UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Analysis of Sealing Parameter for Laminated Glass Installation to Facilitate Efficient Dismantling in End-of-Life Vehicles.

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (AUTOMOTIVE) WITH HONOURS

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Faculty of Mechanical Technology and Engineering

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Bachelor of Mechanical Engineering Technology (Automotive) with Honours

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ANALYSIS OF SEALING PARAMETER FOR LAMINATED GLASS INSTALLATION TO FACILITATE EFFICIENT DISMANTLING IN END-OF-LIFE VEHICLES

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A THESIS SUBMITTED
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TAJUK: **ANALYSIS OF SEALING PARAMETER FOR LAMINATED GLASS INSTALLATION TO FACILITATE EFFICIENT DISMANTLING IN END-OF-LIFE VEHICLES.**

SESI PENGAJIAN: **2024-2025 Semester 1**

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Date : 18/5/2024

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Automotive) with Honours

Signature : .....

Supervisor Name : *Mohd Khairul Nizam Bin Suhaimin*

Date : 8/1/2025

DEDICATION

I dedicate this project to my supervisors, parents and family members, lectures and my fellow friends. Thanks for all the support and encouragement given.

ABSTRACT

The aim of this study is to find the best key parameter of sealant that is designed for the delamination of laminated glass in ELVs. When one give efficiency and workability as the major principles to be considered in the process of dismantling, it will be easy to undertake. To this effect, the project will be implemented in three phases. Firstly, a literature review of the existing academic works will be made to determine certain potential parameters affecting efficiency of dismantling, and afterwards, the surveys with the specialists in the ELV business will be also carried out to reveal primary parameters. These are variables that will thereafter be explored with the aim of ascertaining the extent to which they impact of the ease of dismantling. Finally, a scientific study will be conducted to determine the optimal values of these parameters a range in question. The deconstruction of ELVs, measuring time taken in this process, observing the process, and using self-completion questionnaires to gather information from ELV personnel on experiences and attitudes. The research shall in addition employ both quantitative as well as qualitative data collection methods in order to ascertain the best properties that define effortless removal of a sealant. The outcome will thereby improve the effectiveness of dismantling for ELV workers and improve the rates of resource recovery for ELV's within the automotive industry—a move towards a more sustainable approach to ELV management.

ABSTRAK

Matlamat kajian ini adalah untuk mencari parameter utama terbaik bagi pengedap yang direka untuk penembusan kaca berlamina dalam ELV. Apabila seseorang memberikan kecekapan dan kebolehkerjaan sebagai prinsip utama yang perlu dipertimbangkan dalam proses pembongkaran, ia akan menjadi mudah untuk dilaksanakan. Untuk kesan ini, projek itu akan dilaksanakan dalam tiga fasa. Pertama, kajian literatur terhadap karya akademik sedia ada akan dibuat untuk menentukan parameter berpotensi tertentu yang menjejaskan kecekapan pembongkaran, dan selepas itu, tinjauan dengan pakar dalam perniagaan ELV juga akan dijalankan untuk mendedahkan parameter utama. Ini adalah pembolehubah yang selepas itu akan diterokai dengan tujuan untuk memastikan sejauh mana ia memberi kesan terhadap kemudahan pembongkaran. Akhir sekali, kajian saintifik akan dijalankan untuk menentukan nilai optimum parameter ini julat yang dipersoalkan. Penyahbinaan ELV, mengukur masa yang diambil dalam proses ini, memerhati proses, dan menggunakan soal selidik pelengkap kendiri untuk mengumpul maklumat daripada kakitangan ELV tentang pengalaman dan sikap. Penyelidikan ini juga akan menggunakan kaedah pengumpulan data kuantitatif dan juga kualitatif untuk memastikan sifat terbaik yang menentukan penyingkiran mudah pengedap. Hasilnya akan meningkatkan keberkesanan pembongkaran untuk pekerja ELV dan meningkatkan kadar pemulihan sumber untuk ELV dalam industri automotif—satu langkah ke arah pendekatan yang lebih mampan terhadap pengurusan ELV.

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In the Name of Allah, the Most Gracious, the Most Merciful.

All praise to Allah that allows me to successfully finish my final year project in my bachelor's degree study.

The objective of the project is achieved through a number of researches done using the internet, previous thesis, research papers and journals. With all the supports and encouragement that I received thorough this final year project; the credit has to be given to all those people who helped me sincerely.

A special thanks dedicated to Sir Mohd Khairul Nizam Bin Suhaimin as my supervisor who has been very helpful assisting me during my final year project. His encouragement, guidance and advice has been the source of my motivation to keep going from the start until finish.

Last but not least, thanks to my parents, lectures and fellow friends that have been with me giving emotional and physical support for me keep going finishing my final year project. The help I received will always be remembered and may Allah reward them with eternal blessing.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

ELV	-	End life vehicle
PCD	-	Pitch circle diameter
CFC	-	Chlorofluorocarbons
UV	-	Ultraviolet
AHP	-	Analytic Hierarchy Process
MILP	-	Mixed-integer linear programming
LPG	-	Liquid Petroleum Gas

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

The current use of vehicles has reached dangerous levels, with the numbers steadily increasing throughout the year. In the present circumstances in Malaysia, the acquisition of cars has commenced at a young age. Malaysians perceive the growing number of vehicles on the road as the optimal means of transportation between different locations.

In addition to the growing number of cars on the road, the presence of heavy vehicles is also increasing in line with Malaysia's quick growth process. Products are being distributed nationwide. In Malaysia, the primary mode of transportation for delivering goods is still by lorry, as it is considered the most optimal method.

Every vehicle that is in operation will ultimately reach its end. The exponential increase in the number of vehicles in Malaysia has resulted in a significant accumulation of vehicles that will soon reach the end of their operational lifespan. These decommissioned automobiles are a vital component of the automotive sector that must be considered, as they might contribute to environmental damage.

The effective management of these unused vehicles, also known as end-of-life vehicles, is still in the developmental stage, with only a limited number of agencies and companies

currently focused on its management. Nevertheless, it is imperative to conduct additional research and advancements in the management of these types of automobiles to guarantee a more environmentally friendly outcome.

1.2 Project Motivation

The absence of adequate instruments for managing end-of-life vehicles (ELVs) is a significant hindrance to the efficient management of this process. The method of car assembly has been significantly advanced, resulting in the invention and production of specialised tools to aid in the assembly process. However, the process of disassembling a vehicle is currently not well-developed, and there is a scarcity of specialised tools that could enhance the efficiency of the dismantling process. Developing a tool to facilitate the vehicle dismantling process can serve as a catalyst for advancing the dismantling process and ultimately mitigating the pollution resulting from unused vehicles.

1.3 Problem Statement

When expressing the subject or topic that the study intends to answer, a research problem statement ought to be succinct, to the point, and specific in its description. Ensure that it is written in a way that is understandable to both subject-matter experts and general readers.

Because it is long-lasting and resistant to breaking, laminate glass is a good material to use for the windows of various vehicles. An interlayer that is composed of polyvinyl butyral (butyl rubber) or ethylene-vinyl acetate (silicone) is typically utilized in order to bond the glass layers together. This is a generally accepted procedure. The installation of laminate glass in automobiles requires the use of many sealants in order to ensure its safe installation. This prevents water from penetrating the glass and also offers structural support. When a vehicle

reaches the end of its life cycle, removing laminated glass can be a significant challenge due to the high adhesive properties of the sealants that were utilized.

When it comes to electric automobiles, the most significant challenge is to locate sealants that maintain their effectiveness throughout the lifetime of the vehicle and are simple to remove in a secure manner. Using the sealants that are currently available to remove laminated glass can be a process that is not only difficult but also dangerous and requires the use of specialized instruments. This method not only drives up labor costs, but it also raises the possibility of glass damage and puts the safety of the workers in jeopardy. It is possible that the adhesives used in the production of glass and interlayer materials make recycling them more challenging than recycling other materials.

1.4 Research Question

This research describes how variations in sealing parameters such as type of adhesive, method of application, and curing conditions during the setting of laminated glass in vehicles can contribute to the ease and efficiency, and cost-effectiveness of the separation processes for glass chunk. The study has a focus on establishing the best sealing parameters that will aid an easier and cheaper split-up of glass layers during recycling of the vehicle and thereby pave the way toward more sustainable and environmentally friendly end-of-life vehicle management.

1.5 Research Objective

The objectives for this research are:

i. To identify the Key Parameters in sealant used for laminated glass installation toward effective ELV dismantling process.

ii. To analyses the key parameters on efficiency toward ELV's dismantling process by using survey methodology.

iii. To verify the best key parameters toward ELV's dismantling process by using experiment set up methodology.

1.6 Scope of Research

1. To achieve objective 1:
   i. Conduct a comprehensive literature review to identify existing research and information on the type of sealant used, particularly focusing on applications in dismantling ELV-laminated glass.
   ii. Identify key parameters commonly considered in dismantling process and their effects on cleaning efficiency and material compatibility.
2. To achieve objective 2:
   i. Design a survey questionnaire to gather data from industry professionals, researchers, and practitioners familiar with applying sealant techniques and ELV laminated glass dismantling process.
   ii. The survey should focus on identifying the key parameters perceived as important in sealant used for installation processes for ELV-laminated glass dismantling as well as their experiences and opinions on the effectiveness of different parameters
3. To achieve objective 3:
   i. Develop an experimental setup to verify and validate the effectiveness of sealing used for laminated glass install and dismantling process parameters identified in the literature review and survey.
   ii. Select representative samples of ELV-sealant types such as Polyurethane (PU) sealants, Butyl sealants and establish controlled experimental conditions.
   iii. Systematically vary the key parameters, such as seal strength, application temperature, curing time according to the research objectives.

1.7 Significance of Project

The project aims to produce an analysis that can facilitate the dismantling process of ELV (End-of-Life Vehicles). The instrument might be utilised by the dismantling organisation to enhance the quantity of vehicles that can be dismantled inside a specific timeframe. The invention of sealant can enhance the efficiency of the dismantling process. That being stated, the efficiency of workers can be maximised, allowing them more time to commence work on other tasks.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

Year after year, the number of cars had risen dramatically. As to a report from Business Insider, the number of cars on the road is projected to reach 2 billion by 2040, up from an estimated 1.5 billion in 2015. Countries with large populations, like India and China, are seeing a surge in the number of registered vehicles due to improvements in transportation. There was also an upward trend in people's quality of life. In order to go around, most people these days think having a car is essential. The more people want to buy cars, the more the producers have to crank out of the vehicles. Perodua was planning to raise its output from 28,20,000 vehicles in 2022 to 31,40,000 in 2023, as reported by Paultan.org. Meeting the demand of the buyer is the only reason for this increase in production pace. The number of End-of-Life Vehicles (ELVs) is rising in tandem with the number of vehicles produced. When people upgrade their cars, some may not part with their old ones; as a result, they may end up in the ELV category due to abandonment.

2.2 End of Life Vehicle

2.2.1 Definition, Concept and Philosophy

European legislation designates certain vehicles as waste, and one such vehicle is the End-of-Life Vehicle (ELV). An item is considered wasteful if it is thrown out, whether on purpose or by accident. In most cases, a discarded vehicle is one whose owner no longer has any use for it, either because of the owner's passing or because the vehicle is not in high demand. It is common practice to discard vehicles if they are no longer functional. A wrecked

vehicle might be the consequence of severe damage sustained in an accident or as a consequence of a natural catastrophe. One of the biggest problems that households have when it comes to waste management is ELVs, or vehicles that have reached the end of their useful life (Karagoz et al., 2022). The negative effects of ELVs on both the environment and their users have increased the worldwide importance of ELV-related worries (Rešetar et al., 2018; Karagoz et al., 2020). Many initiatives have been launched by the European Union (EU) to deal with the issue of End-of-Life Vehicles (ELVs) (Inghels et al., 2016; Simic, 2016). The term "ELV" refers to vehicles that have been driven to the point where they provide an unsafe driving risk on public roads, whether because of their age or condition (Viri et al., 2021; Yan et al., 2021).

End-of-life cars (ELVs) have become more common as the economy and auto industry have grown (Zeng et al., 2020; Zhang et al., 2022). Because ELVs have a lot of recyclable metal and non-metal materials, they are considered high-value urban minerals (UMs). Not only would improperly getting rid of ELVs waste resources, but it would also hurt the environment by polluting surfaces and fields with heavy metals (Li et al., 2014; Li et al., 2022). Now, the circular economy is growing quickly around the world, and collecting UMs is being seen as a unique way to make sure that resources will be available for a long time (Li et al., 2015; Nickless, 2017). There was official recycling of about 77% of ELVs in Europe (D'Adamo et al., 2020). In the US, the rate of recycling is over 80%, and in China, it's only about 30% (W. Li et al., 2016). As more waste-free cities are built around the world, the amount of ELVs and the formal recycling rate are slowly going up. This is especially true in China, which is rapidly developing and has a lot of people (Tan et al., 2021; Xavier et al., 2021). A lot of ELV recycling bases are being set up in a planned way there.

2.2.2 Elv Practices

"Recycling, reuse, reclamation or any other process with a view to extract secondary raw materials, or the use of waste as source of energy" is one definition of waste recovery (European Economic Community, 1970). **Figure 2.1** shows the steps involved in recovery, which include collecting items at the end of their life cycle and cleaning, classifying, and dismantling them (Jayal et al., 2010; Jun et al., 2007; Mohan and Amit, 2021).

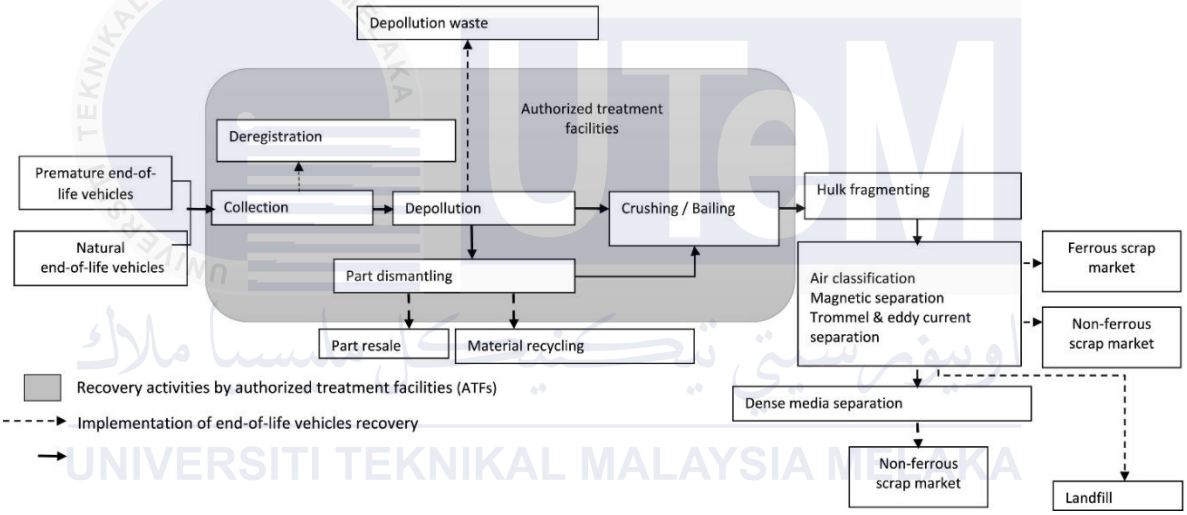

Figure 2.1 Flow chart of ELV practices

(Source: (Jayal et al., 2010)

2.3 Overview of The Dismantling Process in Elv's.

2.3.1 Identification of Challenges Specific to Dismantling Laminated Glass.

More and more, laminated glass is being used these days. The building industry and the automotive industry are also affected by this. The front and back windows of an automobile are the most common examples of this, whereas railings and window glass in a building are examples of technical safety glass. The purpose of this glass is to offer enough protection from mechanical impacts and bad weather. In the case of damage, it must shatter into the tiniest bits

imaginable or, if feasible, the glass must stay attached to the interlayer film so that no one or animal nearby can be hurt by flying fragments (Šooš et al., 2021).

From an ecological, energy, and technological perspective, recycling glass is highly significant; as a result, glass is a valuable secondary raw resource that is now considered waste. Worldwide, almost 90 million cars are manufactured each year, according to statistics from the International Organisation of Motor Vehicle Manufacturers (OICA). Assuming that one vehicle windshield contains approximately 13 kg of glass and 1 kg of PVB film, the total amount of glass for windshield production is approximately 1170 mil. kg and 90 mil. kg of PVB film per year. The total worldwide amount of PVB film produced for the automotive and construction industries is estimated at around 170 mil. kg per year. (2014 Statistics | www.oica.net, n.d.) (Dhaliwal & Hay, 2002) (Gorokhovsky et al., 2005) (Swain et al., 2015).

Materials from end-of-life vehicles (ELVs) are attracting the attention of recycling firms and researchers. The reason behind this is the presence of numerous stringent environmental legislation and directives from different governments, including the US Resource Conservation and Recovery Act (RCRA), K-REACH, and the EU directive on ELV. Because it establishes a recovery limit of 95% by weight of ELV, with 85% of that weight to be recycled, European directive number 2000/53/CE poses a challenge to the automotive sector.

This initiative has the full backing of the automotive sector across the European Union. But so far, recycling efforts have focused on more desirable resources like steel and aluminum, rather than on less desirable byproducts like glass (Gerrard & Kandlikar, 2007). The equal importance is the obvious need to greatly enhance the efficacy of windscreen recycling. However, when it comes to disassembly, the minimum operating obligations for ELV

specifically state that glazing removal needs to be done

2.3.2 Impact of Improper Dismantling on Environmental Sustainability and Safety.

Among the most significant and widely utilized products of the last decade has been the automobile. With a 3.1% average yearly rise, the number of vehicle registrations will virtually exceed 1.1 billion units by 2019 (Sperling & DeLuchi, 1989). The automobile now serves multiple vital purposes in many spheres of modern society and the economy, including the public and professional spheres. Numerous causes, including rising purchasing power and market demand due to a growing global population, will cause these figures to rise. The Malaysian car business is no different. The automobile sector in Malaysia is experiencing fast development, with an average yearly percentage change of 7.9% from 1990 to 2019 (Go et al., 2010). When comparing 2018 and 2019, the total registration for passenger vehicles increased by almost 17,080 units (Fernando et al., 2021). The Total Industry Volume (TIV) of newly registered motor vehicles has surpassed 600,000 units after three consecutive years of being below the value, despite the difficult climate in 2019.

There are a number of obstacles to ensuring the stability of the supply and demand in the automobile industry due to the large volume of business (Fernando et al., 2021). Optimal implementation of a circular economy strategy in the automobile sector requires a number of measures from the government (Fernando et al., 2021). There has been an uptick in the amount of abandoned or discarded vehicles due to the high number of vehicles used by consumers in recent times. Vehicles that have served their useful life but are no longer roadworthy are likewise referred to as end-of-life vehicles (ELVs) (Ahmed, 2014) and are subsequently discarded (End of Life Vehicles, n.d.). Even though manufacturers predicted a 15-year lifespan for their vehicles (Azmi et al., 2013) (Hao et al., 2011), approximately 20% of the world's cars

were 15 years old or older in 2013(Sperling & DeLuchi, 1989) . More than 5 million vehicles in Malaysia are between the ages of 10 and 15 (Ahmed, 2014). Because vehicles are used for long periods of time, the number of vehicles that have reached the end of their life cycle is growing quickly. This massive quantity necessitates swift and accurate preparation for these cars in order to forestall the enormous risks that ELV poses to the long-term viability of the automotive industry (Sulaiman et al., 2023).

A number of ELV issues in Malaysia have been brought to light by the Malaysian Automotive, Robotic and Internet of Things (MARii) initiative, including careless abandonment, poorly handled scrap, and vehicles that are unfit for use on the road (Fernando et al., 2021). Due to its neglect, this ELV has become a haven for a wide variety of pests, including rats and cockroaches, which can spread disease to nearby residents. Unattended ELV is unsightly and dangerous due to rusty metal and broken glass; it is usual to see such vehicles abandoned in residential roads or back alleys (Ahmed, 2014). In addition to being a source of traffic congestion and potential vandalism, these abandoned ELVs often block parking spaces and roads. More than 3.3% of accidents that occur on public roads involve ELVs, according to studies on abandoned vehicles (Ahmed, 2014). Accidents like these happen because people frequently leave these ELVs unattended and let them obstruct traffic. Furthermore, these unattended ELVs are vulnerable to theft and may be exploited for criminal purposes. Even worse, these ELVs can ruin the vibe of the whole community and make people afraid to act inappropriately.

Furthermore, without adequate management, the space-inhabiting landfills will quickly become overflowing with solid waste from ELV. Tyres and plastics are examples of non-biodegradable waste that will continue to fill up landfills for the foreseeable future. A large

quantity of hazardous wastes follows, which together constitute an ELV. The release of these hazardous wastes into the environment, if not properly treated and contained, will have negative effects on both the environment and the communities most at risk from them.

Although ELV poses significant risks to the long-term viability of ecosystems, this is not a novel problem. The intricate webs of ELV waste streams do in reality cause problems for a number of nations. As a result, numerous nations have passed laws and regulations to control these issues and make sure everyone is playing by the rules. **Figure 2.2** depicts a typical ELV recycling network that relies on various key partners. Effective application of the ELV standard is crucial from this point on, as it benefits stakeholders and ensures the longevity of the ecosystem.

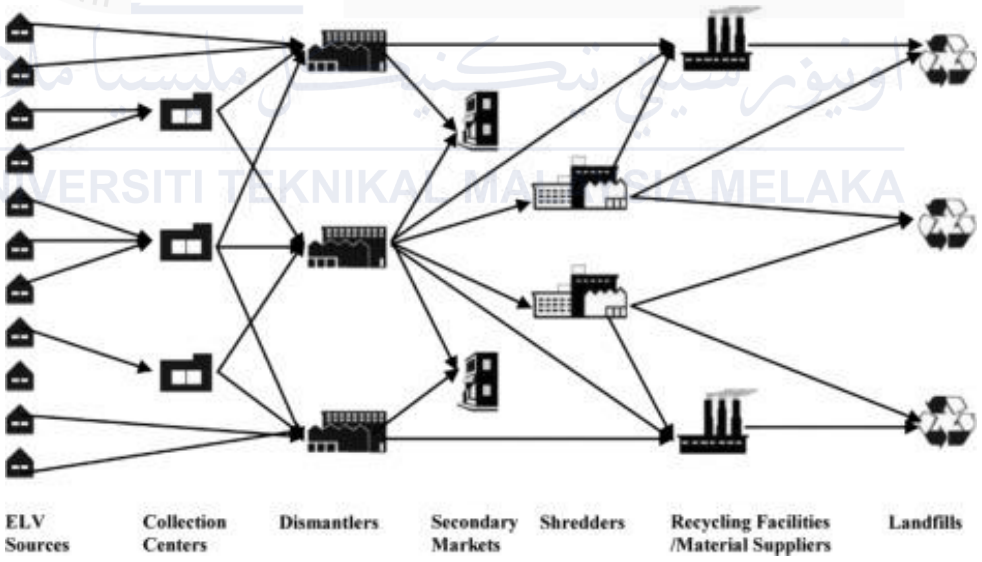

Figure 2.2 Flow of ELV's on environment

(Source: Sulaiman et al., 2023)

Despite Malaysia's large domestic automobile sector, the country has failed to enact ELV regulations and laws (Sulaiman et al., 2023). Without doing adequate studies, the 2009 enforcement effort mandated yearly mandatory inspections for all cars 15 years old and older

(Sulaiman et al., 2023). This policy was later withdrawn, nevertheless, as a result of public outcry (Sulaiman et al., 2023). Beginning with the implementation of the Malaysian National Automotive Policy (NAP) in 2014 and continuing with its continuance in 2020, numerous projects have been launched to create the ELV ecosystem since then. Part of the ELV ecosystem framework, the Malaysia Automotive Remanufacturing Roadmap and the construction of the Automotive Authorised Treatment Facility (AATF) are two major features introduced in the NAP2014. The National Roadmap for the Automotive Aftermarket (NRAA) reiterates remanufacturing and AATF, two components that are carried over into NAP2020.After that, the government should finish off the ELV ecosystem before introducing its own EL management.

There is currently no defined practice for the treatment and processing of ELV in Malaysia, even though over 5,000 small businesses bound by various associations (Sperling & DeLuchi, 1989), such as the Malaysia Automotive Recyclers Association (MAARA), do so (Ahmed, 2014). Because ELVs are unique, there are a disproportionately large number of treatment centres in Malaysia. Even while ELV has a lot of dangerous trash, it also has a lot of recyclable metals—a significant secondary sector that's in high demand both at home and abroad .But without rules, these businesses can't be held accountable for their actions, which increases the danger if their procedures and treatments are harmful to the environment. Additionally, many questions regarding the present treatments and procedures arise from the lack of clarity on the functions of these 5,000 companies within the Malaysia ELV ecosystem. The key players in Malaysia's ELV ecosystem, according to studies on the country's present ELV management and the problems it faces, are recycling centres, landfills, and facilities for dismantling and shredding. on pages 25 and 26.

The ELV trash is quickly stacking up and damaging our environment because of the growing number of ELV that need treatment and the immaturity of the ELV ecosystem. As a result, we will conduct baseline research on ELV recycling and recovery rates in order to gauge the stakeholder's capacities. Because of the many national measures that have encouraged AATF, this study will centre on that organisation in Malaysia. To get a feel for where things stand and how ELV treatment is being used in Malaysia, we also recorded the current AATF practices (Sulaiman et al., 2023).

2.4 Sealing for Laminated Glass Installation

2.4.1 Definition

Sealant, as the name implies, repairs small fissures around the perimeter of a windscreen gasket. Make sure to inquire about the specific kind of sealant used by your windscreen repair service when you schedule an appointment. You can trust that any glass sealant you use will be safe from water, extreme heat or cold, and even vibrations (Experts, 2022).

To make a long-lasting seal, these gel-like sealants are designed to seep into the gaps between the gasket and windscreen. Getting the sealant all the way to the bottom of a chip must be a mystery to you. A specialist uses gravity to spread the sealant throughout the length of the fissure after dropping it from the top of the window, as these chemicals are quite liquid. It completely fills any cracks or holes that could let water in as it moves along a dent (Experts, 2022).

Once dried, the sealant is completely see-through and won't obstruct your eyesight. The sealant, when properly applied, will adhere to the glass, securing the structure for an extended period of time. This chemical isn't just for windscreens; it works well on side and back window chips as well (Experts, 2022).

The silicone gels that make up a glass sealer are what actually create the long-lasting seal. Since silicone is very fluid, it seeps into the window's microscopic crevices and holes when placed on top of the glass (What Is a Glass Sealant and How Can You Apply It?, n.d.)

Screens, side windows, sunroofs, and RV windows are just some of the surfaces that this sealant can repair. Additionally, the glass and molten silicone should adhere properly, leaving no spaces between them, if the application is done appropriately (What Is a Glass Sealant and How Can You Apply It?, n.d.)

There is so many importance of sealing in laminated glass installation such as when it comes to windscreens, they expertly repair tiny chips and fissures that were creating leaks. Some vehicle models have a little space between the windscreen and the frame it's attached to. This crack promotes water to seep inside a car despite being undetectable to the human eye. While it may not seem like a big deal now, imagine how much worse the damage will be when winter rolls out and the water in your car or chip becomes frozen. But this space can be filled with a sealant. One of the many long-term consequences of condensation from a leaking windscreen is the formation of rust on metal frames and other components of your vehicle. Applying a sealant will temporarily stop this disaster.

2.4.2 Current Sealing Used in Automotive Industry.

Windscreen bonding and underbody coating are only two of the many uses for sealants in the automobile industry. Within these general guidelines, though, are a number of intriguing uses for materials used during the "body-in-white" phase of vehicle assembly. The term "body-in-white" describes an automobile's uncoated exterior. This is where materials with dual sealing and adhesive properties come into play. Coated with an equal amount of oils, they can be used

as sealants to keep out water, salt, dirt, and other contaminants, and as adhesives to cling to an endless variety of surfaces. The excellent adhesion performance needs to be preserved across many types of ageing tests with different degrees of severity and across a broad range of test temperatures, usually from -30°C to +90°C. We will now delve into these points in greater depth (Lavery, 2002).

Classification of sealants is based on the common names of the polymer bases used. Some of the most common types of polymers include acrylics, polyurethanes, and polysulfides; additional types include polybutylene, polychloroprene, styrene-butadiene-styrene copolymers, and polysulfide. The guidelines regulate the quantity of solvent used in sealants. Previously, sealants were categorized into two groups: those with a volatile organic compound content (VOC) below 10% and those with a VOC above 10%. The limit of volatile organic compounds (VOCs) for class A sealant was raised to 20% and a provision was provided to allow water-based acrylics.

The first solvent-free polyurethane sealant was manufactured in 1994, and since then, structural adhesives and polyurethane sealants have been developed without the use of solvents. The sealant's viscosity is decreased and the polymer is made easier with the addition of nine solvents. Toluene, xylene, mineral spirits, and other similar solvents are commonly utilized. Curatives containing methyl ethyl ketone release a trace amount of solvent. Silicone sealants do not often use solvents in their formulas. Trace amounts of benzene and toluene are detected in certain sealants.

While most acrylic sealants are based on water, some additionally include ethylene and propylene glycols, mineral spirits, mineral oil, and even mineral ethers. In addition, you can

get acrylic sealants that are based on solvents, which include mineral spirits, toluene, and xylene, among others. Although methyl ethyl ketone is more commonly utilized, toluene is still an ingredient in polysulfide sealants.

The majority of class B sealants contain solvents, with a few notable exceptions, at concentrations as high as 40% by volume. Plastisol-based PVC sealants can be produced solvent-free. Sealants made of butyl rubber often include hydrocarbons (C6-C12). Common solvents used in styrene-butadiene-styrene sealants include toluene, heptane, hexane, methyl ethyl ketone, isobutyl is butyrate, n-amyl acetate, and n-amyl ketone. Solvent combinations are typically used for processing them. Solvents such as aromatic and aliphatic hydrocarbons, ketones, esters, and others are typically used to dissolve polychloroprene. The following are included in the list: naphtha, hexane, acetone, benzene, and toluene.

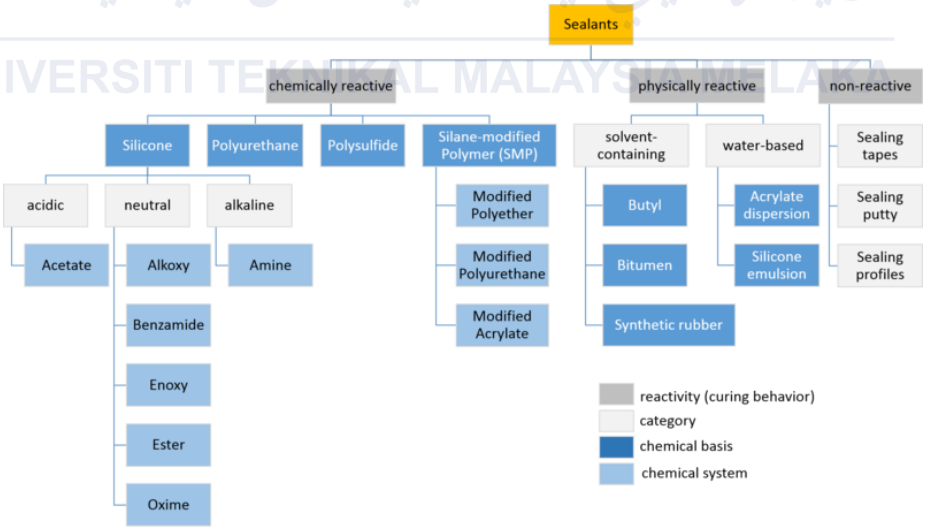

Figure 2.3 Current sealant used

(Source: Wikipedia contributors, 2024)

2.5 ELV Recycling System

2.5.1 Introduction

According to several studies (Ahmed et al., 2015; Cucchiella et al., 2016; Lu et al., 2014; Manzetti and Mariasiu, 2015; Sabaghi et al., 2015; Sawyer-Beaulieu and Tam, 2006), ELVs undergo recycling operations to enhance energy savings and resource exhaustion. The ELV business is also driven by the principles of the circular economy, which promote operations of recovery, recycling, and reusing. Although there has been some progress in China, most ELVs end up on the illicit market in developing regions as used cars (Hou et al., 2018; Zhou et al., 2016a). The expansion of the ELV recycling sector is impeded by the absence of market standardization in China. To help the Chinese government encourage ELV recycling businesses, academic institutions and industrial groups are turning their attention to this sector (Li et al., 2016). As of late, regulations have been put in place to encourage car factories to take responsibility for the regular use, consumption, and recycling of their products through the warranty policy and expanded 3R principles (Pan and Li, 2016; Zhou et al., 2018a).

Numerous studies have broken down ELV recycling into its component parts, such as those dealing with policymaking, operational performance, cost-benefit analysis, recycling mechanisms, etc. (Chen et al., 2015; Tang et al., 2018; Wang and Chen, 2013). Research on disassembly, critical part re-manufacturing, material recycling, renewable resources, and similar topics has been conducted to support circular recycling in the domestic automotive industry (Bulach et al., 2018; Elwert et al., 2018; Fang et al., 2018; Yang et al., 2017a,b, Soo et al., 2017). Another area of focus has been the ELV recycling industry. Despite China's status as the world leader in vehicle production and sales in the past decade, there has been surprisingly little comprehensive assessment of the ELV recycling business in the Chinese market up to this point (Zhou et al., 2019). Despite the abundance of literature on sustainable

practices in the vehicle supply chain and driving forces analysis, the ELV recycling business has seen surprisingly little management practice.

According to Binnemans et al. (2013) and Chen and Zhang (2009), industrialized nations that have been producing cars for a long time have a more developed system for recycling products at the end of their useful life. Thanks to cutting-edge recycling methods and an ideal ELV recycling support system, ELVs—recognized as a recyclable resource in the United States—have been able to enter the market-oriented operation (Jawi et al., 2017). Automakers in Japan are motivated to recycle government-regulated vehicle products due to the country's eco-consciousness and concern for limited resources; this practice seeks to increase the useful life of important auto-components (Che et al., 2011). Japanese researchers are putting the recycling process and end-of-life vehicle disposal technologies under the microscope in an effort to boost ELV recycling efficiency and promote the sustainable growth of the automotive sector. According to Chen and Zhang (2009) and Simic and Dimitrijevic (2013), the European Union is making efforts to standardize and control the ELV recycling business. This is achieved through the implementation of a deposit system and market access permission, which ultimately leads to an improvement in recycling efficiency.

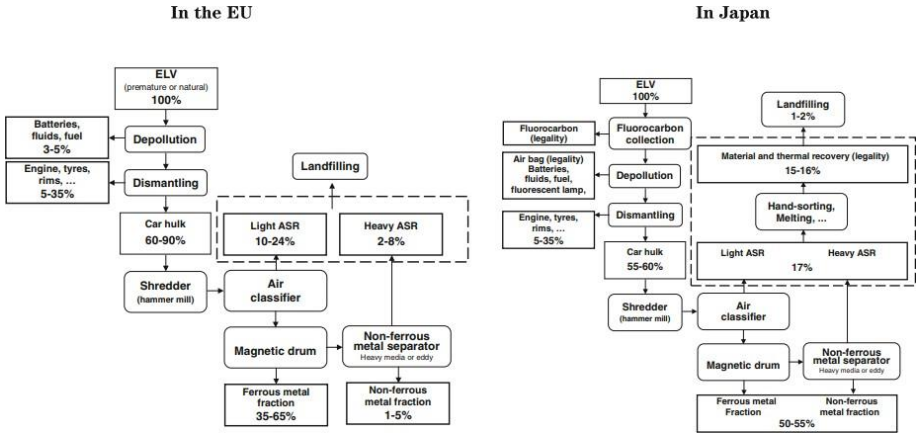

Figure 2.4 Different ELVs recycling on the EU and in Japan

(Source: Journal of Material Cycles and Waste Management, 2025)

2.5.2 Idea of Recycling Process

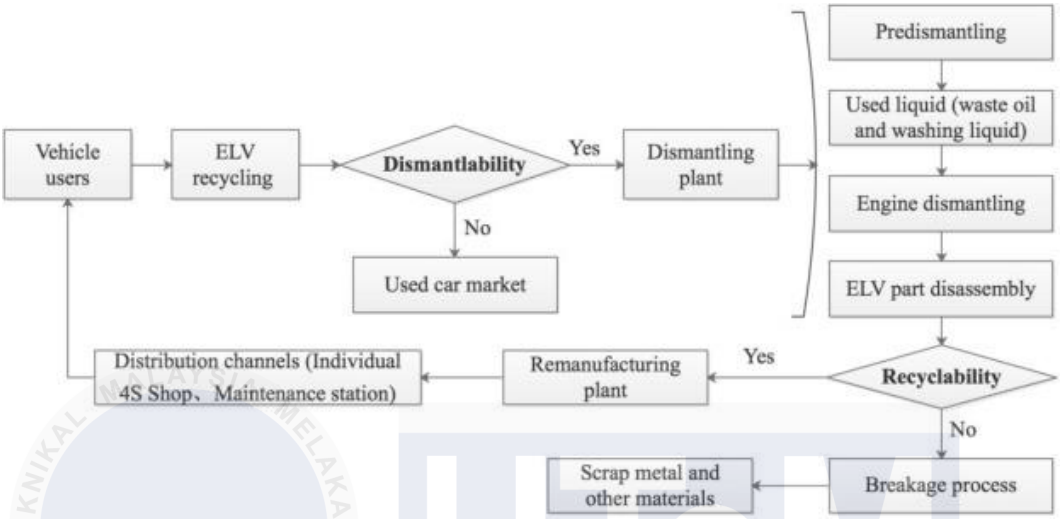

Figure 2.5 ELV recycling process in the Chinese market
(Source: Zhou et al., 2019)

A thorough comprehension of the ELV recycling procedure served as a springboard for the investigation of component elements. Investigating the current ELV recycling technique and key operations is the first step in comprehending the drivers of the ELV recycling sector. Figure 5 shows the various steps that the ELV recycling process in the Chinese market has taken so far, including the participation of recycling organizations, dismantling plants, ELV owners, and designated activities for reusing, recovering, and recycling (Zhou et al., 2018).

2.6 ELV's Component Chosen

2.6.1 Laminated Glass

The process of making laminated glass involves using butyl rubber (polyvinyl butyral) resin adhesive film to attach multiple sheets of glass. The sheets are then heated, pressed, and bonded together to form a compound glass product, which can be flat or curved. A variety of

glass types, including regular, float, tempered, coloured, heat-absorbing, heat-reflecting, etc., can be used to make laminated glass. (Barry, 2009).

The number of layers might range from 2 to 9. Sheets of 2 + 3, 3 + 3, 3 + 5, etc., are typical thicknesses for double-layer laminated glass. The impact resistance of laminated glass is many times greater than that of regular sheet glass, and it also offers excellent transparency. The compounding of numerous layers of regular or tempered glass produces bulletproof glass (Barry, 2009).

Even if the glass breaks, the pieces will stay on to the thin layer and won't damage anyone. What's more, the surface of the broken glass is clean and smooth, so there's no need to worry about the pieces dropping or penetrating. Features like heat resistance, moisture resistance, and durability are just a few of the many benefits of laminated glass (Barry, 2009).

The robust anti-shocking and anti-break-in properties of laminated glass make it an essential safety feature in most buildings throughout the United States and Europe. This product is designed to withstand repeated strikes from dangerous tools like hammers and wood-cutting blades, as well as bullet penetration for a specific duration, ensuring a high level of protection (Barry, 2009).

One of the key criteria for judging the quality of contemporary home construction is the sound-insulation effect. A peaceful and pleasant work environment can be maintained by using glass with butyl rubber interlayer coatings to block out sound wave (Barry, 2009). s. Not only does it shield the skin from harmful UV rays, but it also keeps priceless artwork and antique furniture from deteriorating. Light transmission is reduced, and refrigeration energy is saved.

Laminated glass has so many uses and benefits that it can make extraordinary decorative effects in the home. For example, frosted glass is commonly used for residential doors (including kitchen doors), but it attracts oily smoke easily (Barry, 2009). This problem can be solved by switching to laminated glass. Applying laminated glass will alleviate parents' concerns about the safety of their active children, especially in homes with broad surface partitions.

Even if it breaks, individuals can still safely handle laminated glass. When a hard ball hits it, the glass is likely to shatter into pieces. However, the entire block stays together, and the adhesive film in the center prevents the debris and small sharp pieces from breaking apart. Doors, windows, and skylights in tall structures often use laminated glass because of its safety features. Stores, banks, jewelry shops, and other commercial establishments often use laminated glass for their showcases and dividers. For safety purposes, modern vehicles adhere glazing to the vehicle's body. Typically, it is adhered during application, which increases its resistance to removal.

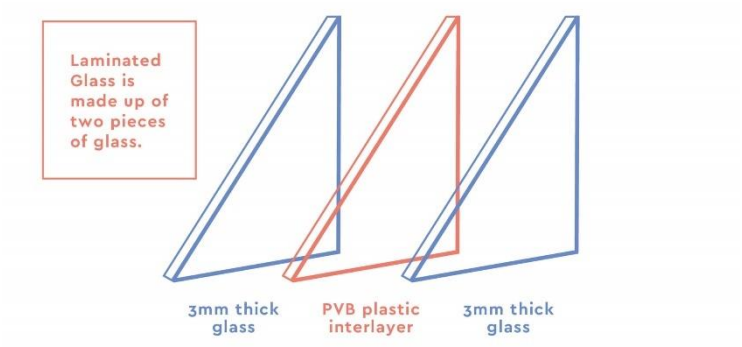

Figure 2.6 Laminated glass composition

(Source: Qunfeng et al., 2009)

2.7 Parameters for Sealing Employed for Efficacy of Dismantling Practices In ELV

Adhesion strength, application temperature, adhesion elasticity and liquid consume are four critical elements that influence the disassembly of laminated glass in the ELV process. All of these things work together in a complex web that affects how well, how safely, and efficiently glasses break down in different contexts. Each operator will achieve remarkable outcomes while disassembling glasses in ELV by meticulously using all of the supplied parameters. The displayed parameters significantly affect this procedure since they have the potential to make it easier and more efficient.

2.7.1 Adhesion Strength

Dismantlable adhesives designed to fulfill these criteria have enough adhesion strength when used, but they separate quickly when exposed to external stimuli, making them ideal for materials that require repair or recycling (Banea et al., 2015) (Hutchinson et al., 2016). Ensuring adequate adhesion strength also depends on the adherends' surface treatment; changing the surface treatment is more effective than changing the bulk (Ebnesajjad & Ebnesajjad, 2013). Ensuring adequate adhesion strength also depends on the adherends' surface treatment; changing the surface treatment is more effective than changing the bulk state. (Abrahami et al., 2017). For instance, zirconia ceramics and resin cements typically have a hard time getting a good bond, but phosphoric acid primers make all the difference. (Kitayama et al., 2010) (Thompson et al., 2011). To make metal and rubber stick together better, organ silane chemicals are applied as coatings. (Sang et al., 2017). These coating procedures show that molecularly thin layers can influence adhesion behavior. By zeroing in on the events occurring at the interface, it would be possible to adjust the strength of the adhesion in a very efficient and selective manner. However, a coating-process-based disassembly method that can be controlled from the adhesive interface has not been devised yet. This problem arises because

the variables that influence adhesion at the interface must be directly controlled. Yes, the most popular ways to study adhesion are removable adhesion techniques that center on the sticky interface's chemical connections.

2.7.2 Adhesion Elasticity

Two types of glass are used in cars—reinforced and laminated. Tempered glass is easy to remove from a vehicle when it breaks. Laminated glass does not break, so it needs to be removed manually, which requires a lot of time and resources. The ease of removing the glass in the disassembly phase depends on the way the glass is sealed during production. The use of rubber seals makes the process of removing glass much easier compared to the method of direct glued (Petronijević et al., 2020). In the case of rubber seals, the complete window can be removed, but the more commonly used procedure of direct bonding with glue involves cutting the glass disk in as large a diameter as possible, leaving a significant part of the glass in one piece (Petronijević et al., 2020). Important role played by elasticity and deduce how the relative stiffness of the layers modulates the decohesion behavior, with the system undergoing a ductile–fragile detachment transition (Di Stefano et al., 2022).

2.7.3 Liquid Consume

For perfect separation and achieving clean phases of the laminate, according to the literature, a wet method of separating the layers of glass from the film seems to be the only usable one (Šooš et al., 2021). The basis of the decomposition technology is therefore the decrease of the butyl rubber adhesiveness through an increasing content of water in the film. The problem with this method is the economic effectiveness of the entire technological process (Šooš et al., 2021). One example of a combined wet technology is the continuous line from the company Xinology Co., Ltd., Hong Kong, for the recycling of laminated glass and the

separation of butyl rubber or silicone film from glass residues (Šooš et al., 2021).

2.7.4 Application Temperature

Accordingly, it is an object of the present invention to provide a method for separating laminated glass components in which the load imposed by the heat treatment is reduced to such an extent that at least a part of the laminated glass is nondestructively recovered (Wambach et al., 1997).

According to the present invention, a laminated glass comprising at least one inorganic glass plate, optionally bonded to a plastic layer by a base adhesive, is heated to a final temperature of at least 300 ° C. at a maximum heating rate of 50 ° C./min. It is preferred to operate at a maximum heating rate of 30 ° C./min, especially a maximum heating rate of 5 ° C./min. Of course, the heat treatment is usually started from room temperature. Following the heating step, according to the invention, the laminated glass is held at the final temperature in the holding step until the plastic layer is essentially pyrolyzed and / or Silicone orated (Wambach et al., 1997).

Table 2.1 shows that recent studies on parameters that affect the effectiveness of laminated dismantling practice in ELV's to see what parameters have the highest impact onto the process and the research about this process.

Table 2.1 Recent studies on parameters that affect the effectiveness of laminated dismantling practice in ELV's

Parameters that affect sealing glass effectiveness	Adhesion strength	Adhesion elasticity	Liquid consume	Application temperature
(Banea et al., 2015)	X			X
(Hutchinson et al., 2016).	X		X	
(Ebnesajjad & Ebnesajjad, 2013).	X	X		
(Abrahami et al., 2017).	X	X		
(Kitayama et al., 2010)	X			
(Thompson et al., 2011)	X			X
(Sang et al., 2017)	X			
(Petronijević et al., 2020)		X		X
(Šooš et al., 2021)		X		
(Wambach et al., 1997).			X	X
(Swain et al., 2015)		X	X	X
(Wahab & Z.F. Fadzil, 2014)	X			
(Chen et al., 2022)		X	X	
(Experts, 2022)		X		
(Fernando et al., 2021)		X		
(Mamat et al., 2016)	X			X
TOTAL	**9**	**8**	**4**	**6**

2.7.5 Two Highest Parameters Will Be Chosen and Tested in Experiment

Examining how adhesive elasticity and strength affect the sealants during the assembly and disassembly of laminated glass will be the primary goal of this research. Since both the amount of liquid consumed and the temperature are fixed, these two parameters were selected for their interdependence.

Several applications related to laminated glass in ELVs have variations, which can be found to be useful when it comes to dismantling as well as recycling. Laminated glass can be of two types of layering formation which is butyl rubber layer or silicone layer and this kind of glass is formed by the process of joining two or more layers of glass together with a special type of adhesive layer. This laminated construction forms a significantly stronger bond between the baffle layers than for example regular annealed (non-tempered) glass. In the case when the glass splits or cracks, the adhesive interlayer plays a role of two components joining the glass. This better adhesion strength comes handy for the ELV dismantling as it allows the glass to stay as one piece during the dismantling, instead of cracking into many small sharp pieces which are hard to manage during dismantling process. It is also easier to strip the lamination apart in larger unshaped panels than tiny irregular pieces of glass, making the dismantling of the glass more effective and safer due to its laminated structure. Furthermore, it becomes easier to separate the laminated glass in large pieces which means the glass material that is recovered is of high quality and of more value to glass recyclers and manufacturers who prefer large glass cullet. Also, reduced risk of the glass breaking during the dismantling as well as sharp edges that posed dangers to ELV workers contributes to improved safety at work and fewer dangers of getting hurt.

2.9 Summary

The number of cars on the road is projected to reach 2 billion by 2040, up from 1.5 billion in 2015. Countries with large populations, like India and China, are seeing a surge in registered vehicles due to improvements in transportation and an upward trend in people's quality of life. As people upgrade their cars, some may not part with their old ones, leading to the rise of End-of-Life Vehicles (ELVs). European legislation designates certain vehicles as waste, and ELVs are considered high-value urban minerals (UMs) due to their recyclable metal and non-metal materials. The circular economy is growing

globally, and collecting UMs is seen as a unique way to ensure resources are available for a long time. ELV practices include recycling, reuse, reclamation, and dismantling. Challenges specific to dismantling laminated glass are significant, as glass is a valuable secondary raw resource that is now considered waste. Recycling efforts have focused on more desirable resources like steel and aluminum, rather than less desirable byproducts like glass. Improper dismantling can have a negative impact on environmental sustainability and safety.

The automobile industry in Malaysia is experiencing rapid growth, with an average yearly percentage change of 7.9% from 1990 to 2019. However, the industry faces challenges such as an increase in end-of-life vehicles (ELVs), which pose significant risks to the long-term viability of the industry. These vehicles are often abandoned, causing pests, traffic congestion, vandalism, and potential criminal activities. Additionally, ELVs can block parking spaces and roads, causing traffic congestion and potential theft. Without proper management, landfills will overflow with solid waste from ELVs, releasing hazardous waste into the environment. Laws and regulations have been passed to control these issues and ensure the longevity of the ecosystem.

Malaysia's automobile sector has not enacted ELV regulations and laws, despite its large domestic automobile sector. The Malaysian National Automotive Policy (NAP) introduced the Malaysia Automotive Remanufacturing Roadmap and the construction of the Automotive Authorized Treatment Facility (AATF) in 2014 and 2020 respectively. However, there is no defined practice for ELV treatment and processing in Malaysia, despite over 5,000 small businesses like the Malaysia Automotive Recyclers Association (MAARA) doing so. The growing number of ELVs requiring treatment and the immaturity of the ELV ecosystem contribute to environmental damage. Baseline research on ELV recycling and recovery rates will be conducted to gauge stakeholder capacities. Sealing for laminated glass installation is crucial for repairing small fissures around the perimeter of a windscreen gasket and preventing condensation from leaking into the vehicle.

Sealants play a crucial role in the automotive industry, particularly during the "body-in-white" phase of vehicle assembly. These materials, coated with equal amounts of oils, can be used as sealants to keep out contaminants and as adhesives to various surfaces. Sealants are classified based on the polymer bases used, with the first solvent-free polyurethane sealant manufactured in 1994. Since then, structural adhesives and polyurethane sealants have been developed without the use of solvents. The ELV recycling system is a key focus in the automotive industry, driven by the principles of the circular economy and the need for energy savings and resource exhaustion. Despite China's status as the world leader in vehicle production and sales, there has been little comprehensive assessment of the ELV recycling business in the Chinese market.

Industrialized nations with long-standing car production have developed systems for recycling end-of-life vehicles (ELVs), leading to increased market-oriented operations in the United States and Japan. Japan's eco-consciousness and concern for limited resources motivate automakers to recycle government-regulated vehicle products, aiming to increase the useful life of important auto-components. The European Union is working to standardize and control the ELV recycling business through a deposit system and market access permission.

Laminated glass is a key component in ELV recycling, with its impact resistance, heat resistance, moisture resistance, durability, and anti-shocking properties making it an essential safety feature in buildings. It also offers sound-insulation, reducing light transmission and refrigeration energy.

The disassembly of laminated glass in ELV processes is influenced by adhesion strength, application temperature, adhesion elasticity, and liquid consumption. Adhesion strength depends on the surface treatment of the materials and the adhesive film used. Removable adhesion techniques that focus on the sticky interface's chemical connections are popular ways to study adhesion behavior.

The use of reinforced and laminated glass in cars is influenced by parameters such as adhesion elasticity, liquid consumption, and application temperature. Laminated glass, which can be butyl rubber or silicone, has a stronger bond between the baffle layers than regular annealed glass, making it easier to dismantle and recycle. The use of rubber seals makes removing glass easier, while direct bonding with glue involves cutting the glass disk in large diameters. The application temperature of the laminated glass is also a factor. The research aims to examine how adhesive elasticity and strength affect sealants during assembly and disassembly of laminated glass, considering both the amount of liquid consumed and the temperature. This research will help improve safety and reduce the risk of glass breaking during dismantling.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In order to ensure functionality and effectively address the challenges faced by the ELV organisation, a product development must undergo a rigorous development process. Regarding the disassembly of glasses, the sealant is anticipated to fulfil the criteria of facilitating the removal of the glass by reducing time and effort required, while also ensuring durability. To accomplish the objective, the experiment process relies on researching and studying existing types of sealants that are intended to perform the same duty. Additionally, the mechanism is enhanced to facilitate the process of removing the glass. During the design phase, the workability and efficiency of the product are taken into consideration, specifically in relation to the existing condition of the tool in the ELV industry.

This chapter will include the study's methodology, which includes explanations on how the study's objectives can be attained. This study requires the following three steps of investigation: (i) In the first stage, we will identify the key parameters in dismantling process that are influence to ease the work of dismantling. (ii) In the second stage, we will analyze the parameters and their impact on the efficiency of the dismantling process. (iii) In the third stage, we will use experimental methodology to verify the best parameters for dismantling laminated glass that are efficient in the context of ELVs part.

In the first stage, the literature review is used to identify the key parameters in the sealant. Important variables in this research are those that have an impact on how efficient and

productive are laminated glass dismantling process in ELV's. Step 2 involves conducting a survey to see how well the laminated glass dismantling in ELV's worked. In Stage 3, the experimental setup from this chapter will be used to validate the significant parameters collected in Stage 2. Chapter 4 and Chapter 5 will offer the specifics of carrying out the experiments and discussing the outcomes.

3.2 Flowchart of Project

This research methodology's primary process flow is depicted in **Figure 3.1**. This study employs a methodical strategy that begins with a literature review in order to determine the important parameters influencing the efficacy of laminated glass dismantling in end-of-life vehicles

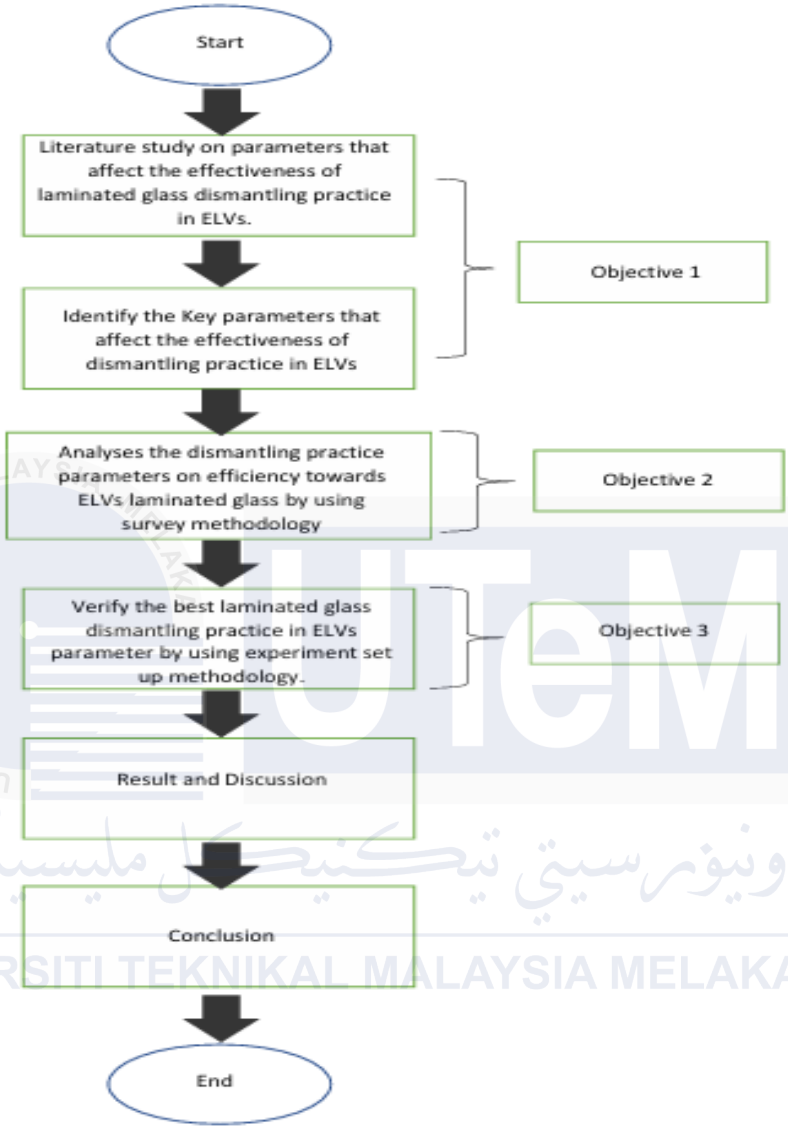

Figure 3.1 Main process flow of the research methodology

This research therefore follows a three-part structure: (i) Review pertinent articles published in recent sealing parameter for laminated glass installation journals to identify important parameters influencing the effectiveness of to facilitate efficient dismantling in end-of-life vehicles; (ii) Use survey methodology to analyze the impact of sealing various parameters on efficiency; and (iii) Run experiments to determine the optimal parameters for facilitate efficient dismantling in end-of-life vehicles

3.3 Gantt chart Of Project

Table 3.1 shows the Gantt chart of the project. Gantt charts are a graphical representation used in project management to present the project schedule and this is accomplished by breaking down the project into tasks and allotting a specific start and finish date to each task and representing it in visual fashion. Such a visual representation permits project managers to effectively plan, schedule, monitor progress, and communicate all details.

Table 3. 1 Gantt chart of the project

Gantt Chart for PSM 1															
No	**Task Project**	**Plan / Actual**	**Week**												
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	PSM title registration	Plan														
		Actual														
2	Project briefing with supervisor.	Plan														
		Actual														
3	Research about this PSMtittle	Plan														
		Actual														
4	Introduction (Chapter 1)	Plan														
		Actual														
5	Literature Review (Chapter2)	Plan														
		Actual														
6	Design idea brainstorming	Plan														
		Actual														
7	Feature and function specification	Plan														
		Actual														
8	Methodology (Chapter 3	Plan														
		Actual														
9	Construct planning for experiment	Plan														
		Actual														
10	Writing PSM report	Plan														
		Actual														
11	Sent full report to supervisorfor checking															
12	Presentation PSM	Plan														
		Actual														

3.4 Data Collection and Sample Size

The research relies on both qualitative and quantitative information. In Stages 1 and 2, we use qualitative data to determine the optimal key parameters of the laminated glass dismantling practice in ELV's. In Stage 3, we use this information to validate our experiment approach. In Stage 3, the most effective key parameters are confirmed using quantitative data, which can be transformed into useful statistics. Stages 2 and 3 utilize the quantitative data while this is happening. In the second stage, we use the data from the survey to Silicon eluate the key parameters of dismantling practice in ELV's. The data from stages 2 and 3 are used to Silicon eluate the two best key parameters for the tests in stage 3, which proves that the data from stages 2 and 3 are accurate.

3.5 Stage 1: Identifying the Key Parameters

Stage 1 literature review aims to identify key elements influencing dismantling in end-of-life vehicles effectiveness. The literature review aims to examine recent improvements in dismantling in end-of-life vehicles. At the same time, voids are found, allowing the present study to fix them. The research was done and detailed in Chapter 2: Literature Review. **Figure 3.2** shows the flow chart for Stage 1, the methodology utilized to achieve the first objective of this research

3.5.1 Data Collection and Literature Study

A literature review is an analysis and synthesis of published works on a certain subject. Not only do graduate students need to do literature reviews, but academics in general do so at various points in their research careers. A literature review is a summary and analysis of prior research in a certain area (Knopf, 2006).

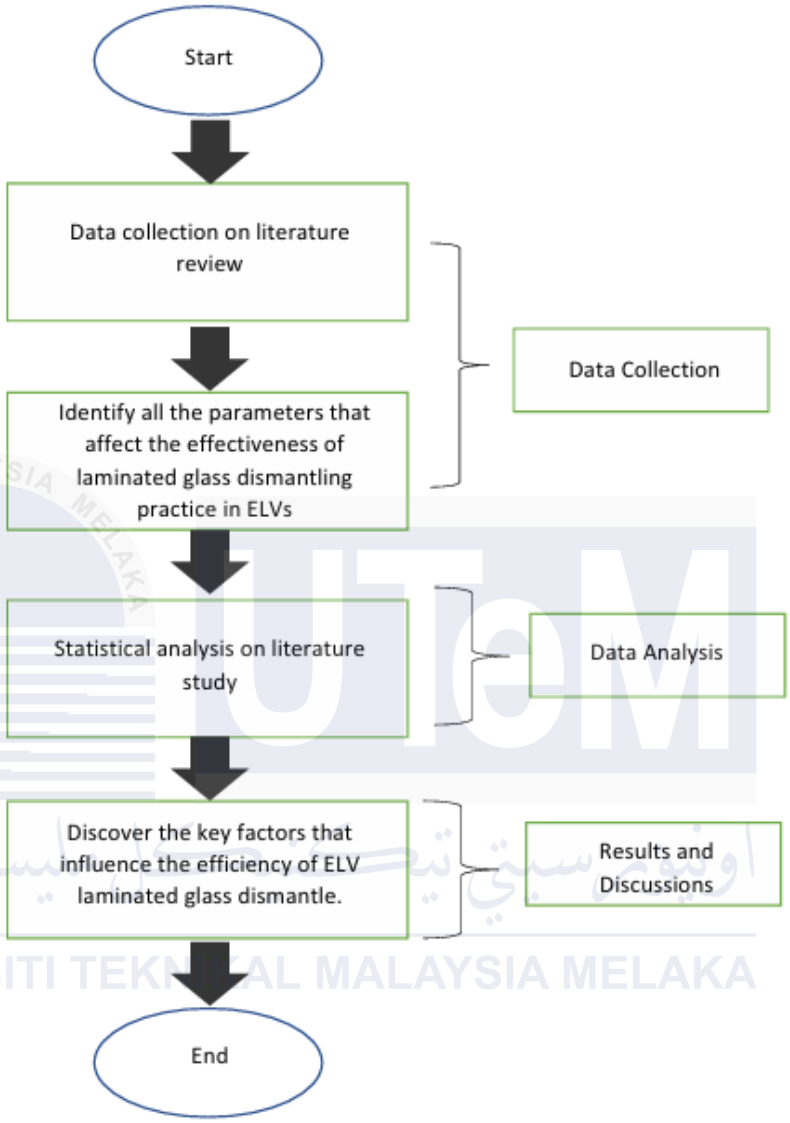

Figure 3.2 Stage 1 process flow

3.5.2 Data Analysis

In order to be thorough, a literature review must consult and assess several sources, such as scholarly and professional journals, books, and online databases. The purpose of the literature review is to find and locate papers and other sources that are pertinent to the topic. Web resources and bibliographic databases can be searched using search engines. When learning about a new topic, conceptual frameworks might be helpful. Analyze, Scanning, note-

taking, structuring, writing, and bibliography-building are the steps involved in creating the literature review (Rowley & Slack, 2004). There are two sections to the results: first, a summary of the literature on ELV laminated glass dismantle practices; and second, an analysis of the variables that affect its effectiveness.

In order to find out how effective the process of dismantling laminated glass is in ELVs, a set of criteria is developed. The most extensively researched characteristics in laminated glass dismantling procedure for ELVs effectiveness are thought to be the most crucial aspects impacting the efficacy of this practice. We use a bar chart statistic to look at all of the components. A thorough literature analysis on the subject reveals the most critical criteria for deconstructing laminated glass in ELVs. The significance and Resilience of laminated glass dismantling practice in ELVs criteria are indicated by the lowest and maximum number of journal study, according to simple statistics

3.5.3 Result and Discussion

In this section, we will go further into the literature research findings regarding important variables in laminated glass dismantling practice in ELVs. We will use the bar chart to examine the parameters that determine the efficiency of this practice. The following criteria will be applied to the analysis of the literature study data to support the conclusions, since the survey used a three-point rating system:

i. A factor is deemed important if it appears in more than half of the research on laminated glass dismantling procedure in ELVs variables overall.
ii. A factor is not deemed significant for effective laminated glass dismantling practice in ELVs if it appears in less than 50% of the study on the topic overall.

3.6 Stage 2: Analyzing the Sealing Parameter.

Finding out what matters most for ELV laminated glass dismantle efficacy is the goal of the stage 2 survey approach. Through the use of a survey technique among highly competent individuals, this approach seeks to shed light on and uncover novel advancements in the breakdown of laminated glass in ELVs. After the study was finished, as described in Chapter 2: Literature Review, a follow-up survey was conducted to get opinions from people who are more knowledgeable and skilled in this field. Finding the best key criterion was the goal.

Quantitative studies in social science and marketing often make use of questionnaires. In order to collect statistically meaningful information about a specific issue, researchers often employ questionnaires, which consist of a sequence of questions asked to individuals. In order to make statements about specific groups or populations, questionnaires are crucial when they are well-designed and used ethically. We can get a lot of useful information from a big number of people (the "respondents") with these surveys. The effectiveness of a survey depends on well-designed questionnaires. In order for the survey to be useful, it needs to ask the right questions in the right order, use the right scaling, and have a proper format so that the results are reflective of the participants' actual thoughts and feelings. Pretesting using a smaller fraction of the target respondents is a good way to Silicon eluate if a questionnaire is capturing the required information effectively (Roopa & Rani, 2012).

3.6.1 Data Collection Survey Methodology

The data collection procedure for the literature review has been supported by the systematic use of a survey methodology based on questionnaires to gather and synthesize data. Experts in Malaysia were polled via questionnaire to gauge their level of familiarity with the sealant used for laminated glass installation that significantly impact the effectiveness of the

dismantling process.

Parameters that influence the efficiency of the dismantling process for ELVs include respondents' demographic information, their knowledge and experience with the sealant used for laminated glass installation, their perceptions and preferences regarding the process, challenges and barriers, and, most importantly, the most crucial components. The materials and features of the glass dismantling machine are two such criteria.

As you can see in **Figure 3.3** it is a stage 2 process flow, the data was examined using a quantitative methodology once it was obtained from the respondents. The highly trained workforce in Malaysia, especially in the automotive sector (including repair shops and other associated businesses), receives structured products in a methodical fashion. The primary goal is to acquire highly reliable and thoroughly verified data from experts in the industrial sector. After every responder has given their answer, a bar chart statistic is used to analyze each item.

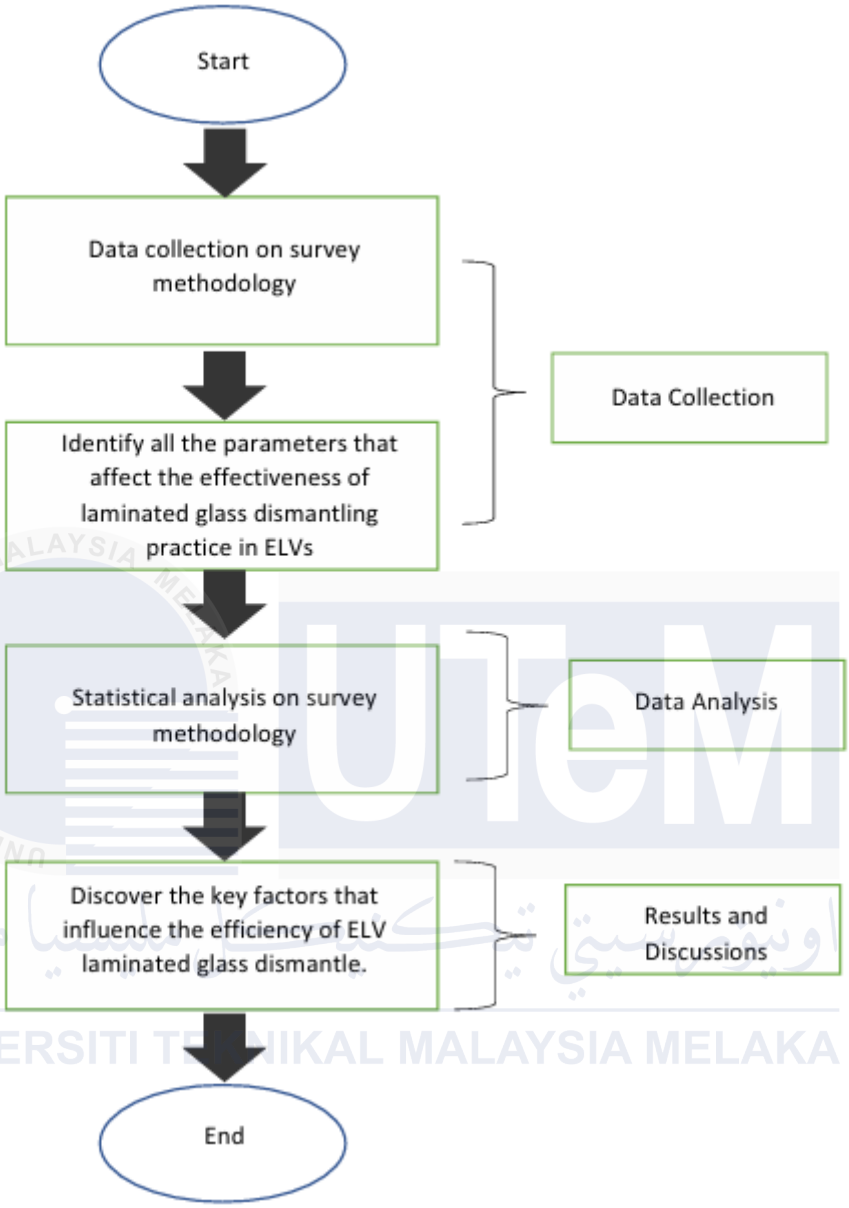

Figure 3.3 Stage 2 process flow

3.6.2 Data Analysis

3.6.3 Result and Discussions

Based on the survey data, this part will discuss the important parameters affecting the efficacy of disassembling ELVs, such as the sealant used for laminated glass installation procedures. Using the criteria to build a bar chart, we may identify the components that impact the success of laminated glass dismantling procedure in ELVs. Since the survey used a three-

point grading system, the following criteria will be used to analyze the survey methodology data and support the findings:

i. In the data collected from the survey technique generally, a laminated glass dismantling practice is deemed significant if it appears in more than 80% of the cases.

ii. A component is not deemed a major element of effective ultrasonic cleaning if it shows in less than 80% of the data collected from the survey method generally when it relates to ELV's laminated glass disassembly.

3.7 Stage 3: Verifying the Best Sealant Parameter.

The third and last stage of this study is to identify the optimal sealant for laminated glass installation, which has a substantial influence on the efficiency of dismantling ELVs. In addition, there are two input variables in the experimental design. Reason being, those parts that can be measured are described in terms of numerical attributes. Make the case that subjective judgment can be reduced to appropriately measure quantitative qualities. The third objective of this study was achieved in stage 3 using the technique flowchart shown in **Figure 3.4**.

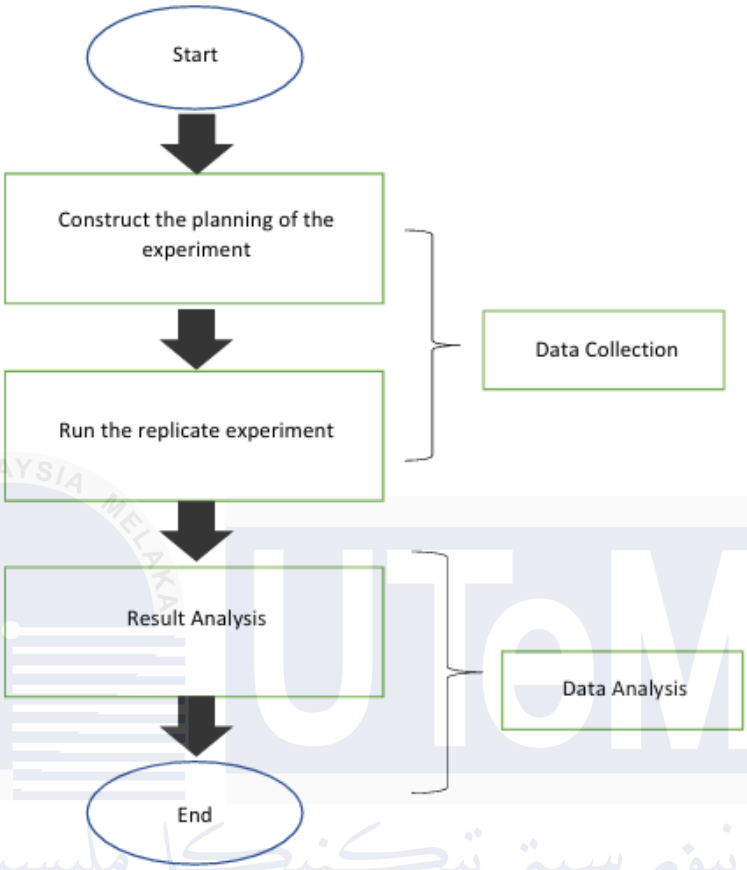

Figure 3.4 Stage 3 process flow

3.7.1 Construct the Planning of The Experiment

Because laminated glass is the most important aspect of this investigation, a great number of panels made of this material were produced in order to be utilized throughout the planning stages of the experiment. In order to determine whether or not this experiment was successful, the laminated glass that was made must be consistent in both its size and its strength. The thicknesses of 6.38mm (0.25 inches), 8.38mm (0.33 inches), 10.38mm (0.39 inches), and 12.38mm (0.47 inches) are the most frequently seen for laminated glass. Performance and cost of laminated glass are both impacted by the thickness of the glass (Laminated Glass Thickness 101: Understanding the Basics and Benefits | glassforum.org, 2024). An application of a sealer was made to the laminated glass panel after the parameters were chosen based on the technique

of conducting the survey and conducting research on the Resilient literature.

3.7.2 Experiment Procedure

In preparation for the upcoming experiment, three work breakdowns have been established in order to demonstrate the most effective sealant for laminated glass installation. This is because the effectiveness of the sealant has a significant effect on the efficiency of ELV dismantling. This research therefore follows a three-part procedure; (i) In the first procedure, dismantling time measurement (ii) the second one is observational Study (iii) and the last one is qualitative interviews

The Dismantling Time Measurement will be measured during the first step of the procedure. The amount of time in order to determine how long it takes for ELV staff to disassemble each panel will be measured during this step. In this way, a quantifiable measurement of the ease with which the object can be dismantled is provided.

Observational Research is the process of disassembling laminated glass panels will be monitored by ELV employees. Thorough notes will be kept during these inspections to record any problems or obstacles that arise during disassembly. As a result, we can see if there is a connection between the type of sealant used and the problems that workers have when disassembling.

For the qualitative interviews, it is to learn more about the dismantle procedures and sealant performance preferences of ELV workers, in-depth interviews will be carried out. Insights into the effects of various sealants on the worker-perceived ease and efficiency of disassembly can be gained from this qualitative data. Employees will be motivated to discuss their experiences with different sealants, including the difficulties they face and the qualities

of the optimal sealer they use while deconstructing laminated glass in ELVs.

3.8 Data Analysis

Information gathered from interviews and observations will be combined. Quantitative statistics on dismantle time, qualitative notes on observations, and quantitative transcripts of interviews will all be part of this. The purpose of this research is to find correlations between several sealant parameters (such as strength and heat activation) and the ease of disassembly by examining this combined dataset. In order to find statistically significant connections between these variables, we will examine dismantling time data using statistical methods. In addition, the interview data will be analyzed qualitatively to find patterns and themes in the experiences and preferences of the workers when it comes to different types of sealants.

We will replicate the research across multiple circumstances to ensure the reliability and generalizability of the findings. Incorporating a broader variety of ELV models with maybe varying sealant kinds or monitoring disassembly operations at various ELV dismantle sites are two possible ways to achieve this goal. The study can confirm the found relationships between sealant characteristics and disassembly ease by comparing outcomes across various replications.

This study will optimize ELV personnel' dismantling efficiency by recommending sealant selection and application procedures based on the combined quantitative and qualitative findings. Not only will the ease of layer separation be considered in these suggestions, but other pertinent sealant features including initial strength and durability will also be acknowledged as important.

3.9 Expected Result

The experiment will be conducted and based on previous research on the effectiveness of laminated glass dismantling process using survey methodology and experimental setup, the ideal of sealing parameter between adhesion strength or adhesion elasticity. These are the expected results for this study. The adhesive's strength is a major selling point for many. They put spent a lot of time testing the adhesive to make sure it will hold. What you've read in this article, though, shows that strength isn't everything. We at the adhesive producer know that strength is a major consideration when picking an adhesive. You should now be as convinced as we are that flexibility is just as crucial as strength.

When connecting to a rigid structure and working with highly strong substrates (such as metal), strength takes precedence over flexibility. However, elasticity, not strength, is crucial when the structure is going to experience movement and for this analysis adhesion elasticity will be the Sealing Parameter for Laminated Glass Installation to Facilitate Efficient Dismantling in End-of-Life Vehicles.

4.0 Summary

This study aims to develop a sealant for dismantling glass in the ELV industry, focusing on efficiency and workability. The research involves three stages: identifying key parameters in the dismantling process, analysing their impact on efficiency, and using experimental methodology to verify optimal parameters. The study uses literature review, survey analysis, and experimental setup to validate the parameters collected in the literature review and survey. The research focuses on the effectiveness of laminated glass dismantling in end-of-life vehicles (ELVs) using both qualitative and quantitative data. The study uses a literature review to identify key parameters and identify recent improvements in dismantling. The literature review

includes a literature review of Resilient sources, such as journals, books, and online databases. The study identifies the most critical characteristics in disassembling laminated glass in ELVs and uses a bar chart statistic to assess the effectiveness of the process. The findings are presented in a presentation PSM report.

This literature review explores the efficiency of laminated glass dismantling in end-of-life vehicles (ELVs) using a three-point rating system. The study aims to identify key parameters influencing the dismantling process, such as the sealant used. The survey methodology used was a quantitative approach, with experts in Malaysia polled via questionnaires to gauge their familiarity with the sealant used. Parameters influencing the process include demographic information, knowledge and experience, perceptions, challenges, and most crucial components. The results of the study will be used to identify the components that impact the success of the dismantling procedure in ELVs.

This study aims to identify the optimal sealant for laminated glass installation, which significantly impacts the efficiency of dismantling end-of-life vehicles (ELVs). The experiment involves three stages: dismantling time measurement, observational study, and qualitative interviews. The study will measure dismantling time, observe the process, and conduct qualitative interviews to understand the experiences and preferences of ELV workers. The data will be combined to find correlations between sealant parameters and disassembly ease. The research will be replicated across multiple circumstances to ensure reliability and generalizability. The study will optimize ELV personnel's dismantling efficiency by recommending sealant selection and application procedures based on the combined quantitative and qualitative findings.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter is basically an analytical one towards all the findings that have been conducted regarding the sealant parameters for laminated glass installation to enable efficient dismantling in end-of-life vehicles. The results are illustrated in subsections according to the various objectives of this study that comprise data collection and analysis of results and discussion Findings of each objective are stated in separate section. A summary of this chapter is finally presented.

4.2 RO1: Identifying the Significant Parameters That Affect Sealing Effectiveness

This section focuses on various studies on specific parameters such as dismantling process, laminated glass, adhesion strength, adhesion elasticity, liquid consume, adhesion temperature and other related topics which are published in the literature such as books, theses, journals, and proceedings. The aim is to obtain the list of significant parameters of resistance heating. The highlighted keywords are "dismantling", “laminated glass”, "effective", "parameters", and other associated synonyms.

4.2.1 Data Collection

Data for analysis of literature on specific subjects as stated earlier is in descriptive data as the aim of the literature study is to clarify the significant parameters that affect process effectiveness. Thus, selection of referred materials must be done carefully such as the sources of material for example journal, proceeding, articles and others. In this regard, the year of published material has also been accounted in order to ensure the information is updated.

4.2.1.1 Sources of Literature Material

This study focuses on three categories of sources of literature materials; (i) Journal, (ii) Proceeding, and (iii) Thesis/article. These three categories of sources of literature material provide research information on particular subjects for this study. **Table 4.1** shows the percentages of different sources of literature papers studied.

Table 4.1 Percentages of different sources of literature papers studied.

Percentages of different types of Literature Papers Studied	
Journal	70%
Proceeding	23%
Thesis / Articles	7%

70% of total literature materials are from journals publication which shows the significant of the sources of material referred by this study. The journal covers on international and national journal which is also include in Scopus Index.

4.2.1.2 Publishing Year of Literature Papers Studied

The significance of publishing year of literature papers studied is to ensure the related of research which should cover on update previous research. **Table 4.2** shows the percentages of literature studies based on year-range

Table 4.2 Percentage of different types if literature papers studied

Percentages of different types of Literature Papers Studied	
2014-2024	84%
2001-2013	13%
2000 and below	3%

Based on **Table 4.2**, 84% of the 70 references are published in the recent ten years (2014-2024). Hence, these references are relatively recent and up-to-date research articles in resistance heating. It can be observed that most of the literature studies are published in the years of 2014-2024; this means the articles contain recent and related information.

4.2.2 Data Analysis

Here, data analysis refers to the analysis of the literature study in clarifying the significant parameters that affect sealing in installation and dismantle laminated glass on ELV's effectiveness. It can be clarified through identification of the most frequent parameters that have been studied. For instance, strength and elasticity are among the parameters that commonly become a subject of research on sealing parameters. In this regard, a simple statistic has been used to identify the significant parameters.

4.2.2.1 Analysis of The Best Combination of Significant Sealing Parameters

This sub section listed out all the parameters that affect process effectiveness which is essential to determine the most significant parameters. **Figure 4.1** shows the parameters that influence the effectiveness of the process.

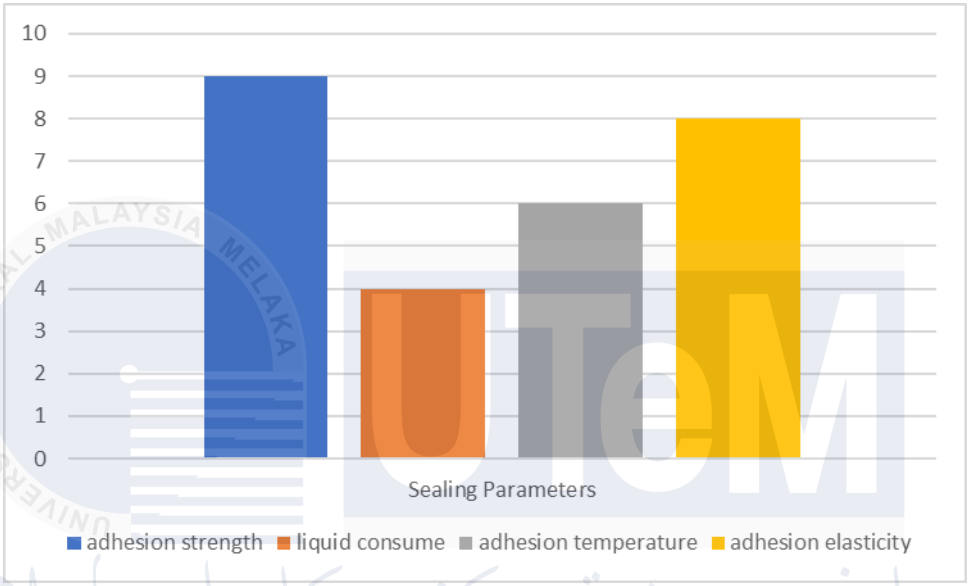

Figure 4.1 Sealing parameters influencing the effectiveness of process

Based on the list of sealing parameters that influence the effectiveness of installation and dismantling process laminated glass on ELV's the parameter of 'adhesion strength' is the most commonly investigated factor, accounting for 53 studies; this is followed by 'adhesion elasticity' with 40 studies, and both of the parameters constitute more than 50% of the total number of articles studied. For other parameters, 'adhesion temperature' is in 33 studies; Lastly, the remaining parameters listed below is, more or less, which is under 10: 'liquid consume'. The rest of this section presents a brief explanation of the review findings.

From the literature review, 'adhesion strength' is the most significant factor that contributes to the effectiveness installation and dismantling process of laminated glass on ELV's. Meanwhile, 'adhesion elasticity' is also a significant parameter. As discussed earlier,

‘adhesion strength’ and ‘adhesion elasticity’ are discussed in more than 50% of the total number of journal papers. Therefore, ‘adhesion strength’ and ‘adhesion elasticity’ are the most significant parameters that affect the process effectiveness.

Based on graph, the other parameters such as ‘adhesion temperature’, and ‘liquid consume’, also cannot be neglected as important parameters for effective of process. For example, the temperature might affect the physical and mechanical properties of adhesive materials by reducing the polymerization rate (Akarsu et al., 2019). (Li et al., 2020) claimed that a adhesive materials that are resistant to low temperatures have wide applications in daily life, scientific research, and industry.

Thus, it has been suggested that low temperature adhesive is the best temperature for a sealing for install and dismantle laminated glass. Furthermore, liquid consume of adhesion also have affected the effectiveness of process. For example, (Adhesion, n.d.), in his research and meeting stated that while adhesive is in storage, there should be no separation of liquid phases or precipitation of solids. The amount of liquid consume is actually depends on the width and depth of the area being sealed. Liquid consume by a sealant take a certain amount of time to cure and form a seal and suitable for use in a wide temperature range and chemical environment, but may require special condition (Zhang et al., 2024).

In this study, only two significant parameters which are adhesion strength and adhesion elasticity are chosen to be investigated for sealing parameters effectiveness in install and dismantle for ELV’s because in this literature review stated that these two parameters have a huge impact on the effectiveness of the process.

4.2.3 Result and Discussion

As can be seen in **Figure 4.1**, there are numbers of parameters that affect process effectiveness for example liquid consumption, adhesion temperature, adhesion strength and adhesion elasticity. However, in this subsection, the two significant sealing parameters gleaned from the results of the literature studies are discussed, namely ‘adhesion strength’ and ‘adhesion elasticity’.

4.2.3.1 Adhesion Strength

The result of the literature study shows that adhesion strength is the most frequent parameter that is being studied over the years since the introduction of sealing in automobiles process. In these times, not only is adhesive for sealing, anti-vibration or anti-noise, but they are also type of structural joining which, to a large extent, influences the strength and stiffness of a car body and thus the safety and total comfort. Structures normally use the thinnest (namely steel) sheets, which are then welded together, and logically all glasses in a car can easily break with a great impact. However, nowadays all joints of the car body begin to be bonded with any adhesion in the manufacturing process. Proper designing of the adhesive strength will reduce welding problems as well as improve the quality (Kolnerová et al., 2010).

In this light, as stated by (ThreeBond et. al. 2024), the examples taken under consideration of strength delivering adhesion are structural adhesive, cyanoacrylate adhesives, etc. Structural adhesives that hold the automobile landscape together consist of polyurethanes, epoxy resins, and methyl methacrylate. The reason for using epoxy resins is that they can form strong connections between metals, composites, and polymers. They are acknowledged for their strength and endurance. As for methyl methacrylate, it exhibits quick curing properties, thus ensuring the speedy assembly, while polyurethane adhesives present

flexibility, making them suitable for impact-hauling applications. In that way, cyanoacrylate adhesives are distinguished with rapid curing and high bonding strength; thus, they would be as useful at bonding plastics, rubber, and metals in automobiles. She added that adhesives tend to have uniform distribution of stress. Preventing failure or corrosion due to fatigue is a solution used to extend the lifespan of components that are assembled. One very important factor is the strength and reliability of parts joined by adhesive bondages in automobile bodies and other forms of transport. That is why the adhesives used for the adhesive bonding in the automotive industry are characterized by their increased strength and resistance (Valášek & Müller, 2015).

4.2.3.2 Adhesion Elasticity

Adhesion elasticity has been a topic of research since the beginning times of the sealing process. Then, hot stamping becomes a necessary parameter that should strengthen the process. According to Mori et. al. (2013), the impact of modern adhesive technology demand is such high in the modern automobile industry that it can be reckoned important as an improvement in the vehicle's performance, durability, and safety. In general aspects, it offers promises in dampening the vibrations and reducing some noise that comes into a more comfortable ride experience for the passengers. Their dependency on bonded joints is distributed evenly by reducing stress concentration and enhancing the structure's fatigue resistance; it also helps in cohesive distribution of loads in the bonded joints which would help improve fatigue resistance of the affected joints. It should also be noted that effective damping whenever vehicles move includes thermal expansion, contraction, and vibrational movements, as well as those used for maintenance to promote durability in bonded joints. It might also help absorb impact energy, thereby reducing damage severity to the vehicle and increasing occupant safety during a collision. Finally, use of such high elastic adhesives

results in lightweight and more efficient vehicles in fuel consumption as they use adhesives in Lugar or substitution of mechanical fasteners such as rivets or welds.

It was found from the literature reviews that adhesive elasticity has been studied a lot since the sealing process came into existence. Therefore, heating time is one of the parameters that can improve the efficiency of the process. According to Mori et. al. (2013), current adhesive technology demand is incredibly great in the automobile industry and can be taken as an improvement in vehicle performance, durability, and safety. In general aspects, it offers promises in dampening the vibrations and reducing some noise that comes into a more comfortable ride experience for the passengers. It further ensures placing dependence on bonded joints evenly by reducing stress concentration and hence improving fatigue resistance of the structure. In addition to that, it is observable that effective damping whenever vehicles expose their movements involves thermal expansion and contraction as well as vibrational movements. Moreover, there is maintenance for durability in bonded joints at that point. This might also help absorb impact energy, thereby reducing damage severity to the vehicle and increasing occupant safety during a collision. Finally, such highly elastic adhesives could replace traditional mechanical fasteners, like rivets and welds, thus reducing total vehicle weight and, in turn, improving the efficiencies with which fuel is consumed.

4.2.3.3 Findings

Based on above results, it can be concluded that adhesion strength and adhesion elasticity are the signification parameters that affect the process of installation and dismantle laminated glass on ELV's. In this study, the effectiveness of parameters refers to the number of usages in the production or automotive industry. Hence, adhesion strength and adhesion elasticity will be the dependent variables for the survey method in the Stage 2 of this study.

4.3 RO2: Analysis of The Effect for Adhesion Strength and Adhesion Using Survey Method.

This section discusses the effect or impact of adhesion strength and elasticity on the ease of installation and dismantling laminated glass in end-of-life vehicles. In this regard, survey technique or method has been applied in determining the optimum parameters for both parameters that give ease for the process in this sector.

4.3.1 Data Collection

The experimental design employed within this work will take advantage of the flexibility offered by the Google Form. The survey approach, of course, serves the research well as it enables the researcher to cover quite a broad spectrum of respondents. These include important actors in the automotive industry comprising automakers, glass makers, recycling firms, and automotive service technicians. While targeting these professionals, the study would be contributing to collecting rich perspectives from persons who directly experience the laminate glass manufacturing installation, dismantling, and recycling in vehicles. A sample of possible inquiries on the survey might include the following:

i. Perceptions of Adhesion Properties:

The perceived importance of adhesion strength and elasticity in different aspects of the process, such as ease of installation, dismantling, and recycling efficiency, can be achieved by means of Likert scales or other suitable rating systems.

ii. Current Challenges and Pin Points:

In identifying the specific difficulties and challenges encountered during the installation process and dismantling processes. This would help identify areas for possible improvement in adhesion properties that may have significant benefit.

iii. Desired Characteristics of Adhesives:

Gathering information on the desired characteristics of adhesives from the perspective of different workers or experts. This can inform the development of new adhesive technologies that better meet the needs of the industry.

iv. Current State of Glass Recycling:

Describing in detail the present scenario of recycling end-of-life vehicle glass along with challenges and limitations in the existing processes of recycling.

4.3.2 Analysis of Result and Discussion

It would also be possible to analyze the data using combined quant and qual approaches.

i. Quantitative Analysis:

For example, descriptive statistics such as mean, medians, and standard deviations can be computed with the data to summarize it in terms of general trends. A statistical analysis, such as correlation and regression analyses can be performed about the relationship between the adhesion properties and other parameters, including easy installation, time for dismantling, and recycling efficiency.

ii. Qualitative Analysis:

Open-ended questions in the survey will now be viable qualitative data for very elaborative descriptions of problems, suggestions for improvements, as well as industry insights. Here, the qualitative data can be analyzed with the aim of finding striking themes, trends, or other patterns that will not emerge clearly through statistics.

To use these approaches of analysis, the outcome would be to understand fully the influences of adhesion strength and elasticity on end-of-life management of laminated glass within vehicles. It can now be harnessed to build more robust and efficient recycling and new designs of adhesive technologies that optimize the entire lifecycle of automotive glass.

This research had about 10 responses from diverse work background and place, and survey type has five sections including response demographics. Such valuable demographic sections in the survey make a research project an advantage to researcher and organizations themselves. This is through collecting essential information about respondents, say in relation to age and gender, occupation and the level of education, and even location; thus, the demographic sections would give indepth insight into the target audience. Such insights allow the researcher to comprehend the perspectives, preferences, and behaviors of the respondents, allowing them to judge, analyze, and conclude their research accordingly.

4.3.2.1 Analysis Result by Section in Survey Method

Demographic sections in this survey provides multiple advantages to researchers as well as organizations. These sections capture important details about age, sex, occupation, education, or geographical location regarding respondents and provide insights into the audience being targeted. With this data, researchers can acquire a better understanding of the respondents on their viewpoints, preferences, and behaviors, allowing them to customize their analysis and conclusions. Additionally, there are several ways to use demographic data to identify trends and patterns within a pool of respondents. For instance, age distribution analysis shows whether there are particular age groups with a particular opinion or behavior. In the same way, the geographical distribution can help interpret the open-ended responses, thus allowing understanding of regional opinions or priorities. Such deep levels of granularity empower researchers to formulate more precise, nuanced conclusions that escape broad

generalizations.

In addition, these demographics sections broaden generalizability of research findings. By assessing (or understanding) the respondent characteristics, researchers can then determine how far the findings could be extrapolated from the wider population. If representative of the target population on demographics, it is highly likely that the findings could be applied to a wider audience. They give strength and compliment "the validity and impact" of research and provide further confidence in generalizations and decisions. What in this research and this technique is actually the most important is actually key players in the industry, such as in **Figure 4.2** that shows role of the respondents in this research survey.

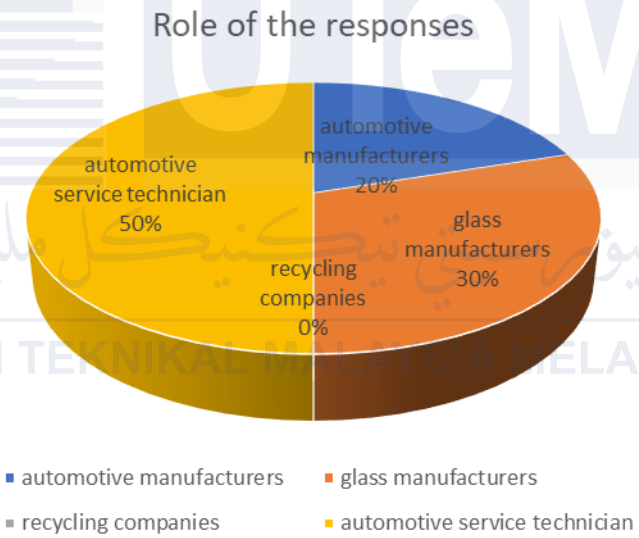

Figure 4.2 Role of the respondents

:According to the **Figure 4.2**, responses to the survey were weighted heavily toward the views of auto service technicians (50%) and automotive manufacturers (30%), leaving little to say for glass manufacturers (20%) and not at all for recycling companies, which has rendered this finding terribly limited. There is no representation from this significant sector, and this leads to an incomplete analysis of what happens with end-of-life considerations and the adoption of circular economy approaches in the automotive industry. Hence, the conclusions may not reflect the complete extent of challenges or

opportunities on sustainable automotive practice in terms of material recovery and recycling. This limitation should, therefore, be kept in mind when interpreting results and making broad generalizations on the present and future state of the industry.

Adhesion properties and how they are perceived are part of the inquiry presented in the second section. The results of the survey strongly indicate a high level of importance concerning adhesion properties in the automotive industry. A large percentage of respondents (80%) regarded adhesion strength as "extremely important" to ensure that bonded components lasted for a very long time and remained reliable, while the other 20% thought that it was "very important." Adhesion elasticity was also perceived to be extremely critical; 80% rated it as "extremely important" and 20% as "very important." In addition, for achieving the balance between adhesion strength and elasticity, 80% respondents tagged it as "extremely important," which shows that there is indeed a requirement for adhesive solutions that really cover both of these strong attributes. In terms of priority given to adhesion properties, 70% rated adhesion elasticity as most significant, while 30% considered adhesion strength the most significant.

Section three even states the query about current challenge and pinpoint. Survey results showed several key-revealing challenges in terms of which the respondent would like to have adhesion. The primary constraints are indicated: "lack of long-term durability" and "problems with adhesive application and curing processes;" both mentioned by roughly 60% of replies. The suitability of adhesives to certain applications was identified as a limiting constraint by 20% of participants, while unreliable adhesive bond strength was cited as important by the remaining 20%. Given an open-ended response, in terms of specific areas, the most flagged area would be "adhesive material development," picked up by 60% of respondents, followed by "adhesive application techniques" as a view held by 40% of

respondents. And finally, at the bottom of this long essay, all claim that "manufacturing processes" are substantially affected by such challenges of present-day adhesion properties.

Particularly, the fourth section presents questions regarding the desired characteristics of adhesives. As discussed in survey results, most of the showing characteristics were varied concerning the desires of the automotive adhesive users. In total, 40 percent were focused on "High Strength" plus "Good Flexibility and Impact Resistance," while another 40 percent were more concerned about "Environmental Friendliness" as regards the adhesive characteristics. Another 20 percent based their consideration on "Excellent Durability." Adrift from specific performance requirements, all have got "Vibration and Shock Resistance" and "Resistance to UV Radiation and Weathering," which resulted in them deeming these two performance characteristics really crucial. In addition, 20 percent underscored the importance of high-temperature tolerance. All respondents expressed interest in future research on "Structural Adhesives" and "Adhesives for Lightweight Materials" for use in automotive applications.

Last in this survey method or technique the present state of glass recycling. The survey shows some really good feedback into the present glass recycling programs around the region. 60% of the respondents gave the effectiveness of the programs a 'good' rating while 40% considered it 'excellent'. Another challenge which was identified as the 'Cost of glass recycling when compared to other methods of disposal of waste' was mentioned by 80% of the respondents. This "Contamination of glass with other materials" was revealed by 20% of respondents as well.

4.3.3 Findings

The conclusions that one might deduce from the survey study, that the survey findings indicate that adhesion properties play a crucial role in the automotive industry focusing a lot

in balancing the strength and elasticity. Long-term durability, application processes, and the suitability of adhesives are some of the major problems identified. Respondents are very interested in advancements in adhesive material development, especially focusing on high-strength, flexible, and environmentally friendly solutions. Highlight of the survey is all of respondents stated adhesion elasticity and adhesion strength are the key parameter. The survey also determines cost-efficiency in glass recycling and minimization of contamination to boost recycling rates.

4.4 RO3: Analysis the Sealing Using Real Life Experiment And ANOVA.

This study is based on three different sets of experiments being carried out to analyze the parameters of adhesion strength and adhesion elasticity and their effects at significant levels for the adhesion process. All combinations of these two parameters are carried out at three levels of adhesive-material types: butyl rubber, silicone and urethane-based adhesive. The principal objective of the carried out study is to optimize these sealing parameters for laminated glass in ELVs regarding minimizing the effort and time required for installation both during vehicle manufacturing and for dismantling during the recycling process, identifying the optimal configuration of these sealing parameters to maximize adhesion strength and elasticity, and minimizing effort and time needed for implementation and disassembly.

Prior to running the experiment using ANOVA, a well-known workshop was arranged for visiting the leading automotive glass manufacturing facility to get familiar and understand industry practice and challenges surrounding laminated-glass installation and dismantlement. It included observing in detail how the glass is laminated, starting from initial material preparation through inspection and packaging. The event majorly focused on the following stages of the lamination process: adhesive application, curing, and quality control. This

provided good perspective for the experimental design that follows because all parameters and levels correspond with what actually happens in the real manufacturing environment. It also includes several key interviews between the employees, engineers, technicians, and supervisors at different stages of the glass manufacturing and recycling process to take a qualitative flavor of value like:

i. Now challenges being faced include:

Some of the major challenges during the glass installation and removal in ELVs include erosion of adhesive, difficulty in separating glass layers, and chances of damage to other adjacent components. Also, knowledge of current restrictions within already available technologies and demand for advanced sealing solutions.

ii. Best practices in the industry include:

Awareness on the current industry standards and best practices with regard to glass lamination and recycling. Furthermore, knowledge on the opinions and concerns of professionals within the industry in matters concerning adhesive selection, processing parameters, and overall process.

4.4.1 Data Collection of Workshop Visit

Data collection during the workshop visit focused on gathering information on current industry practices and identifying key parameters influencing glass installation and dismantling in ELVs.

First, information is gathered regarding the different kinds of adhesives being used in layer-up now, specific formulation, and property information. The thickness that may be used for production is taken into account according to the glass type, vehicle model, and desired

performance characteristics. Some of the curing parameters, such as temperature, pressure, and time, were recorded for different glass applications and adhesive types, and in most cases, there was evidence of the thickness of adhesive use in the production.

Second, a time-and-effort study was conducted for every phase of the glass installation and dismantling process. Observations were made to estimate the time required for adhesive application, general assembly, and curing, and qualitative data were collected on perceived effort involved during glass installation and dismantling processes considering task complexity, required tools and equipment, and aspects related to components that may be damaged. The interviews of the technicians and supervisors would also throw light on the challenges and problems regarding both installations and dismantling.

Lastly, information on industry standards evolved into best practices related to glass lamination and recycling. Consultations were held with industry professionals to bring in their insights regarding the importance of such parameters as adhesion strength, elasticity, and ease of dismantling in the overall performance of laminated glass units**. Table 4.3** shows data that was collected during the workshop visit.

Table 4.3 Data collected from workshop visit

Adhesion type	Thickness	Temperature	Pressure	Installation Time	Dismantling Time
Butyl Rubber 	0.38 mm	80ºC	5 Bar	120 min	90 min
Silicone 	0.76 mm	100ºC	7 Bar	115 min	85 min
Urethane-based adhesive 	1.52 mm	120ºC	9 Bar	110 min	82 min

4.4.2 Analysis Using ANOVA

Adhesion strength and adhesion elasticity are the two most important sealing parameters; their effects are verified through 3 sets of experiments by varying configurations for different response parameters. Finally, combinations of adhesion strength and adhesion elasticity are categorized into three levels of adhesives: Butyl Rubber, Silicone and urethane-based adhesive. These analyses aim at optimizing the application of sealing parameters in laminated glass of ELVs. The objective is to make it easier to install during vehicle manufacturing as well as dismantle during the recycling process and, more importantly, to determine the optimum combination of sealing parameters maximizing adhesion strength and elasticity but reducing installation and dismantling effort and time.

4.4.2.1 Factor

Aspects of manufacturing and recycling were identified to include critical parameters that could significantly influence laminated glass performance in ELVs: types of adhesive such as Butyl Rubber or Silicone or: Urethane-based ones, adhesive layer thickness also investigated; in terms of possible effects on adhesion strength and elasticity and ease of dismantling.

Curing was multifarious: temperature and pressure, in addition to time. A number of temperature levels were used to assess their effect on curing and bond properties. The activation of curing pressure was studied to optimize the bond formation and reduce voids. The curing cycle time was varied in order to determine the best possible time to achieve improved bond strength and elasticity.

In the end, the quality of the glass surface to which the adhesive will be applied is regarded as one of the critical parameters. It will subject all the glass surfaces to a range of preparations-abrasive blasting, chemical etching, primer application-before determining the extent to which they affect overall adhesion performance and durability of the bond.

4.4.2.2 Response Variables

This study had a thorough analysis of various response variables to make a more complete assessment of laminated glass performance. Adhesion Strength was one of the important variables that was measured through standardized tests like tensile shear tests, which help to quantify the bond between the glass layers. Adhesion Elasticity, on the other hand, proved the level of latent deformability and vibration resistance with tests such as impact tests.

In addition, this work analyses some site-theoretically staring glass installation and demount ability aspects. Installation Time-the time taken to fit the glass unit into a vehicle-in-vehicle efficiency related to lamination process. Dismantling time mean the time taken to demount the glass units during the vehicle recycling process.

Finally, both installation effort and dismantling effort were assessed. These parameters were insert using a combination of subjective ratings by experienced technicians and objective measures, such as the force required to install or dismantle the glass unit, to quantify the difficulty and physical exertion involved in these processes. As shown in **Figure 4.3** data that we collected will be included in table of ANOVA.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Adhesive type	Thickness	Temperature	Preassure	Time	Surface preparation	Adhesion strength	Adhesion Elasticity	Installation time	Dismantling time	Installation effort	Dismantling effort
2	Butyl Rubber	0.38 mm	80	5 bar	30 min	Abrasive blasting	15.2	85	120	90	3	2
3	Silicone	0.76 mm	100	7 bar	45 min	Chemical etching	14.8	82	115	85	2	2
4	Urethane-based adhesive	1.52 mm	120	9 bar	60 min	Primer	14.6	80	110	82	2	2

Figure 4.3 Data include in table of ANOVA

It indicates some spreadsheet data from experimentations with lamination glasses relating to sealing parameters, as shown in Figure 13. The columns include Adhesive Type (Butyl Rubber, Silicone, Urethane-based adhesive), Thickness (0.38 mm, 0.76 mm, 1.52 mm), Curing Temperature (80°C, 100°C, 120°C), Curing Pressure (5 bar, 7 bar, 9 bar), Curing Time (30 min, 45 min, 60 min), and Surface Preparation (Abrasive blasting, Chemical etching, Primer). The corresponding columns show measured values for the Adhesion Strength in MPa, Adhesion Elasticity in percentage, Installation Time in seconds, Dismantling Time in seconds, and subjective ratings for installation effort and dismantling effort on a 1-5 scale. Three visible rows show data of the different experimental condition with different combinations of the parameters and their respective measurements. This important spreadsheet gives indications on optimizing laminated glass sealing for better performance in disable vehicle recycling.

4.4.3 Analysis Result and Discussion

Figure 4.4 is a part art of an excel spreadsheet showing output from an ANOVA test. The main body of the main table is divided into two sections: "Summary": the Summary report section summarizes data across each of the groups involved in the analysis. It indicates that these are 3 groups, and further note that for each group, the Count is 3; thus, it implies there are 3 observations concerning each group. The sum of values within each runs from 44.6 to 247 with respective Average ranges 14.86667 to 82.33333. The Variance within each group is varied; it starts from 0.093333 and goes up to 25.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Adhesion	3	44.6	14.86667	0.093333
Adhesion	3	247	82.33333	6.333333
Installatio	3	345	115	25
Dismantli	3	257	85.66667	16.33333
Installatio	3	7	2.333333	0.333333
Dismantli	3	6	2	0

ANOVA

ce of Varic	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between (	37056.63	5	7411.327	924.618	4.4E-15	3.105875
Within Gr	96.18667	12	8.015556			
Total	37152.82	17				

Figure 4.4 Data summary of ANOVA

The ANOVA section shows ANOVA results. The source of variation is grouped into the following: Between Groups and Within Groups. The summary values showed that, for Between Groups, the SS were 3705.63 while, for Within Groups, it was 96.18667. The gf indicates 5 for Between Groups and 12 for Within Groups. Alike, the MS for Between Groups was calculated to be 741.1327; whereas, for Within Groups, it had been calculated to be equal to 8.015556. The F-value is calculated as 924.618, and thus p = 4.4E-15 (which is very small). The critical F-value (F crit) is 3.105875.

This table summarizes both data and an ANOVA test to show that definitely significant differences exist between groups being compared, as indicated by an extremely low p-value.

4.4.4 Findings

It shows that the ANOVA table comparison between groups indicates a difference. The very low p-value of 4.4E-15 essentially does imply that changes in the dependent variable are

not simply chance occurrences. This is further backed up by the comparatively high F-statistic value of 924.618 as compared with the within-groups values, which indicate that the between-group variances are very much greater than the within-groups variances.

Again, very compelling evidence to this regard is the high "Between Groups" sum of squares (3705.63) relative to the "Within Groups" sum of squares (96.18667). That translates to a good portion of the total variation in the data being attributable to group differences, and not random variation within each group.

4.5 Summary

In summary, the effects of the sealing parameters on the effectiveness installation and dismantling process on ELV's are clearly explained in detail. Based on the literature review, more than 50% of the 60 related articles studied, indicate that adhesion strength and adhesion elasticity are the two most significant parameters that affect the process.

The effects of the two significant parameters on the effectiveness of ease install and dismantle laminated glass process and analyzed. In this regard, the design of experiment approach is implemented based on the two variable inputs, which are adhesion strength and adhesion elasticity. Based on second objective finding, it can be concluded that survey findings underscore the critical role of adhesion properties in the automotive industry, with a strong emphasis on achieving a balance between strength and elasticity. Challenges related to long-term durability, application processes, and the availability of suitable adhesives were identified as key obstacles. Respondents expressed a strong interest in advancements in adhesive material development, particularly focusing on high-strength, flexible, and environmentally friendly solutions. Highlight of the survey is 70% of respondents ranked adhesion elasticity as the most important. Furthermore, the survey highlighted the importance of addressing the cost-

effectiveness of glass recycling and minimizing contamination to improve recycling rates.

To achieve the third objective, the same settings are applied to the experiments for ascertaining the effects on the adhesives or sealants in different settings. To sum up, the experimental setup using real life experiment at workshop visit and ANOVA really help to find the key parameters. However, world know that best sealants to install and dismantle laminated glass process on ELV's is includes these two parameters that complete each other perspective to give the best performance. Adhesion strength and adhesion elasticity has been decided as a key parameter for sealing parameter for laminated glass installation to facilitate efficient dismantling in end-of-life vehicles.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter concludes the research work reported in this thesis. The main themes which have been explored in the analysis are the major elements that construct good perceptions of adhesion properties, the growing importance of the relationship between significance sealing parameters and the understanding of installation and dismantle process in ending of life vehicles industry. In this regard, a number of experiments have been successfully conducted to obtain the key parameter of sealant. The aim of improving the recycle of windshield glass that use laminated glass is ensure to keep and maintain better production of end of life vehicles for the automotive manufacturer.

5.2 Conclusion from Research Findings

The first research objective was conducted to discover the significant sealing parameters that affect the process of installation and dismantle laminated glass on ELV's. Hence, to identify the parameters of sealant effectiveness the author closely review 70 related research papers from specific areas such as material, mechanical properties, manufacturing and engineering which are published in the literature such as books, theses, journals, and proceedings. The results from literature review study shows that adhesion strength and adhesion elasticity are the significance parameters that has been frequently studied along 2014-2024. It can be concluded that adhesion strength and adhesion elasticity are the signification

sealing parameters that affect the effectiveness installation and dismantling laminated glass process on ELV's.

In this study, the effectiveness of process refers to the parameters of the sealant. Hence, adhesion strength and adhesion elasticity will be the dependent variables for the Design of Experiment (DoE) in order to analyses their effect of sealing parameters to ease install and dismantle laminated glass process that has been frequently studied along 2014-2024. It can be concluded that adhesion strength and adhesion elasticity are the sealing parameters that affect the effectiveness of process.

In this study, the effectiveness of process refers to the sealing parameters. Hence, adhesion strength and adhesion elasticity will be the dependent variables for the Design of Experiment (DoE) in order to analyses their effect of ease install and dismantle laminated glass process.

Figure 5.1 shows the brief conclusion that can be obtained for research objective 2. This study proceeds to the second objective which is to analyzed the key parameters on efficiency toward ELV's dismantling process by using survey methodology. In this regard, the design of experiment approach is implemented based on the two key parameters, which are adhesion strength and adhesion elasticity. A full factorial DoE plan is generated, which consists of 10 respondents from different background and workplace and 5 sections.

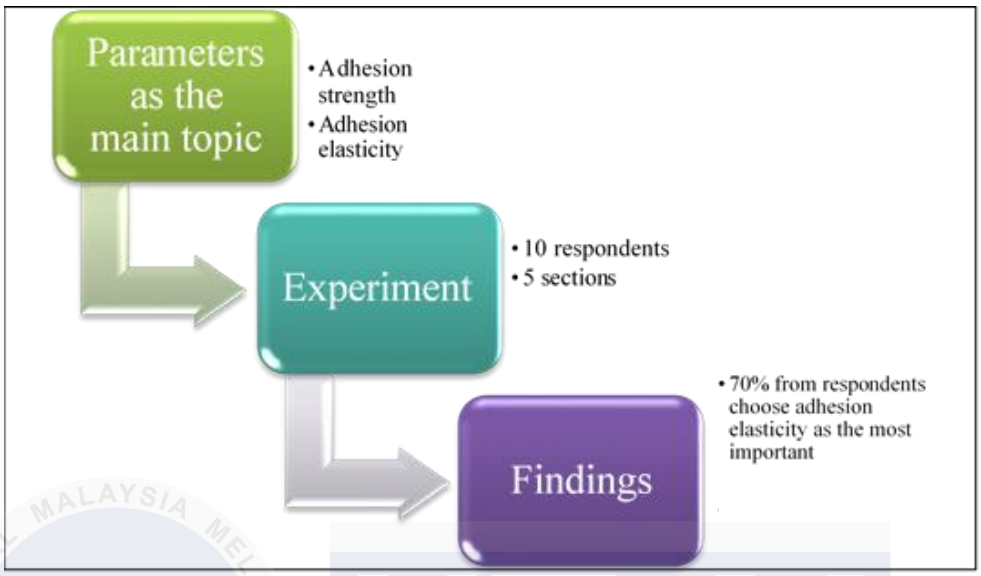

Figure 5. 1 Conclusion for Research Objective 2

Based on **Figure 5.2**, the experiment for research objective three have two different experiment that go through. Hence, adhesion strength and adhesion elasticity will be the dependent variables for the Design of Experiment (DoE) in order to analyses their effect

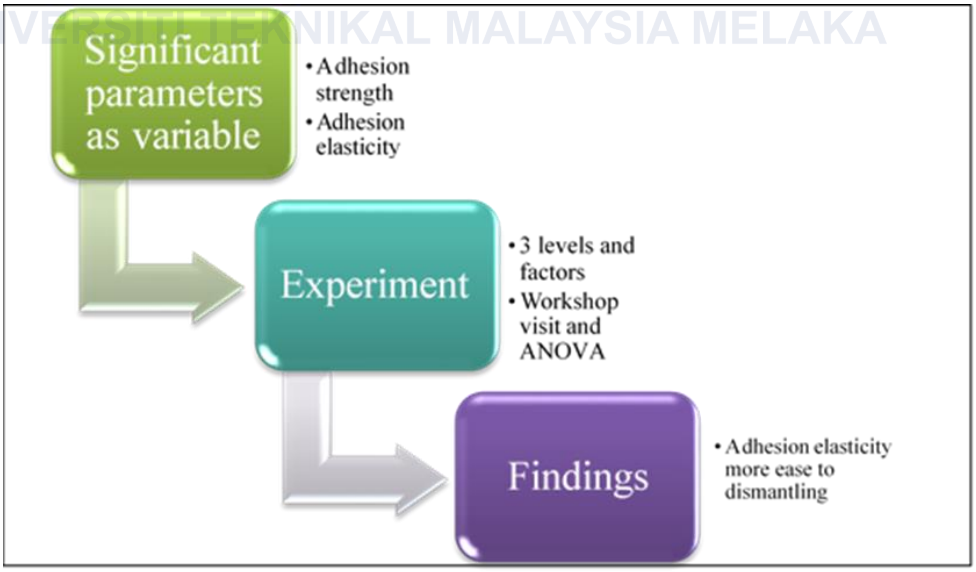

Figure 5.2 Conclusion for Research Objective 3

5.3 Recommendations

5.3.1 Minimum and Ideal of Adhesion Strength and Adhesion Elasticity

Sealant or adhesive based on the Adhesion strength needs to have minimum adhesion strength of 1 MPa, as analysis says. It is considered acceptable for most automotive applications. But particular standards and regulations may have stricter requirements. For ideal recommendation, however, a higher value like 5 MPa and above will provide a safety margin and durability.

Also, with Adhesion Elasticity, 5% minimum elongation at break is often deemed to be acceptable for most adhesive types used in windshield replacement. This indicates an amount of flexibility to withstand stressors and movement. A high elongation at break, like 10% and higher, would be considered better for gobbling shock effects and resisting effects on impact.

5.3.2 Future Research Recommendations

Self-healing adhesives would tend to tend on their own to minor damage of the bond, thus prolonging its life and safety. This could be a feature offered by shape memory polymers as it "remembers" its shape and returns after deformation, which may be useful in repairs or fine-tuning. In addition, research into bio-based alternatives to classic petroleum-derived adhesives could lead to a more sustainable future.

New and improved testing and characterization methods are essential and typically would advance this field. Dynamic testing, which includes simulating real-world driving conditions such as vibrations and impacts, is potentially revealing in adhesive behaviour under stress. Because it will allow far better long-term performance predictions under environmental conditions, more accurate accelerated aging tests have to be developed. Additionally, a diagnostic evaluation technique hydro-acoustics or potentially by infrared thermography

evaluation would be non-invasive approaches, but it might be interesting to explore.

Integration of adhesive technology in vehicle design indeed has great potential. Finite element analysis, for instance, can be employed to optimize adhesive layer thickness and placement, thus altering stress distribution and generally improving performance. Moreover, integrating smart glass technology, for example, self-tinting or electrochromic glass, into the adhesive layer could lead to additional functions and better performances.

Last but not the least, it should address end-of-life scenarios to truly make a comprehensive sustainable picture. For example, degradable adhesives that would be readily broken down at the end of a vehicle's life cycle will make the whole process easy in recycling and less harm to nature. Studying the possibility of using or repurposing adhesive materials after wind

5.4 Contribution of Research (Laminated Glass)

The discovery from this research offer the depth understanding and approach to accommodate the operation of sealing parameters to ease installation and dismantling laminated glass process on ELV's. In summarization, this research has contributed to academics and industry.

5.4.1 Academic Contribution

The parameters theoretically found through previous studies and empirically tested through design of experiment, the analysis of sealing parameters of install and dismantle laminated glass process toward ending-life-vehicles is propitious for researchers to achieve quality manufacturing and recycling enhancement knowledges.

i. This research has identified the Key Parameter in sealant used for laminated glass installation toward effective ELV dismantling process which are adhesion strength and adhesion elasticity.

ii. This research analysed the key parameters on efficiency toward ELV's dismantling process by using survey methodology.

iii. This research verified best key parameters toward ELV's dismantling process by using experiment set up methodology.

5.3.2 Industry Contribution

Overall, the research developed can be act as reference or guide for industrial practitioners about the guideline of adhesion elasticity as a key parameter in sealant used for laminated glass installation toward effective ELV dismantling process.

Second, this research manages to help in reducing reworks for the laminated glass installation toward effective ELV dismantling process. This will lead to saving production cost. The company does not need to pay extra time for the reworks process to the workers.

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APPENDICES

Appendix A AI Turnitin Result

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False positives (incorrectly flagging human-written text as AI-generated) are a possibility in AI models.

AI detection scores under 20%, which we do not surface in new reports, have a higher likelihood of false positives. To reduce the likelihood of misinterpretation, no score or highlights are attributed and are indicated with an asterisk in the report (*%).

The AI writing percentage should not be the sole basis to determine whether misconduct has occurred. The reviewer/instructor should use the percentage as a means to start a formative conversation with their student and/or use it to examine the submitted assignment in accordance with their school's policies.

What does 'qualifying text' mean?
Our model only processes qualifying text in the form of long-form writing. Long-form writing means individual sentences contained in paragraphs that make up a longer piece of written work, such as an essay, a dissertation, or an article, etc. Qualifying text that has been determined to be likely AI-generated will be highlighted in cyan in the submission, and likely AI-generated and then likely AI-paraphrased will be highlighted purple.

Non-qualifying text, such as bullet points, annotated bibliographies, etc., will not be processed and can create disparity between the submission highlights and the percentage shown.

turnitin Page 2 of 99 - AI Writing Overview Submission ID trn:oid:::1:88765:78751921