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Analytic Hierarchy Process Based-Evaluation of Dismantling Practices on End-Life-Vehicle for Automobile Workshops

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ABSTRACT

Nowadays, the number of end-of-life vehicles (ELVs) has increased due to increased automobile production. One of the crucial in processing ELVs is dismantling. However, most of the developing countries still have limited specific dismantling infrastructure. Most of the ELV management started at the automobile workshop. Hence the purpose of this paper is to study the effectiveness of dismantling ELV in automobile workshops. This paper focuses on identifying and analysing factors that can affect the effectiveness of dismantling ELV in automobile workshops. A literature survey has been conducted to identify the factors that influence the effectiveness of ELV's dismantling in automobile workshops. A total of 30 factors are obtained which are further classified into five main factors which are human resources (HR), ELV facilities (EF), ELV material (EM), cost concern (CC), and customer-driven (CD). An approach based on Analytical Hierarchy Process (AHP) is utilized to analyse the factors for developing a list of priority of these factors. The result of this study shows that workshop owner experience in ELV dismantling management, worker skills of ELV dismantling, enough dismantling space, development of suitable tools, and dismantling difficulties of ELV material are identified as the top five factors affecting the effective of ELV dismantling in automobile workshop. The automobile workshop or any policymakers can use the priority list of factors developed in this paper's findings for managing the dismantling process in the automobile workshop.

Keywords:

End-life-vehicle (ELV); Effectiveness factors; Dismantling; Analytical hierarchy process; Automobile workshop

1. Introduction

The world's automobile population is rapidly growing. As the number of automobiles sold grows, so does the number of vehicles that are no longer in use, which are referred to as end-of-life vehicles (ELVs) [1]. As a result, ELV management is becoming increasingly crucial as the automobile industry grows and becomes one of the most critical sectors in the world. ELV management

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involves accepting and storing discarded vehicles, removing hazardous materials, dismantling vehicles for usable or recyclable parts, storing vehicle hulks, storing and disposing of hazardous fluids and materials removed from discarded vehicles, and finally crushing or shredding vehicle hulks are the stages for processing and preparing discarded ELV for disposal (deliver to metal crushing facility if not equipped to complete this activity) [2]. However, most of the developing countries still have limited specific dismantling infrastructure [3]. For the early implementation of ELV management, small facilities, and automobile workshop has become a place for that. An automobile workshop is one of the alternative places for implementing some of the ELV processes. Despite all the ELV process cannot gather in one place, at least one of the crucial processes which are dismantling can be conducted in an automobile workshop [4]. ELV dismantling is the process of destroying or recycling end-of-life vehicles, as well as removing their parts and other trash [5]. The fleet of vehicles contains a significant number of valuable materials that must be safely and effectively recovered, separated, reused, and recycled to create a circular economy and a sustainable society [6]. Vehicles must be disassembled to allow for the effective and profitable reuse of components, the recovery of crucial low-volume materials, and higher (or more) rates of reuse and recycling [7]. Hence, it is crucial to understand the best factors to determine the effectiveness of dismantling ELV in automobile workshops. An approach based on Analytical Hierarchy Process (AHP) is utilized to analyse the factors for developing a list of priority of these factors [8].

2. Background

2.1 Background of Dismantling

Figure 1 depicts how ELV processing is identical over the world. The efficiency of the dismantling process is strongly tied to the processes that follow in the processing of various pieces. Usually, the recycling of an ELV begins with the automobile being brought to the dismantle operator; in certain situations, the ELVs are purchased by these operators to reuse or resell the working pieces of the car. The automobile is disassembled into many categories [9]. First, the most polluting components are removed: engine oil, fuel, refrigerant gases, and the automobile battery [10]. They are supplied to specific recycling units that also handle storage until they are appropriately disposed of. The mechanical pieces (engine, gearbox, turbine, suspension system, injectors, etc.), automobile hulk (divided by sections: doors, bumpers, stops, etc.), tyres, plastic, glass, and textiles are then gathered [11]. In the EU and Japan, the overall weight of the vehicle after dismantling is around 55%-70% of the original weight [12]. What remains after disassembling is fed into shredders before being divided into ASR light and ASR heavy by air classifier [11].

The disassembly process is divided into two types: "European/American mode and "Asian mode" [13]. Because of the high cost of local labour, large-scale automated disassembly is extensively used in Europe and the United States. Because of the low cost of local labour, "mechanical + manual" dismantling procedures are often utilised in Asian countries [5,14,15]. The United States has the most advanced deconstruction process of any country [1]. For more than 30 years, the United States has been researching and developing remanufacturing procedures for ELV parts. The United States has established a large-scale system for decommissioning and remanufacturing ELV parts, which has emerged as the principal source of profit in the ELV recycling business [13].

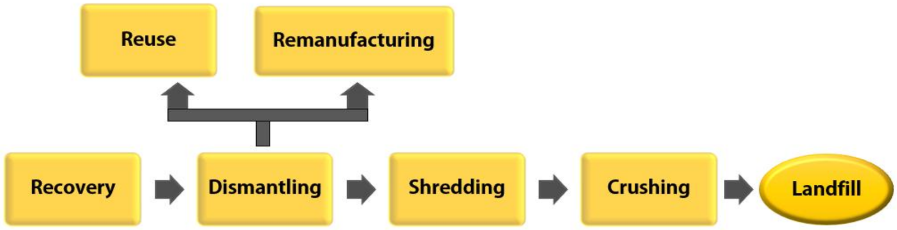

Fig. 1. Basic ELV Processing

Automotive part remanufacturing has grown to be the largest remanufacturing business in the world in terms of the number of companies, jobs, and economic contribution. By remanufacturing parts such as engines, transmission components, clutches, steering wheels, air conditioning compressors, starting dynamos, generators, wiper motors, water pumps, oil pumps, and brake booster pumps, this industry caters to passenger vehicles, commercial vehicles, and special vehicles [13]. However, most developing countries in Asia, have been confronted with the dilemma that the growth of vehicle recycling has lagged behind that of manufacturing, dismantling, and other industrial chain components [16]. ELV recycling has simply gotten little attention, resulting in the loss of ELVs and poor levels of recycling technology [13]. Hence that is more reason to study the dismantling adaptation for automobile workshops as a starting point for further action in the future.

2.2 Previous Studies on Dismantling Process

Dismantling location or facilities is critical in today's ELV management systems since failure to address this aspect may result in inefficient operations and excessive manpower expenditure, both of which have a substantial influence on ELV management's time and expense [14]. As a result, several studies have been done to enhance dismantling facilities, processes, management, and other aspects. For example, according to a study by [17], different time-based cost models have been developed by applying varying levels of automation on workstations to offer realistic cost projections in the design of ELV dismantle systems. Apart from that, [18] claimed in their research that effective dismantling facilities aid in the recovery of valuable components and pieces from End of Life (EOL) or abandoned items, which would otherwise end up in landfills and damage the water bodies and air. It also contributes to resource conservation and minimizes the demand for new materials. According to [7], cars must be deconstructed to enable effective and lucrative reuse of components, recovery of key low-volume materials, and high(er) reuse and recycling rates. In 2017, 293 approved automobile dismantlers in Sweden completed dismantling operations [6]. Every year, around 190,000 automobiles are dismantled as either natural or premature ELVs [6]. Vehicles are depolluted and components are disassembled for reuse as spare parts, material recycling, or sale to remanufacturers [19]. Mechanical disassembly is utilized for material recycling in some circumstances; however, most dismantling is done manually by expert mechanics. The automobile wreck is compacted and shipped to firms where it is shredded and materials are sifted once it has been dismantled [20]. The material fractions then are sold to material producers.

Schmid *et al.,* [20] contrasted the French and German methods in earlier writings, which supported, respectively, a high degree of disassembly before shredding or an optimum development of sorting technologies after shredding. Three scenarios were tested on a commercial ELV disassembly and destruction facility [21]. The degree of ELV disassembly varied between the scenarios, which were initially contrasted in terms of their technical performance [22]. In this experimental program, several data were gathered about environmental emissions at various phases of the treatment line, including depollution, dismantling, and shredding/sorting processes, in addition to measurements taken to compute the percentages of material and energy recovery. Although some developed countries have created dismantling facilities, underdeveloped nations still have few facilities and equipment for ideal ELV handling [7]. As a result, several researchers have tested an ELV procedure that involves disassembling at an auto shop. According to [18], the researcher has interviewed some of the owners of the workshop in Jerantut and found that for the dismantling of ELV, workers involved in the scrap car area for Perodua get the training to handle the scrap car properly and according to the step that has been set in the rule. But there is also a workshop where their worker only manages the scrap car using basic training based on the internet and training. [19] reports that scrap scavengers visit various mechanic workplaces to gather and purchase disassembled and removed scrap components before supplying the junk to the smelting businesses. According to some studies, for people to adjust to disassembling there, the workshop needs to have appropriate space, developed equipment, and superior technology [21]. However, several researchers said that it is sufficient to perform the dismantling process initially as long as the workshop owner has the mentality of ELV awareness, sufficient training to have ELV skills workers, and knowledge [23]. Of course, for it to succeed, it must also take into account client demand and ecological consciousness [24].

To establish the order in which ELV are dismantled after they arrive at the dismantling site, [14] has presented a novel approach for ELV dismantling selection. Since it affects the selection and effectiveness of ELV waste management solutions at dismantling facilities, its resolution is crucial for the challenge of managing ELV waste. Some car recyclers have adopted machine-based disassembly to increase their output in response to recent developments in the effective handling of End-of-Life Vehicles. The tools are modified excavators that provide more control and force while disassembling vehicles [10]. The report from [25] demonstrates the need for deconstruction companies, automakers, and other businesses of a similar nature to collaborate, advance the introduction of environmentally friendly design (also known as Design for Environment or DfE), share information, and then continuously conduct follow-up for these activities. By recycling more copper and polymers and increasing energy recovery from incineration, manual dismantling greatly lessens the impact of climate change and the depletion of metals. Increased recycling and energy recovery, with more than half of the reduction being related to polymer recycling and energy recovery, are the key reasons why the CED is significantly lower in the manual scenario than in the shredding scenario [26]. According to [2], to cut down on storage time and lessen the chance of leaking fluid and contaminating the environment, it's crucial to start disassembling and processing abandoned vehicles as soon as feasible. In line with the report from [26], in a small or medium-sized workshop, crews of 4 to 6 people, occasionally fewer or even just one man, disassemble scrap cars. One crew needs one to two hours to disassemble and cut an automobile with one to three tonnes of weight into all of its parts. The knowledge and skills of the dismantling team on how and along which lines to cut the hard metal to separate the solid automobile body into practical pieces within the lowest amount of time is of particular economic importance [27].

2.3 Study Gap

Although, much effort has been done by the researchers to improve the implementation of the dismantling process in ELV facilities the role of the automobile workshop as an alternative dismantling place has been overlooked by the researchers. The alternative dismantling place can help the government to plan ELV management well in advance. A list of 30 different effectiveness factors is identified which are provided in Table 1 along with their literature sources.

Table 1
Effectiveness Factors of Dismantling for End-Life-Vehicle in Automobile Workshop

No	Effectiveness Factors of Dismantling for ELV in Automobile Workshop	Reference	Classification
1	Operational cost	[7]	Cost Concern [CC1]
2	Investment cost	[6,20]	Cost Concern [CC2]
3	Recovery cost	[16,20]	Cost Concern [CC3]
4	Reverse logistic cost	[32-34]	Cost Concern [CC4]
5	Consumer ecological knowledge and awareness	[11,12]	Customer-Driven [CD1]
6	Customer demand	[19]	Customer-Driven [CD2]
7	Customer service	[31]	Customer-Driven [CD3]
8	Customer incentives	[31]	Customer-Driven [CD4]
9	Consumer right protection	[1]	Customer-Driven [CD5]
10	Enough dismantling space	[2,15,28]	ELV Facilities [EF1]
11	ELV dismantling machinery	[10]	ELV Facilities [EF2]
12	Development of suitable tools	[6]	ELV Facilities [EF3]
13	Smart Technology	[7]	ELV Facilities [EF4]
14	Ecofriendly technology	[22,26]	ELV Facilities [EF5]
15	Automation infrastructure	[17]	ELV Facilities [EF6]
16	Technology partnership	[22]	ELV Facilities [EF7]
17	Safety ELV material for user	[1]	ELV Material [EM1]
18	Calorific value of ELV material	[13]	ELV Material [EM2]
19	Information of ELV part	[3]	ELV Material [EM3]
20	Dismantling difficulties of ELV Material	[13,30]	ELV Material [EM4]
21	Present of polymer in ELV material	[13]	ELV Material [EM5]
22	Condition of ELV Material	[9,31]	ELV Material [EM6]
23	ELV component identification	[35]	ELV Material [EM7]
24	Occupational risk	[4,20]	Human Resource [HR1]
25	Minimum human error	[13]	Human Resource [HR2]
26	Worker skills of ELV dismantling	[1,2,4,20]	Human Resource [HR3]
27	Technical performance	[20]	Human Resource [HR4]
28	Workshop owner experience on ELV dismantling management	[6,11,18,20,29]	Human Resource [HR5]
29	Worker knowledge	[18,21]	Human Resource [HR6]
30	Enough manpower	[22,26]	Human Resource [HR7]

Human resources, ELV materials, ELV facilities, cost-concern, and customer-driven are the five key categories for these 30 elements. Figure 2 under Section 3 presents this classification as a hierarchy.

3. Methodology

This section describes the approach recommended for assessing the effectiveness of dismantling ELV in automobile workshops. The Analytic Hierarchy Process (AHP) invented by Saaty in 1980 is a multi-criteria decision-making approach which is the suggested approach employed in the method for this purpose [36]. The AHP approach begins with defining the problem and determining its scope. The problem's hierarchical structure is developed in the next stage. The first level of the hierarchical structure has a goal, and the lesser levels include elements and options. The following are the many phases of the AHP method [7].

3.1 Step 1

Define the study's principal aim and identify the major factors and sub-factors that are connected to it. Create a hierarchy by putting the major aim first, followed by the study's factors and sub-factors. Figure 2 depicts this hierarchical structure.

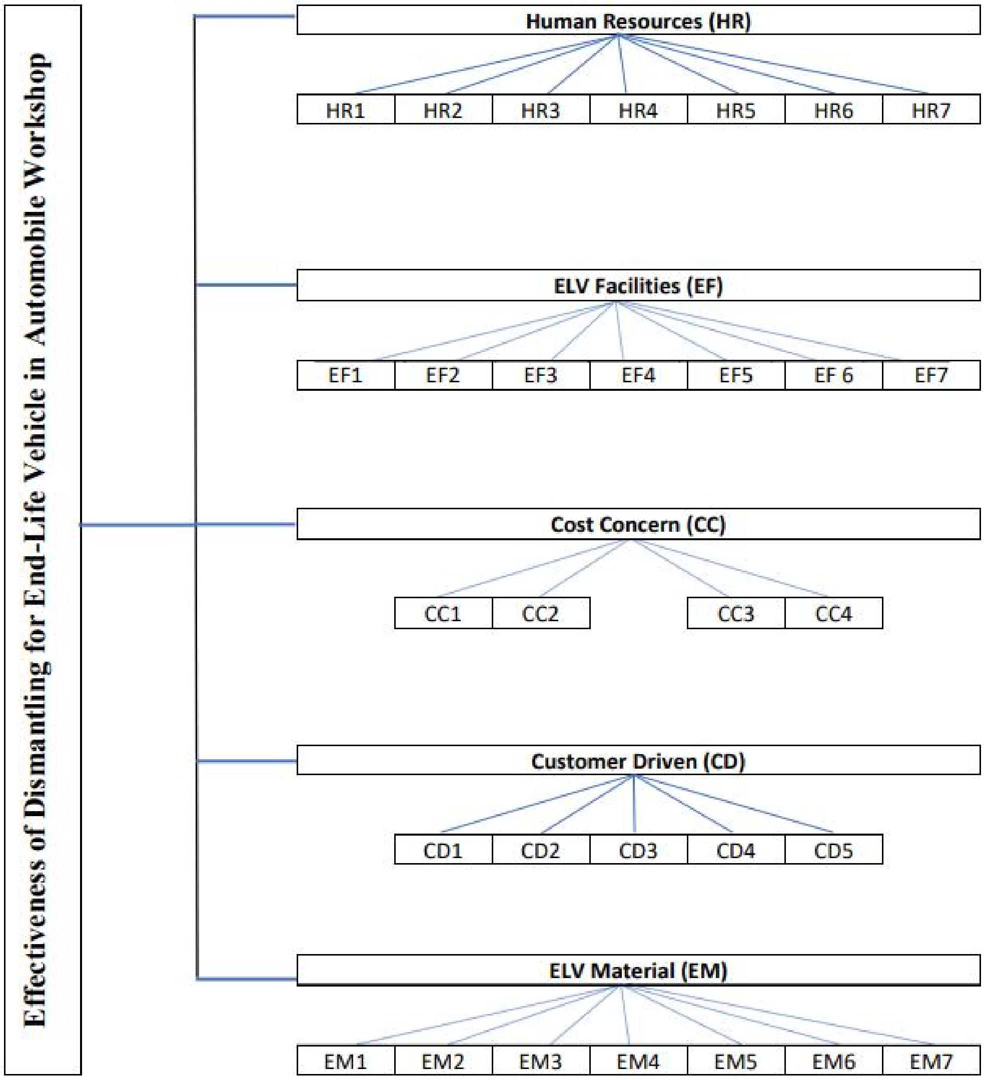

Fig. 2. AHP main factors and sub-factors which affect dismantling for ELV in Automobile workshop

3.2 Step 2

Using the experts' feedback, create a comparison matrix for each component and sub-factor. Table 2 shows how experts provide their opinions using a rating scale. Table 2 provides a brief summary of each rating value to aid comprehension.

Table 2
Rating scale to develop the comparison matrix for different criteria

Rating	Importance	Description
1	Equally important	When two factors have equal contribution
3	Somewhat more important	When one factor is slightly preferred over the other
5	Much more important	When one factor is strongly preferred over the other
7	Very much more important	When one factor is very strongly preferred over another
9	Absolutely more important	When there are valid evidences preferring one factor over the other
2, 4, 6, 8	Intermediate values	When there is a compromise between two odd ratings

If there are N factors and k experts, then the comparison matrix P is defined as:

$$P^k = \begin{bmatrix} P_{11}^k & P_{12}^k & \dots & P_{1N}^k \\ P_{21}^k & P_{22}^k & \dots & P_{2N}^k \\ \vdots & \vdots & \dots & \vdots \\ P_{N1}^k & P_{N2}^k & \dots & P_{NN}^k \end{bmatrix} P_{ji} = \frac{1}{P_{ij}}, P_{ij} \neq 0, k \neq 0 \tag{1}$$

3.3 Step 3

Compute the weight ϖ i of each factor using the Eq. (2).

$$\varpi_i = \frac{\left\{\prod_{j=1}^{N} p_{ij}\right\}^{\frac{1}{N}}}{\sum_{i=1}^{N}\left\{\prod_{j=1}^{N} p_{ij}\right\}^{\frac{1}{N}}} \tag{2}$$

where i, j = 1, 2, ……. N.

3.4 Step 4

Check the consistency of the weights by determining the consistency ratio (CR). This ratio is defined as:

CR = CI/RI (3)

Here, CI is known as Consistency Index and RI is known as Random Index. If CR < 0.1, then it ensures a consistency in the opinion of the experts and hence the calculated weights are accepted.

4. Results

The steps of the AHP technique described in the preceding section are used to calculate each factor's weight. Table 3 provides the pairwise comparison matrix created for the primary factors with the help of expert input.

Table 3
Rating scale to develop the comparison matrix for different criteria

Main goals	HR	EF	CC	EM	CD	Weights
HR	1	1	3	3	2	0.312
EF	1	1	3	2	3	0.308
CC	1/3	1/2	1/3	1	2	0.116
EM	1/3	1/3	1	3	2	0.171
CD	1/2	1/3	1/2	1/2	1	0.093
CR: 0.07						

In the present study, local weights and consistency ratios were calculated via Expert Choice (2000). When Table 3 is examined, pairwise comparisons of the main goals can be seen. In addition, the local weights of each main goal can be seen in the last column. Each primary goal's local weight reflects its relative relevance. In other words, it shows the relative importance of each aim within the overall objective. The sum of all local goal weights is one. The relative weights of "human resource," "ELV facilities," "cost concern," "ELV material," and "customer driven" for the current study are, in that order, 0.312, 0.308, 0.171, 0.116, and 0.093. The consistency ratio, which is calculated and comes out to be 0.07—a value far below 0.1—is used to demonstrate the reliability of these weights. The pairwise comparisons are consistent according to the threshold values expected by AHP assumptions, which guarantees the trustworthiness of the weights.

Table 4 calculates and displays the weights for each sub-factor. Once the weights of the main factors and sub-factors are known, the global weights of all factors are calculated by multiplying the weight of each sub-factor by the weight of the corresponding main factor. Each component is prioritized based on its overall weight, as seen in the last column of Table 4.

Table 4
Global weights and ranking of the factors of ELV dismantling effectiveness in automobile workshop

Main factors	Weight of main factors	Sub-factors	Weight of sub-factors	Global weight	Ranking
Human Resources (HR)	0.312	HR1	0.3861	0.1189	8
		HR2	0.3298	0.1029	12
		HR3	0.5115	0.1596	2
		HR4	0.3861	0.1205	7
		HR5	0.793	0.2466	1
		HR6	0.2506	0.0782	17
		HR7	0.3189	0.0995	13
ELV- Facilities (EF)	0.308	EF1	0.4691	0.1445	3
		EF2	0.3142	0.0968	14
		EF3	0.4597	0.1416	4
		EF4	0.3529	0.1087	10
		EF5	0.2243	0.0691	18
		EF6	0.3415	0.1052	11
		EF7	0.3926	0.1225	6
Cost-concern (CC)	0.116	CC1	0.4422	0.0513	21
		CC2	0.1922	0.0223	26
		CC3	0.0793	0.0092	28
		CC4	0.2974	0.0348	23
Customer-Driven (CD)	0.093	CD1	0.1301	0.0121	27
		CD2	0.3483	0.0324	24
		CD3	0.0462	0.0043	30
		CD4	0.0698	0.0065	29
		CD5	0.2397	0.0287	25

ELV Material (EM)	0.171	EM1	0.4771	0.0816	16
		EM2	0.6584	0.1126	9
		EM 3	0.3397	0.0581	20
		EM 4	0.7590	0.1298	5
		EM 5	0.3754	0.0642	19
		EM 6	0.5140	0.0879	15
		EM 7	0.2974	0.0452	22

The outcomes show that clearly that the order of significance of the main factors on the dismantling effectiveness is found as, Human Resources (HR) > ELV Facilities (EF) > ELV Material (EM) > Cost Concern (CC) > Customer Driven (CD). Thus, product attributes are the key factors affecting the effectiveness dismantling of ELV in automobile workshops. The influence of customer drives on the effectiveness of ELV dismantling in automobile workshops is not very significant. 'Workshop owner experience on ELV dismantling management' is obtained as the most significant factor among the all 30 factors identified in this study. This is the factor that drives the ELV policymaker toward the decision of whether to encourage the implementation of dismantling in automobile workshops or not. Generally, the dismantling skills of workers in the procedure of cutting the hard metal to separate the solid vehicle body into practical pieces within the fastest amount of time is of particular economic importance [27] which indicates its effectiveness. 'Worker skills of ELV dismantling' is found to be the next most significant factor that affects the effectiveness of dismantling for ELV in automobile workshops. Dismantler might take a long time which leads to overtime in case of that worker has low skills in ELV dismantling. In such a case, the cost and complexity associated with the dismantling of ELV material in automobile workshops may be significantly high. 'Customer service' and 'customer incentives' are found to be the two least significant factors in this study. Although these factors have the potential to influence the effectiveness of dismantling in an automobile workshop the significance of their influence is very limited. This result demonstrates consistency with a prior study carried out by [31] which stated that most countries offer incentives by promoting the disposal of ELVs through legal channels, such as road taxes paid by drivers in the absence of documentation proving the vehicle's legal disposal. There is no such legal avenue to offer such incentives in the majority of developing nations, including Malaysia. So, without consumer encouragement, customer service is likewise essentially worthless.

5. Conclusion

This study is carried out to find out those factors which have the potential to influence the effectiveness of dismantling ELV in automobile workshops. Once these factors are identified, the dismantling operation can be executed more effectively in automobile workshops which may result in an improved ELV management ecosystem in developing countries especially in Malaysia as one of the vehicle manufacturers nations. This research mainly focuses on the strategic aspects such as human resources, ELV facilities, ELV material cost concern, and customer driven. This study concludes that human resources such as Workshop owner experience in ELV dismantling management and workers' skills in ELV dismantling are the key factors in the effectiveness of ELV dismantling in automobile workshops. In addition, ELV facilities factors such as enough dismantling space and the development of suitable ELV tools also should be neglected for ELV dismantling in automobile workshops. Other factors studied can also indirectly influence the effectiveness of dismantling ELV in automobile workshops but these influences will have a limited scope. The priority list of factors which is developed in this study can be used by the decision-makers in ELV investors or ELV policy makers for carrying out a better dismantling of ELV products in automobile workshops.

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