
    - นำไปแลกเทิร์นรถใหม่กับศูนย์บริการยี่ห้อนั้น ๆ
    - นำไปขายที่เต๊นรถมือสองหรือศูนย์บริการยี่ห้อนั้น ๆ

- ขายต่อให้อู่ซ่อมรถ
- ขายต่อร้านอะไหล่ หรือเซียงกง เพื่อนำไปแยกชิ้นส่วน
- ประกาศขายเป็นรถมือสอง
- ทิ้งตามสุสานรถยนต์ หรือตามข้างถนน

BIOGRAPHY

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