



# Impact of Socio-demographic Factors and Public Perception towards Different Levels of Autonomous Vehicles: A Case Study of Seoul, South Korea

MD RIZWANE MUZTABA KHAN<sup>a,d,\*</sup>, MD HISHAMUR RAHMAN<sup>b,e</sup>, JINHEE KIM<sup>c</sup>, JOONHONG PARK<sup>d</sup>, JIN-HYUK CHUNG<sup>c</sup>

*a. Department of Civil Engineering, East West University, Aftabnagar, Dhaka-1212, Bangladesh*

*b. Department of Civil and Environmental Engineering, University of Utah, Salt Lake City, Utah, United States*

*c. Department of Urban Planning & Engineering, Yonsei University, Seoul, Republic of Korea, 03722*

*d. Department of Civil and Environmental Engineering, Yonsei University, Seoul, Republic of Korea, 03722*

*e. Department of Civil Engineering, IUBAT – International University of Business Agriculture and Technology, Uttara, Dhaka, Bangladesh*

**ABSTRACT:** The adoption of autonomous vehicles (AVs) promises significant benefits, yet public acceptance varies across different automation levels. This study examines factors influencing public concern over using Level 3 (conditional automation), Level 4 (high automation), and Level 5 (full automation) AVs among Seoul citizens. Analyzing survey data from 209 participants with a Seemingly Unrelated Ordered Logit regression model, the study identifies key socio-demographic and perceptual factors affecting AV acceptance. Findings reveal that younger individuals (aged 20–29) are significantly less concerned about Level 5 AVs compared to older age groups, indicating age influences openness to full automation. Those with a bachelor's degree show higher concern over Level 3 AVs but lower concern over Level 4 AVs, suggesting the education level affects perceptions differently across automation levels. Frequent drivers (30–40 hours per week)

exhibit more apprehension toward Level 3 AVs, possibly due to attachment to manual driving. Concerns about system safety, security threats from hackers, and skepticism about AVs' ability to reduce accidents or emissions significantly increase apprehension across all levels. Notably, individuals willing to pay for self-driving technology are less concerned about Level 5 AVs, reflecting that investment willingness correlates with acceptance. These findings provide valuable insights for planners and policymakers to develop targeted strategies that address specific public concerns, inform policy decisions, and promote effective adoption of AV technology.

**KEYWORDS:** Autonomous Vehicles (AVs); Public Perception; Seemingly Unrelated Ordered Logit (SUOL) Regression; Socio-economic factors; Demographic factors.

## 1. INTRODUCTION

The automotive industry is undergoing a profound transformation with the advent of advanced vehicular technologies, including autonomous vehicles (AVs), smart vehicle options, and alternative fuel sources. Over the past few decades, rapid technological advancements have profoundly reshaped the automotive sector, with autonomous vehicles (AVs) emerging as one of the most transformative innovations in contemporary transportation and mobility systems (Hussain et al., 2021). The emergence of autonomous vehicle (AV) technology marks a transformative shift in urban life and human mobility, presenting both opportunities and challenges that will increasingly influence various aspects of society as the technology evolves (Woldeamanuel & Nguyen, 2018). To mitigate human errors in driving, a variety of advanced driver-assistance systems have been integrated into modern vehicles, making the progressive enhancement of automation levels an inevitable direction in automotive development (Li et al., 2023). Autonomous vehicles, also known as driverless or robotic cars, are motor vehicles capable of autonomous driving, leveraging technologies such as radar, GPS, and computer vision to sense their surroundings (Howard & Dai, 2014). The adoption of autonomous vehicles is anticipated to offer a range of societal benefits, including enhanced safety and

comfort, more efficient use of land and energy resources, and improved environmental sustainability (Yuen et al., 2020). Autonomous vehicle technologies have the potential to save thousands of lives in the transportation industry, as human conduct is responsible for nine out of ten serious traffic accidents. They can also ease traffic, increase mobility, and boost productivity (Chao, 2017). According to U.S. Department of transportation (DOT) and the national highway traffic safety administration (NHTSA), their main mission is to save lives, prevent injuries, and reduce the economic costs of roadway crashes through education, research, safety standards, and enforcement activity. As autonomous car technologies develop, they could significantly lower the number of people killed in traffic accidents every day (Chao, 2017). Following this structure, the US society of automotive engineers (SAE) have defined six levels of autonomous driving, from 0 to 5. Descriptions of each level of autonomous vehicle technology are given in Table 1.

Traffic crashes and pollution have increasingly burdened daily life, with significant consequences. Traffic accidents are a major global public health issue, causing over 1.35 million deaths or disabilities annually—primarily in low- and middle-income countries—and are projected to become the seventh leading cause of death by 2030 (Ahmed et al., 2023). For high income countries like USA, they recorded 34,080 fatalities from automobile crashes, with 90% attributed to driver error in 2012, while Europe saw over 28,000 deaths on the roads, with four times as many people permanently disabled (Kyri-

\* Corresponding author: rizwane.khan@ewubd.edu

<b>Level 0 (No Automation)</b>	Zero autonomy; the driver performs all driving tasks.
<b>Level 1 (Driver Assistance)</b>	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.
<b>Level 2 (Partial Automation)</b>	Vehicle has combined autonomous functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.
<b>Level 3 (Conditional Automation)</b>	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.
<b>Level 4 (High Automation)</b>	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.
<b>Level 5 (Full Automation)</b>	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

**Table 1: Descriptions of each level of autonomous vehicle technology (Chao, 2017)**

akidis et al., 2015). In addition, USA road accident fatalities increased to 40,000 in 2020 (Ahmed et al., 2023) and 42,915 in 2021 (Ehsani et al., 2023). In South Korea, 2008 data from the Korea Road Traffic Authority reported 215,822 traffic accidents, resulting in 5,870 fatalities and 338,962 injuries, equating to a daily average of 591.3 accidents, 16.1 deaths, and 928.7 injuries. But after covid-19 pandemic, Korea has seen decreased number in road fatalities as of 2735 (ITF, 2024). If current trends continue, road traffic injuries are projected to become the fifth leading cause of death globally by 2030, with disparities between developed and developing countries expected to widen (Kyriakidis et al., 2015).

In response to growing concerns over rising carbon emissions, high rates of traffic accidents, and congestion, the development and adoption of AVs are seen as revolutionary steps toward addressing these global transportation challenges (Anderson et al., 2016). Autonomous vehicles (AVs) aim to enhance road safety by transferring control of critical driving tasks from humans to machines; however, achieving these safety benefits relies not only on technological progress but also on the extent and pace of public acceptance and adoption (Moody et al., 2020). Safety improvements may be realized shortly after widespread AV adoption, addressing issues like distracted driving, which claimed 3,154 lives and injured an estimated 424,000 more in the U.S. in 2015 (Chao, 2017). AV sensors can adhere to traffic rules with greater alertness and responsiveness than human drivers. Moreover, the automation of vehicles is likely to result in smoother traffic flow and reduced congestion, as human input is minimized. Fuel efficiency and environmental benefits further emphasize the feasibility of AVs, particularly through vehicle platooning, which enhances efficiency regardless of fuel type. Automated vehicles' ability to navigate in non-conventional ways compared to human drivers can reduce overall energy consumption in the transportation sector (Howard & Dai, 2014). Additionally, shared driverless vehicles present an affordable access point for the public, potentially increasing adoption, lowering costs, and maximizing network benefits. This shift could also reduce the land required for parking and the resources needed for vehicle production, contributing to significant environmental gains.

Autonomous vehicles (AVs), tested and deployed in several cities worldwide, are considered a promising mode of transport; however, understanding their transformative impact on transportation remains limited due to reliance on attitudinal measures and the lack of future-oriented public perspectives (Dai et al., 2023). Despite the potential benefits, the success of AV technology depends on public acceptance. People's mindsets and attitudes play a crucial role in determining the pace of new technology adoption, thereby influencing the extent to which the benefits of automated vehicles can be realized (Liljamo et al., 2018). The degree to which indi-

viduals are willing to adopt this technology will ultimately determine its future. Although driverless technology has the capacity to reshape society, there remains reluctance due to concerns over safety, control, and liability. The AV industry continues to advance its technology in preparation for public deployment, with experts anticipating that greater integration will yield numerous benefits while also introducing various challenges and potential adverse effects (Woldeamanuel & Nguyen, 2018). Social demographics also play a critical role in the adoption process, revealing which segments of the population are more receptive to this shift and which remain hesitant. For instance, a survey conducted in Germany, China, Japan, and the U.S. found that while 59% of respondents viewed autonomous driving as a useful advancement, 31% were uneasy about the prospect of riding in an autonomous vehicle, and 54% doubted the technology's reliability. Awareness of autonomous driving was notably higher in Germany (67%) and China (64%) compared to Japan (29%) (Kyriakidis et al., 2015).

While extensive research has explored public perceptions of AVs as a whole, there is a lack of detailed understanding of how perceptions vary across different levels of automation (Levels 3, 4, and 5), which is critical given the distinct shifts in control between humans and machines at each level. This gap in knowledge is particularly critical as these levels represent distinct transitions in the balance of control between humans and machines. Understanding these perceptions is essential for policymakers and industry stakeholders to address public concerns effectively and promote smoother adoption of AV technology. Furthermore, existing studies often focus on general attitudes toward AVs in western contexts, with limited research examining perceptions in technologically advanced cities like Seoul, South Korea. Given Seoul's rapid innovation in smart technologies and urban mobility solutions, the city provides a unique context for studying how public perceptions align with advanced AV technologies.

This study aims to identify the factors influencing public perception and concern regarding the use of Level 3, Level 4, and Level 5 autonomous vehicles in Seoul, South Korea—a city at the forefront of technological innovation. Rather than treating AVs as a monolith, we study level-specific perceptions aligned with today's limited-scope deployments (L3 conditional automation; geofenced L4 pilots). L5 is included solely as a forward-looking benchmark, not as an assumed near-term reality. By analyzing survey data from 209 Seoul citizens, the study aims to understand how individuals in this technologically advanced environment perceive different levels of AVs and how these perceptions might influence their willingness to transition from conventional vehicles to those with varying degrees of automation. The necessity for detailed modeling, specifically through Seemingly Unrelated Ordered Logit (SUOL) regression, allows for a comprehensive

examination of these perceptions across different levels of AVs, considering the interdependencies among them. The main contributions of this study are as follows:

1. The study identifies critical socio-demographic and perceptual factors that influence public concerns across different levels of AVs (Levels 3, 4, and 5) by utilizing Seemingly Unrelated Ordered Logit (SUOL) regression, which provides a robust analytical framework that accounts for the interdependencies between concerns at different AV levels.
2. The study offers valuable insights into how different segments of the population in Seoul perceive AV technology, highlighting potential barriers to adoption and areas where public education and policy interventions may be necessary. The findings can inform policymakers and transportation planners in developing strategies that address public concerns, thereby facilitating smoother integration of AV technology into society.

The remainder of this paper is structured as follows: Section 2 provides a comprehensive literature review on public perceptions of autonomous vehicles and the factors influencing their adoption. Section 3 describes the survey design and data collection methods used to gather insights from Seoul citizens. In Section 4, we outline the methodology, including the formulation of the Seemingly Unrelated Ordered Logit (SUOL) regression model employed in the analysis. Section 5 presents the results and discusses the implications of the findings for policymakers and industry stakeholders. Finally, Section 6 concludes the study, highlighting limitations and suggesting directions for future research.

## 2. LITERATURE REVIEW

The literature on autonomous vehicles (AVs) is extensive, exploring a wide range of topics from public perceptions to the social and economic impacts of AV adoption. To provide a comprehensive understanding, this literature review is organized into two sections. The first section focuses on the socio-demographic, technological, and urban planning dimensions that influence adoption rates and the transformative potential of AVs in creating safer, more sustainable cities. The second section acceptance, and concerns surrounding AV technology, highlighting how demographic, cultural, and financial factors shape public attitudes.

### 2.1 AV Adoption Factors and Their Social Implications

The adoption of autonomous vehicles (AVs) is shaped by a variety of socio-demographic, technological, and urban planning factors, all of which play important roles in determining the pace and scale of integration. Socio-demographic characteristics, such as age, income, education, and driving experience, significantly influence attitudes toward AVs. Clark et al. (2016) observed that individuals with higher incomes and prior experience with advanced driving aids, such as adaptive cruise control, were more likely to trust and invest in AV technology. Alessandrini et al. (2015) noted that older adults and individuals with disabilities could benefit significantly from AVs due to improved mobility and independence, making these groups more likely to support adoption.

Public acceptance of highly autonomous (HAV) and fully autonomous vehicles (FAV) is strongly influenced by perceived benefits and trust, with FAVs viewed more positively than HAVs; perceived benefits had a greater impact than perceived risks on general acceptance, behavioral intention, and willingness to pay, providing insights for strategies to enhance AV adoption (Liu et al., 2019). A survey in Saudi Arabia found that the public is generally receptive to auto-

nomous vehicles (AVs), with attitudes influenced by perceived benefits, costs, convenience, and safety, and awareness of AV advantages increasing with age, providing insights to guide their development and deployment regionally and globally (Aldakkhelallah et al., 2023). Othman (2021) provides a review of research on public acceptance of autonomous vehicles (AVs), emphasizing that, despite their potential benefits in mobility, energy efficiency, and emissions reduction, successful adoption is contingent upon factors such as social acceptance, safety, ethics, liability, regulatory frameworks, and the impact of recent events like the pandemic, while legal and regulatory systems remain largely reactive to technological advancements. Mircea et al. (2025) found that demographic factors significantly influence public perception and trust in Autonomous Vehicles (AVs): younger individuals are more familiar and receptive to AVs, higher education correlates with reliance on academic sources, and certain professional groups are more concerned about job impacts, while cybersecurity concerns are independent of age. These findings highlight the need to consider demographics when designing strategies for AV adoption and public education.

Economic considerations also drive AV adoption. Alessandrini et al. (2015) emphasized that shared autonomous vehicles (SAVs) could reduce the financial burden of private vehicle ownership by shifting to pay-per-use models. This transition could democratize access to mobility while simultaneously reducing the environmental footprint of transportation. Gkartzonikas & Gkritza (2019) highlighted that younger generations, particularly Generation Y, are more inclined to adopt SAVs due to their preference for flexible and cost-effective transportation options.

Urban planning and infrastructure readiness are equally critical in facilitating AV adoption. Harrow et al. (2018) argued that AVs have the potential to transform urban landscapes by reducing the need for parking spaces and promoting more sustainable city designs. Alessandrini et al. (2015) noted that AVs could free up significant amounts of urban land currently devoted to parking, enabling the development of greener, more pedestrian-friendly environments. Moreover, Litman (2020) stressed the importance of proactive policies and investments in infrastructure, such as high-speed communication networks and dedicated AV lanes, to support the seamless operation of AVs. Elliott et al. (2019) highlights that while connected and autonomous Vehicle (CAV) technologies have advanced rapidly, integrating various components—such as collision and pedestrian avoidance—into a unified, secure, and efficient system remains a key challenge, especially in complex urban intersections.

Safety remains a key barrier to AV adoption, with concerns over equipment failure and cybersecurity risks often cited as major deterrents. Bansal et al. (2016) identified equipment failure as a primary concern among potential users, while Schoettle & Sivak (2014) highlighted apprehensions about the reliability of AV systems in dynamic traffic environments. Public education campaigns emphasizing the safety benefits of AVs, such as their ability to reduce crashes caused by human error, could help alleviate these concerns and build trust in the technology. Trust in autonomous vehicles (AVs) is strongly influenced by the type of explanation provided and the perceived level of driving risk, with attributional explanations enhancing trust under low-risk conditions but reducing it when risk is high, highlighting the complex interaction between communication strategies and user trust (Ha et al., 2020). Lazányi (2023) paper highlights that while autonomous vehicles (AVs) are already available, their adoption is limited due to perceived technological, IT, and ethical risks, emphasizing that cultural factors, alongside individual demographics, play a significant role in shaping public risk perception and acceptance of AVs.

Environmental benefits of AVs also play an important role in their adoption. Vehicle platooning and optimized traffic flow enabled by AV technology can significantly reduce fuel consumption and greenhouse gas emissions, making AVs an attractive option for addressing climate change (Milakis et al., 2017). Furthermore, the integration of electric vehicle (EV) technology with AV systems could amplify these environmental benefits, contributing to a cleaner and more sustainable transportation future.

Despite these advancements, gaps in policy and public understanding remain significant hurdles. Studies like Milakis et al. (2017) emphasize the need for collaboration between policymakers, industry stakeholders, and researchers to ensure that AV technology is integrated in a way that maximizes social benefits while minimizing potential drawbacks. Addressing these gaps through targeted interventions, such as subsidies for AV adoption or investments in infrastructure, will be essential for accelerating the transition to autonomous mobility.

## 2.2 Public Perceptions of Autonomous Vehicles

Public perception is a critical factor in the widespread adoption of autonomous vehicles (AVs). Awareness, trust, and concerns about AVs vary significantly across regions, demographics, and cultural contexts. Schoettle & Sivak (2014) found that while 71% of respondents in the US, 66% in the UK, and 61% in Australia were familiar with AVs, concerns about safety, security, and performance compared to human drivers persisted. These concerns underline the challenge of building public trust in the technology. Public concerns remain a major barrier to the adoption of autonomous vehicles (AVs), as survey findings reveal generally more negative than positive sentiments—particularly among sociable and driving-enthusiastic individuals—suggesting that future research should distinguish between attitudes toward riding in AVs and sharing the road with them to better understand public acceptance dynamics (Tennant et al., 2019). Hilgarter & Granig (2020) reported that respondents generally view autonomous vehicles (AVs) positively, considering them as alternatives rather than replacements for existing transport modes—particularly beneficial in rural areas for enhancing mobility—while perceptions of safety were influenced mainly by prior experience with AVs and vehicle speed. On the other hand, Stoma et al. (2021) found that the traditional car users recognize the potential of autonomous vehicles (AVs), but factors such as cost, legal regulations, and public conviction suggest that AVs will not be widely adopted soon, with hybrid and electric vehicles expected to dominate in the near future.

Kyriakidis et al. (2015) conducted a global survey in Germany, China, Japan, and the US, reporting that 59% of respondents viewed AVs positively. However, 31% expressed unease about riding in autonomous vehicles, and 54% doubted the technology's reliability. Awareness levels were notably higher in Germany and China compared to Japan, highlighting the influence of cultural and national factors in shaping perceptions. Similarly, Xu & Fan (2019) found a generally optimistic outlook on AVs in China, with 45.28% of respondents expecting reduced insurance costs due to fewer crashes and 42.35% anticipating a lower risk of accidents. A study in Ghana found that their public generally holds positive and optimistic views toward Autonomous Vehicles (AVs), though safety concerns persist and most prefer partial control, favoring Level 3 automation or below; it emphasizes the need for government initiatives in infrastructure, policy, and public education to enhance AV acceptance (Ackaah et al., 2021). Das et al. (2020) study in Pittsburgh, Pennsylvania examined non-motorists' perceptions of autonomous vehicles (AVs) and found that attitudes vary by stakeholder type, with

those having prior AV interactions showing higher interest and expectations. Participants skeptical of AV safety were also opposed to using Pittsburgh as an AV testing ground, highlighting the need for strategic management to enhance non-motorist mobility and safety.

Financial considerations also influence public perception. Bansal et al. (2016) observed that individuals are more willing to pay for full automation (Level 4, \$7,253) than partial automation (Level 3, \$3,300). Daziano et al. (2017) noted that willingness to pay (WTP) for AVs is higher among individuals with higher incomes and educational attainment, reflecting the perceived value of safety and convenience provided by automation. Additionally, Clark et al. (2016) highlighted that experience with advanced driving aids, such as adaptive cruise control, positively correlates with trust in AV technology.

Social dynamics further shape attitudes toward AVs. Vinkhuyzen & Cefkin (2016) emphasized the sociocultural aspects of driving, suggesting that AV adoption involves navigating not only technical but also social challenges. For instance, driving involves interpreting cultural signs and maintaining social balance on roads, tasks that AVs must perform seamlessly to gain acceptance. Alessandrini et al. (2015) pointed out that AVs can enhance mobility for older adults and individuals with disabilities, providing these groups with greater independence and convenience.

Concerns about safety and control remain significant barriers. Schoettle & Sivak (2014) identified cybersecurity and system reliability as key concerns among respondents. Harrow et al. (2018) noted that while many believe AVs can reduce traffic fatalities and promote cleaner cities, concerns about technological failure and loss of control prevent full acceptance. A study by Shin et al. (2015) in South Korea revealed that consumer preferences for AVs are shaped by the perceived usefulness of features like wireless internet and real-time traffic updates, underscoring the importance of designing user-centric technologies.

Generational differences also play a role in AV adoption. Gkartzonikas & Gkritza (2019) found that Generation Y is more inclined to embrace AVs and shared mobility solutions compared to Baby Boomers and Generation X. This generational divide reflects shifting attitudes toward vehicle ownership and the increasing importance of flexible, cost-effective transportation options. Alessandrini et al. (2015) highlighted that shared autonomous vehicles (SAVs) could appeal to younger generations, who prioritize affordability and environmental sustainability. Parekh et al. (2022) highlighted both technical and non-technical advancements and challenges in autonomous driving, concluding that Level 3 vehicles are ready for commercialization, while higher levels of automation still require further development. Krizsik & Sipos (2023) explored public opinions on fully autonomous vehicles (SAE Level 5) and found that perceptions and expectations vary across generational groups, gender, and primary modes of transport, highlighting differing attitudes toward this emerging technology. Alqahtani (2025) emphasized on cybersecurity, transparent legal frameworks, and public engagement to guide policymakers, industry, and researchers toward fostering technological advancement and societal acceptance of AVs.

## 2.3 Summary

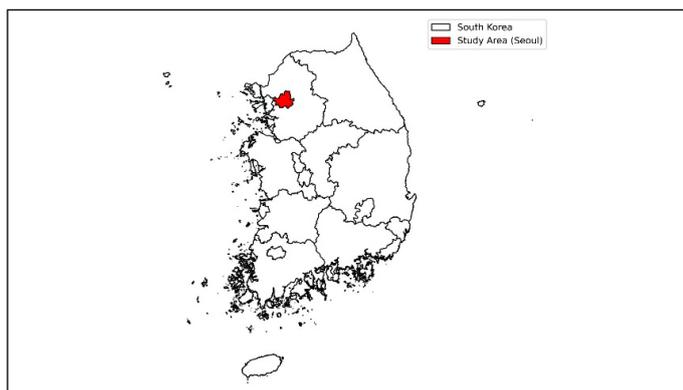
Despite substantial progress, important gaps remain in understanding level-specific perceptions of automation (SAE Levels 3–5). Much of the acceptance literature aggregates AVs, obscuring heterogeneity in perceived benefits, risks, and trade-offs across levels as control shifts from driver to system. This study addresses that gap by examining level-differentiated perceptions in Seoul and estimating a Seemingly Unrelated Ordered Logit (SUOL) model that accounts

for cross-equation correlation in concerns across L3–L5. The analysis identifies socio-demographic and attitudinal determinants unique to each level and their interdependencies, yielding policy-relevant implications for near-term L3/L4 deployment while treating L5 as a forward-looking benchmark.

### 3. SURVEY DESIGN AND DATA COLLECTION

Prior to the implementation of widespread automation, this questionnaire survey was conducted in Seoul during the initial stages of policy discussions on autonomous vehicles, with data collected, processed, and analyzed during the 2021-2022 period. The first part of the questionnaire is about the perceptions of the general people about the futuristic technology of autonomous vehicles; the second part focuses on how the people are willing to accept this technology and how much they think that this technology will be beneficial for a resilient environment. The last part of the questionnaire focuses on social demographics. Before the perception questions, brief descriptions of SAE Levels 0–5 were given in the questionnaire to make sure respondents got an idea about the various levels of AVs.

Participants were recruited via in-person intercept surveys conducted at several public locations in Seoul, as shown in **Figure 1**. Inclusion criteria were age  $\geq 18$  and residence in, study in, or regular travel to Seoul. This was a non-probability convenience sample; no sampling frame or random selection was employed. To ensure the reliability and validity of the collected data, all respondents were required to review the given standardized descriptions of the SAE-defined automation levels in the survey form prior to starting the questionnaire. This procedure helped establish a consistent understanding of the varying degrees of vehicle automation among participants. Through this rigorous approach, and by including detailed items on perceptions of Level 3, Level 4, and Level 5 autonomous vehicles, a total of 209 fully completed and valid responses were obtained. Key demographic details are summarized in Table 2. The majority of respondents (58.9%) were male, with a significant portion (82.8%) in the 20–29 age group. No respondents were aged 60 or above. Educational levels ranged from less than a bachelor's degree (55.5%) to graduate degrees (8.1%). The survey also revealed that 62.7% of participants did not own a personal vehicle, and 57.4% reported an annual income of less than 10 million Korean won. Regarding the willingness to pay, responses varied significantly. While 25.4% of respondents were willing to spend 11–20 million Korean won for AV technology, a notable 13.4% indicated they would not purchase an autonomous vehicle, and 20.1% stated they lacked sufficient information to make a decision. This diversity in willingness to pay reflects the ongoing uncertainties and mixed acceptance of AV technology among the general public.



**Figure 1** Study Area

Description of variables	Count	Percentage (%)
<b>Gender</b>		
Male	123	58.9
Female	86	41.1
<b>Age</b>		
20-29	173	82.8
30-39	27	12.9
40-49	4	1.9
50-59	5	2.4
60-69	0	0
$\geq 70$	0	0
<b>Education</b>		
Less than bachelor degree	116	55.5
Bachelor degree	76	36.4
Graduate degree	17	8.1
<b>Employment Status</b>		
Employed full-time	38	18.2
Employed part-time	10	4.8
Not currently employed	11	5.3
Retired	0	0
Full-time student	146	69.8
Part-time student	4	1.9
<b>Vehicle Type Use Most Often</b>		
Passenger car (Any type or size)	56	26.8
Minivan / van / Multi-Purpose Vehicle	5	2.4
Pickup truck	2	0.9
Sport Utility Vehicle	18	8.6
Motorcycle / scooter	4	1.9
Bicycle	4	1.9
I do not Drive	115	55.1
Other	5	2.4
<b>How Many Hours Drive Per Week</b>		
Less than 30 hours	64	30.6
30-40 hours	8	3.8
40-50 hours	6	2.9
50-60 hours	0	0
More than 60 hours	0	0
I do not have Personal Vehicle	131	62.7
<b>Average Annual Income (Korean won)</b>		
Less than 10 million Korean won	120	57.4
10-20 million Korean won	24	11.5
20-30 million Korean won	29	13.9
30-40 million Korean won	23	11.0
More than 40 million Korean won	13	6.2
<b>What Kind of Vehicle Have</b>		
Car (any type or size)	46	22.0
Minivan / van / MPV (multipurpose vehicle)	0	0
Pickup truck	1	0.5
SUV (sport utility vehicle)	16	7.7
Motorcycle / scooter	4	1.9
Bicycle	10	4.8
I do not drive	131	62.6
Other	1	0.5

Willingness to pay for self-driving technology		
Less than 10 million Korean won	26	12.4
11-20 million Korean won	53	25.4
21-30 million Korean won	28	13.4
31-40 million Korean won	27	12.9
41-50 million Korean won	5	2.4
More than 50 million Korean won	0	0
I will not buy Autonomous Vehicle	28	13.4
I do not have enough information about Autonomous Vehicle to make a decision	42	20.1

**Table 2: Description of Socio-economic and demographic variables**

Table 3 captures public perceptions of AVs across Levels 3, 4, and 5, based on the classification by the Society of Automotive Engineers (SAE). Level 3 represents conditional automation, Level 4 high automation, and Level 5 full automation. As automation levels increase, so do the perceived potential for benefits like accident reduction, emission mitigation, and insurance rate savings. For example, 21% of respondents felt Level 5 AVs were “very likely” to reduce accidents, compared to just 6.2% for Level 3. Similarly, 23% believed Level 5 AVs would significantly reduce vehicle emissions, while only 4.3% expressed the same for Level 3. These findings suggest growing optimism about AV capabilities as automation advances. However, concerns about safety, security, privacy, and operational reliability also intensified with higher levels of automation. At Level 3, 6.7% of respondents were “very concerned” about system safety, increasing to 9.6% at Level 4 and 20.6% at Level 5. Security threats were also a growing issue: 9.6% of respondents expressed being “very concerned” about Level 3 AVs, compared to 31.6% for Level 5. Privacy concerns followed a similar trend, rising from 10% at Level 3 to 31.1% at Level 5. Respondents were also increasingly worried about AVs’ ability to handle unexpected situations, with “very concerned” responses rising from 10.1% for Level 3 to 31.1% for Level 5.

Overall, Table 3 shows a dual pattern: increased automation raises hopes for the advantages of AV, but it also makes privacy, security, and safety issues worse. This implies that the acceptance of AV will be contingent upon not only technical developments but also efficient communication and legislative frameworks that address public concerns. The growing concern surrounding increased automation emphasizes the necessity of understanding the fundamental causes influencing these attitudes. Our research intends to identify the elements that lead to these growing concerns, highlighting the ways in which diverse circumstances affect the public’s attitude toward the introduction of varying degrees of autonomous vehicles.

#### 4. METHODOLOGY

The primary objective of this study is to identify the factors influencing public concern regarding the use of Level 3, Level 4, and Level 5 autonomous vehicles (AVs). The responses concerning the level of concern over using Level 3, Level 4, and Level 5 AVs were categorized into four ordered levels: “Not at all concerned” = 1, “Slightly concerned” = 2, “Moderately concerned” = 3, and “Very concerned” = 4. These categories represent an increasing severity of concern from the least to the most concerned respondents. Given the ordered nature of the responses and the potential correlation between concerns at different AV levels, the SUOL model was chosen as the appropriate analytical tool to capture these dynamics. The SUOL model is an extension of the traditional Ordered Logit model

that accounts for the potential correlation between multiple ordered outcomes. This model is particularly useful when the outcomes are not independent, as it allows for the estimation of correlated error terms across different equations, thereby capturing the interdependencies between the outcomes.

#### 4.1 Mathematical Formulation

Let  $y_{ij}$  represent the observed ordinal response for individual  $i$  on the  $j$ -th outcome, where  $j = 1, 2, 3$  corresponds to concerns over using Level 3, Level 4, and Level 5 AVs, respectively. The SUOL model posits that these observed ordinal outcomes are generated by underlying latent continuous variables  $Y_{ij}$ , which are linearly related to a set of covariates  $X_{ij}$ . The relationship can be expressed as:

$$Y_{ij} = X_{ij}\beta_j + \varepsilon_{ij}, \quad j = 1, 2, 3$$

where  $\beta_j$  is the vector of coefficients associated with the covariates  $X_{ij}$  for the  $j$ -th outcome and  $\varepsilon_{ij}$  is the error term associated with the  $j$ -th outcome for individual  $i$ .

The observed ordinal outcome  $y_{ij}$  is related to the latent variable  $Y_{ij}$  through a series of threshold parameters  $\tau_{jk}$ , which define the boundaries between the ordered categories:

$$y_{ij} = k \text{ if } \tau_{j(k-1)} < Y_{ij} < \tau_{jk} \text{ where } k = 1, 2, \dots, K_j$$

where  $K_j$  denotes the number of ordered categories for the  $j$ -th outcome.

The error terms  $\varepsilon_{i1}$ ,  $\varepsilon_{i2}$ , and  $\varepsilon_{i3}$  are assumed to be jointly normally distributed with mean zero and a covariance matrix  $\Sigma$ , which captures the correlations between the different outcomes:

$$\varepsilon_{i1} = \begin{pmatrix} \varepsilon_{i1} \\ \varepsilon_{i2} \\ \varepsilon_{i3} \end{pmatrix} \sim N(0, \Sigma)$$

The covariance matrix  $\Sigma$  is specified as:

$$\Sigma = \begin{pmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{13} \\ \sigma_{12} & \sigma_2^2 & \sigma_{23} \\ \sigma_{13} & \sigma_{23} & \sigma_3^2 \end{pmatrix}$$

where  $\sigma_j^2$  represents the variance of the error term for the  $j$ -th outcome, and  $\sigma_{jk}$  represents the covariance between the error terms of the  $j$ -th and  $k$ -th outcomes.

#### 4.2 Log-Likelihood Function

The log-likelihood function for the SUOL model is derived based on the joint distribution of the ordered outcomes, taking into account the correlations between them. The likelihood of observing the data for individual  $i$  given the model parameters is expressed as:

$$\mathcal{L}_i(\beta, \tau, \Sigma) = P(y_{i1}, y_{i2}, y_{i3} \mid X_{i1}, X_{i2}, X_{i3}; \beta_1, \beta_2, \beta_3, \tau, \Sigma)$$

Given the ordered nature of the outcomes, this probability is computed by integrating over the multivariate normal distribution of the error terms:

$$\mathcal{L}_i(\beta, \tau, \Sigma) = \int_{\tau_1(\beta_1-1) - X_{i1}\beta_1}^{\tau_1(\beta_1) - X_{i1}\beta_1} \int_{\tau_2(\beta_2-1) - X_{i2}\beta_2}^{\tau_2(\beta_2) - X_{i2}\beta_2} \int_{\tau_3(\beta_3-1) - X_{i3}\beta_3}^{\tau_3(\beta_3) - X_{i3}\beta_3} \phi(\varepsilon_{i1}, \varepsilon_{i2}, \varepsilon_{i3}; 0, \Sigma) d\varepsilon_{i1} d\varepsilon_{i2} d\varepsilon_{i3}$$

where  $\phi(\cdot)$  is the multivariate normal density function. The overall log-likelihood function is then obtained by summing the log of the individual likelihoods across all observations:

$$\mathcal{L}_i(\beta, \tau, \Sigma) = \sum_{i=1}^N \log \mathcal{L}_i(\beta, \tau, \Sigma)$$

Maximizing this log-likelihood function with respect to the parameters  $\beta$ ,  $\tau$ , and  $\Sigma$  yields the estimated coefficients and thresholds, allowing for the interpretation of how vari-

ous factors influence public concern over using different levels of AVs.

Description of variables	Level 3 AV		Level 4 AV		Level 5 AV	
	Count	Percentage (%)	Count	Percentage (%)	Count	Percentage (%)
<b>Perception regarding potential benefits of autonomous vehicles</b>						
<b>Reduce accidents</b>						
Very likely	13	6.2	17	8.1	44	21.0
Somewhat likely	78	37.3	104	49.8	104	49.8
Somewhat unlikely	105	50.3	82	39.2	45	21.5
Very unlikely	13	6.2	6	2.9	16	7.7
<b>Decrease accident damage</b>						
Very likely	12	5.7	12	5.8	48	23.0
Somewhat likely	88	42.2	102	48.8	97	46.4
Somewhat unlikely	97	46.4	87	41.6	45	21.5
Very unlikely	12	5.7	8	3.8	19	9.1
<b>Improvement in response to accidents</b>						
Very likely	19	9.1	23	11.0	66	31.6
Somewhat likely	83	39.7	96	45.9	78	37.3
Somewhat unlikely	78	37.3	81	38.8	44	21.1
Very unlikely	29	13.9	9	4.3	21	10.0
<b>Reduce vehicle emissions</b>						
Very likely	9	4.3	18	8.6	48	23.0
Somewhat likely	79	37.8	92	44.0	77	36.8
Somewhat unlikely	79	37.8	74	35.4	57	27.3
Very unlikely	42	20.1	25	12.0	27	12.9
<b>Insurance rate reduction</b>						
Very likely	12	5.7	15	7.1	44	21.1
Somewhat likely	59	28.2	90	43.1	75	35.9
Somewhat unlikely	105	50.3	79	37.8	60	28.7
Very unlikely	33	15.8	25	12.0	30	14.3
<b>Concern about issues related to using different levels of autonomous vehicles</b>						
<b>System safety</b>						
Very concerned	14	6.7	20	9.6	43	20.6
Moderately concerned	43	20.6	75	35.9	87	41.6
Slightly concerned	135	64.6	105	50.2	61	29.2
Not at all concerned	17	8.1	9	4.3	18	8.6
<b>Security threat</b>						
Very concerned	20	9.6	24	11.5	66	31.6
Moderately concerned	56	26.8	91	43.5	84	40.2
Slightly concerned	106	50.7	83	39.7	41	19.6
Not at all concerned	27	12.9	11	5.3	18	8.6
<b>Vehicle safety</b>						
Very concerned	18	8.6	32	15.3	64	30.6
Moderately concerned	55	26.3	86	41.2	79	37.8
Slightly concerned	95	45.5	77	36.8	47	22.5
Not at all concerned	41	19.6	14	6.7	19	9.1
<b>Personal Information extrusion</b>						
Very concerned	21	10.0	36	17.2	65	31.1
Moderately concerned	48	23.0	78	37.3	71	34.0
Slightly concerned	85	40.7	72	34.5	49	23.4
Not at all concerned	55	26.3	23	11.0	24	11.5

<b>Learning Automated driving</b>						
Very concerned	9	4.3	11	5.2	40	19.1
Moderately concerned	30	14.4	71	34.0	53	25.4
Slightly concerned	98	46.9	71	34.0	57	27.3
Not at all concerned	72	34.4	56	26.8	59	28.2
<b>Automated driving under unexpected situation</b>						
Very concerned	21	10.1	31	14.9	65	31.1
Moderately concerned	60	28.7	93	44.5	65	34.5
Slightly concerned	101	48.3	77	36.8	65	25.8
Not at all concerned	27	12.9	8	3.8	65	8.6
<b>Concern about using different levels of autonomous vehicles</b>						
Very concerned	6	2.9	17	8.1	29	13.9
Moderately concerned	32	15.3	56	26.8	77	36.8
Slightly concerned	122	58.4	100	47.9	74	35.4
Not at all concerned	49	23.4	36	17.2	29	13.9

**Table 3 Perception about different issues related to Level 3, 4 and 5 Autonomous Vehicles**

## 5. RESULTS AND DISCUSSION

Initially, twenty-seven variables associated with socio-economic and demographic factors were considered in the study. After conducting several trials, 15 out of the 27 variables across different categories were found to be statistically

significant at less than 0.1%, 1%, 5%, and 10% significance levels, respectively, as shown in Table 4. Findings should be read through an incremental deployment lens: address handover and driver re-engagement risk at L3, transparency and operational design domain limits at L4, and use L5 only as a perceptual benchmark for longer-term scenarios.

Variable	Concern on using Level 3 AV					Concern on using Level 4 AV					Concern on using Level 5 AV				
	$\beta$	OR	SE	z	p-value	$\beta$	OR	SE	z	p-value	$\beta$	OR	SE	z	p-value
<b>Age (Base: 50 to 59)</b>															
20 to 29											-1.34	0.2	0.7	-1.7	0.089*
30 to 39											-1.05	0.3	0.8	-1.2	0.206
40 to 49											-3.04	0.0	1.2	-2.6	0.008***
50 to 59															
60 to 69															
70 or older															
<b>What is the highest level of education you have completed (Base: Graduate degree (Master's/PhD))</b>															
Less than bachelor degree	0.82	2.2	0.5	1.4	0.154	-0.55	0.5	0.5	-0.9	0.349					
Bachelor degree	1.61	4.9	0.5	3.0	0.003***	-1.18	0.3	0.6	-1.9	0.051*					
<b>How many hours do you drive per week on average (Base: Less than 30 hours)</b>															
30-40 hours	1.74	5.7	0.7	2.3	0.021**										
40-50 hours	0.41	1.5	0.8	0.4	0.634										
50-60 hours															
More than 60 hours															
I do not have personal vehicle	0.58	1.7	0.4	1.3	0.185										
<b>How much Money would you be willing to pay for self-driving technology on a vehicle you own or lease in the future (Base: I do not have enough information about Autonomous Vehicle to make a decision)</b>															
Less than 10 million Korean won											-1.94	0.1	0.5	-3.5	0.000***
11-20 million Korean won											-1.19	0.3	0.4	-2.8	0.004***
21-30 million Korean won											-1.29	0.2	0.4	-2.7	0.006***
31-40 million Korean won											-1.12	0.3	0.5	-2.0	0.041**
41-50 million Korean won											-1.20	0.3	0.8	-1.4	0.137
More than 50 million Korean won															
I will not buy AV											-0.36	0.6	0.6	-0.5	0.552

<b>Reduce accidents (Base: Very Likely)</b>															
Very unlikely	2.81	16.6	1.1	2.4	0.016**										
Somewhat unlikely	2.55	12.7	0.9	2.6	0.008***										
Somewhat likely	2.85	17.2	0.8	3.3	0.001***										
<b>Decrease accident damage (Base: Very Likely)</b>															
Very unlikely						1.81	6.0	1.2	1.4	0.158					
Somewhat unlikely						1.57	4.8	0.7	2.1	0.029**					
Somewhat likely						1.49	4.4	0.7	2.0	0.041**					
<b>Improvement in response to accidents (Base: Very Likely)</b>															
Very unlikely											1.19	3.3	0.7	1.5	0.117
Somewhat unlikely											1.23	3.4	0.4	2.6	0.007***
Somewhat likely											0.79	2.2	0.3	2.0	0.046**
<b>Reduce vehicle emissions (Base: Very unlikely)</b>															
Somewhat unlikely	-0.66	0.5	0.4	-1.6	0.104										
Somewhat likely	-0.12	0.8	0.4	-0.2	0.796										
Very likely	1.97	7.1	0.7	2.4	0.014**										
<b>Insurance rate reduction (Base: Very unlikely)</b>															
Somewhat unlikely											0.97	2.6	0.5	1.6	0.103
Somewhat likely											1.31	3.7	0.5	2.1	0.029**
Very likely											0.79	2.2	0.6	1.2	0.222
<b>System Safety issues due to errors (Base: Not at all concerned)</b>															
Very Concerned	3.79	44.3	1.0	3.4	0.001***	2.89	18.0	1.3	2.1	0.035**	2.83	17.0	1.0	2.6	0.007**
Moderately Concerned	3.07	21.6	0.8	3.6	0.000***	2.53	12.5	1.2	2.0	0.041**	2.49	12.0	1.0	2.4	0.013**
Slightly Concerned	2.29	9.9	0.6	3.3	0.001***	2.01	7.4	1.2	1.6	0.102	2.32	10.2	1.0	2.3	0.022**
<b>Security threat from hackers (Base: Not at all concerned)</b>															
Very Concerned	1.53	4.6	0.7	1.9	0.053*						2.72	15.3	1.5	1.7	0.086*
Moderately Concerned	1.22	3.	0.7	1.5	0.114						3.51	33.6	1.5	2.2	0.027**
Slightly Concerned	1.27	3.5	0.6	1.8	0.068*						3.77	43.7	1.5	2.4	0.014**
<b>Vehicle safety threat from hackers (Base: Not at all concerned)</b>															
Very Concerned						-1.62	0.1	0.7	-2.0	0.041**	-3.21	0.0	1.3	-2.3	0.018**
Moderately Concerned						-1.58	0.2	0.6	-2.6	0.009***	-3.27	0.0	1.3	-2.4	0.013**
Slightly Concerned						-1.25	0.2	0.6	-2.0	0.036**	-3.13	0.0	1.3	-2.3	0.019**
<b>Learning Automated vehicle driving (Base: Very concerned)</b>															
Moderately Concerned	-2.38	0.0	0.8	-2.9	0.004***										
Slightly Concerned	-1.46	0.2	0.6	-2.1	0.029**										
Not at all concerned	-2.95	0.0	0.7	-3.9	0.000***										
<b>Personal Information extrusion (Location, destination exposure) (Base: Very concerned)</b>															
Moderately Concerned						1.08	2.9	0.4	2.3	0.022**					
Slightly Concerned						0.76	2.1	0.5	1.5	0.132					
Not at all concerned						-0.49	0.6	0.6	-0.7	0.455					
<b>Automated driving under unexpected situation (Base: Very concerned)</b>															
Moderately Concerned											-0.84	0.4	0.3	-2.4	0.016**
Slightly Concerned											-1.20	0.3	0.4	-2.5	0.012**
Not at all concerned											-0.59	0.5	0.6	-0.8	0.377

**Table 4: Seemingly Unrelated Ordered Logit model**

Regarding socio-demographic variables, people aged between 20 to 29 and 40 to 49 are found to be less concerned over using Level 5 AVs compared to the senior category of 50 to 59. Individuals aged 20 to 29 have a negative coefficient ( $\beta$ ) of -1.34 and an OR of 0.26, signifying they are 74% less likely to be concerned over using Level 5 AVs compared to the base category. Similarly, those aged 40 to 49 have an OR of 0.03, indicating a 97% reduction in the odds of being concerned.

This result is similar to Hulse et al. (2018), where males and younger adults displayed greater acceptance towards autonomous cars and also Thomas et al. (2020), where they showed that people aged 36 to 65 expressed greater concern and were more likely to decline driving AVs compared to those aged 18-35. No statistically significant variables have been found for the other two levels of AVs in this age category. This signifies that younger people are more likely

to use AVs compared to their older counterparts. Older generations may tend to defer from using AVs as they might not be familiar with modern technologies. Policymakers should take steps to involve elderly people with this new advancement in technology and familiarize all sections of society with all levels of AVs.

Education level also plays a role in concern over using AVs. People having a bachelor's degree are more likely to show concern over using Level 3 AVs, with a positive coefficient ( $\beta$ ) of 1.61 and an OR of 4.99, indicating they are nearly five times more likely to be concerned compared to those with a graduate degree (master's/phd). For Level 4 AVs, people with a bachelor's degree show less concern, with a negative coefficient ( $\beta$ ) of -1.18 and an OR of 0.30. This may occur because individuals with higher degrees may have higher incomes and more family responsibilities, making them think more about value for money and potential risks. This result aligns with Quartulli et al. (2013), where it was demonstrated that greater levels of education were associated with greater degrees of safety concern. It signifies that people need more knowledge about various levels of AVs before making decisions regarding their use. No statistically significant results were found for Level 5 AVs, indicating that people are still less informed about Level 5 AVs or that the description provided in the questionnaire may not have been sufficient for them to make a concrete decision over using the highest level of autonomous vehicles.

People driving 30-40 hours per week on average show statistically significant results about more concern over using Level 3 AVs, with a positive coefficient ( $\beta$ ) of 1.74 and an OR of 5.70, indicating they are over five times more likely to be concerned compared to those who drive less than 30 hours per week. It may happen because people who drive more are more attached to manual driving, and there may be emotional attachments involved with their own cars, impacting their choice. Level 4 and Level 5 AVs have no significant results in this category, which may be because people who drive 30-40 hours per week connect themselves more with Level 3 (Conditional Automation) that requires driver assistance. Policymakers can use advertisements on roadside billboards to familiarize people more with various levels of autonomous driving.

The variable Willingness to pay for self-driving technology shows negative coefficients and odds ratios significantly less than one for price ranges up to 40 million Korean won. For instance, those willing to pay "less than 10 million Korean won" have a coefficient ( $\beta$ ) of -1.94 and an OR of 0.14, meaning they are 86% less likely to be concerned over using Level 5 AVs compared to individuals who lack enough information to make a decision. This suggests that paying for a higher level of automation does not increase concern over using higher-level automation cars. This result aligns with Schoettle & Sivak (2014), where a significant proportion of respondents were willing to spend money to add full self-driving automation to their vehicles. This inclination reflects the social scenario of Seoul, one of the most technologically advanced cities, where residents are willing to invest in technology that serves them well. However, as the exact pricing of Level 5 AVs could not be provided, only the given ranges come out significant, and with exact pricing, the scenario might change. Policymakers should prioritize educating people about the concerns and advantages of using AVs in their daily lives, which can change their perception and acceptance of various levels of AVs.

The next few variables discuss the perceived benefits that will be covered by various levels of AVs. When asked how they think Level 3, 4, and 5 AVs will impact reducing accidents, people who believe it is "very unlikely," "somewhat unlikely," and "somewhat likely" show positive coefficients

and high odds ratios for Level 3 AVs. For example, individuals who think it is "very unlikely" have a coefficient ( $\beta$ ) of 2.81 and an OR of 16.62, indicating they are over 16 times more likely to be concerned over using Level 3 AVs. Those who think it is "somewhat unlikely" or "somewhat likely" also have high ORs of 12.76 and 17.25, respectively. This demonstrates that skepticism about the safety benefits of Level 3 AVs significantly increases concern over their use. No statistically significant results were found for Level 4 and 5 AVs in this category, possibly due to a lack of understanding about various levels of AVs. Policymakers should conduct campaigns to explain the advantages that AVs will provide in daily commuting.

For Decrease accident damage, people who think that this is "somewhat unlikely" or "somewhat likely" show more concern over using Level 4 AVs. They have positive coefficients ( $\beta$ ) of 1.57 and 1.49 and ORs of 4.83 and 4.41, respectively. This suggests that uncertainty about the effectiveness of Level 4 AVs in reducing accident damage correlates with higher concern levels. Similarly, for Improvement in response to accidents, people who think that this is "somewhat unlikely" or "somewhat likely" show increased concern over using Level 5 AVs, with coefficients ( $\beta$ ) of 1.23 and 0.79 and ORs of 3.41 and 2.20, respectively. These results show people's lack of knowledge about various levels of AVs and how they will improve daily commuting.

Interestingly, individuals who believe that Level 3 AVs will "very likely" reduce vehicle emissions still have a positive coefficient ( $\beta$ ) of 1.97 and an OR of 7.13, meaning they are over seven times more likely to be concerned over using Level 3 AVs. This paradoxical result suggests that even when acknowledging environmental benefits, other concerns override their willingness to adopt the technology. The same pattern is observed in the variable Insurance rate reduction for Level 5 AVs. Individuals who think it is "somewhat likely" have a coefficient ( $\beta$ ) of 1.31 and an OR of 3.70, indicating they are over three times more likely to be concerned over using Level 5 AVs. This may reflect uncertainties about the financial implications of adopting fully automated vehicles.

For the variable Security threat from hackers, Level 3 AVs show marginal statistical significance, but Level 5 AVs show significance in all three categories of concern. For Level 5 AVs, the odds ratios are notably high across all concern levels. For instance, individuals who are "slightly concerned" have an OR of 43.74, meaning they are over 43 times more likely to be concerned about using Level 5 AVs compared to those who are "not at all concerned." This indicates a strong association between concern over hacking threats and apprehension towards fully automated vehicles. Level 5 has higher coefficients compared to Level 3, showing that people are more concerned over using or riding in Level 5 (Full Automation) compared to Level 3 (Conditional Automation) when considering security threats from hackers. This may occur because people believe that with Full Automation, they will have less to no control over the vehicle, making it more vulnerable to hackers. In contrast, with Conditional Automation of Level 3, they can take control over driving at any point, possibly reducing their concerns about security threats.

The variable Vehicle safety threat from hackers shows negative coefficients and odds ratios less than one for Level 4 and Level 5 AVs. For example, individuals who are "very concerned" about vehicle safety threats from hackers have an OR of 0.19 for Level 4 AVs and 0.04 for Level 5 AVs. This means they are less likely to be concerned over using these AVs compared to those who are "not at all concerned". Interestingly, the coefficient values increase from Level 4 to Level 5, suggesting that as the automation level increases, people seem to be less concerned over the physical safety of the vehicle from hackers. These results may appear counterintuitive but

could indicate that people trust higher automation levels to mitigate such risks or perhaps lack understanding of the threats involved. Kyriakidis et al. (2015) found similar concerns, with respondents being most worried about software hacking/misuse.

For learning automated vehicle driving, negative coefficients and odds ratios less than one are observed for Level 3 AVs. Individuals who are “not at all concerned” have a coefficient ( $\beta$ ) of -2.95 and an OR of 0.05, indicating they are 95% less likely to be concerned over using Level 3 AVs compared to those who are “very concerned.” This is justifiable, as Level 3 automation requires the driver to be ready to take control of the vehicle at all times, and if individuals are not concerned about learning to drive automated vehicles, they may feel more confident and thus less concerned about using Level 3 AVs. This result implies that Seoul citizens are generally familiar with car ownership and driving, which enables them to be less concerned over learning automated driving for conditional automation. However, no statistically significant variables were found for Level 4 and Level 5 AVs in this category, indicating that as automation increases and driver control decreases, people may become more concerned about riding in higher-level AVs where driver assistance is not a necessity.

An unconventional result is observed with personal Information extrusion (location, destination exposure) for Level 4 AVs. Only the “moderately concerned” category shows statistical significance, with a positive coefficient ( $\beta$ ) of 1.08 and an OR of 2.95. This indicates that individuals who are moderately concerned about personal information exposure are nearly three times more likely to be concerned over using Level 4 AVs compared to those who are “very concerned.” This result may reflect a lack of understanding of various levels of automation, as similar concerns could be applicable to Level 3 or Level 5 AVs as well. Kyriakidis et al. (2015) reported that respondents from more developed countries were less comfortable with their vehicle transmitting data, supporting the observed concern over personal information exposure.

For the variable automated driving under unexpected situations, negative coefficients and odds ratios less than one are observed for Level 5 AVs. Individuals who are “moderately concerned” or “slightly concerned” have ORs of 0.42 and 0.30, respectively, indicating a 58% and 70% decrease in the odds of being concerned about using Level 5 AVs compared to those who are “very Concerned.” This is justifiable, as Level 5 (Full Automation) is expected to handle driving under all conditions without driver assistance, reducing concerns for those who trust the technology. Level 3 and Level 4 AVs do not show any statistically significant results for this variable.

## 6. CONCLUSION

This study aimed to examine the factors influencing Seoul citizens’ concerns about using different levels of autonomous vehicles (AVs). To achieve this goal, a Seemingly Unrelated Ordered Logit (SUOL) model was developed, effectively capturing the impact of socio-economic and demographic variables on public concerns regarding Level 3, 4, and 5 AVs. The findings indicate that individuals who express significant concern about system safety due to errors are substantially more likely to be apprehensive about using AVs across all levels of automation. Similar patterns are observed for concerns about security threats from hackers, which significantly influence apprehension towards Level 5 AVs. This heightened concern may stem from the perception that full automation offers less personal control, making vehicles more vulnerable to hacking. In contrast, concerns about vehicle safety threats from hackers diminish for higher levels of automation, sug-

gesting increased trust in the vehicle’s ability to mitigate hacking risks.

Skepticism about the ability of AVs to reduce accidents or vehicle emissions correlates with greater concern over using Level 3 AVs. This highlights a paradox where acknowledged benefits do not alleviate apprehension. From a socio-demographic perspective, individuals with a bachelor’s degree and those who drive 30-40 hours per week show higher levels of concern regarding Level 3 AVs, possibly due to a stronger attachment to manual driving or greater awareness of potential risks. However, concerns decrease when individuals are less worried about learning automated vehicle driving, indicating that increased confidence reduces overall apprehension. For Level 4 AVs, concerns about system safety, personal information protection, and skepticism about decreasing accident damage are significant factors of apprehension. Conversely, concerns diminish regarding vehicle safety threats from hackers, suggesting increased trust at higher automation levels. Regarding Level 5 AVs, concerns about system safety, security threats, and the vehicle’s ability to improve response to accidents and reduce insurance rates are found to be significant. However, concerns are reduced among those willing to pay less than 10 million to 40 million Korean won for Level 5 AVs, reflecting a willingness to invest as a sign of acceptance. Additionally, younger individuals aged 20-29 and 40-49 are significantly less likely to be concerned, suggesting that age influences openness to new technology.

The study’s findings suggest that policymakers should prioritize the productive population (ages 15 to 64) when promoting the acceptance and market share of autonomous vehicles. This group’s adoption of AV technology is critical to its success. The reluctance to embrace fully autonomous vehicles emphasizes the need for comprehensive safety measures. Policymakers should focus on enhancing public confidence in AV safety by setting long-term objectives, enacting laws aligned with technological advancements, and developing regulations that appeal to this demographic. Commercial enterprises also play an important role in promoting AV technology. The study reveals that while individuals aged 20-29 generally have a positive outlook on driverless cars, their opinions are often mixed due to a lack of information. Companies should collaborate with legislators to increase public awareness and adaptation of AV technology. Investing in educational programs that emphasize the benefits and safety features of autonomous vehicles can address public concerns. By doing so, both governments and businesses can foster a more supportive environment for the widespread adoption of autonomous vehicles, ensuring a smooth and successful transition to this emerging technology.

A limitation of this study is the relatively small sample size, which may have resulted from the more detailed questionnaire used in the survey. The extensive nature of the questionnaire might have discouraged participation, limiting the diversity and number of respondents. Future research should consider expanding the scope to a national level, incorporating diverse geographic areas and populations. Additionally, further studies could explore other factors influencing AV adoption, such as cultural attitudes, technological literacy, and infrastructure readiness, to provide a more comprehensive understanding of the challenges and opportunities in implementing autonomous vehicles across different societal segments.

## ACKNOWLEDGMENTS

We are grateful to Jaehyung Lee, a Graduate student in the Department of Urban Planning and Engineering, Yonsei University, Seoul, Republic of Korea for translating the English version of survey into Korean version and also, we are thank-

ful to three undergraduate students from the Civil and Environmental Engineering Department, Yonsei University, Seoul, Republic of Korea for distributing and collecting maximum number of survey data.

## REFERENCES

- Ackaah, W., Leslie, V. L. D., & Osei, K. K. (2021). Perception of autonomous vehicles – A Ghanaian perspective. *Transportation Research Interdisciplinary Perspectives*, 11. <https://doi.org/10.1016/j.trip.2021.100437>
- Ahmed, S. K., Mohammed, M. G., Abdulqadir, S. O., El-Kader, R. G. A., El-Shall, N. A., Chandran, D., Rehman, M. E. U., & Dhama, K. (2023). Road traffic accidental injuries and deaths: A neglected global health issue. *Health Science Reports*, 6(5). <https://doi.org/10.1002/hsr2.1240>
- Aldakkhelallah, A., Alamri, A. S., Georgiou, S., & Simic, M. (2023). Public Perception of the Introduction of Autonomous Vehicles. *World Electric Vehicle Journal*, 14(12). <https://doi.org/10.3390/wevj14120345>
- Alessandrini, A., Campagna, A., Site, P. D., Filippi, F., & Persia, L. (2015). Automated vehicles and the rethinking of mobility and cities. *Transportation Research Procedia*, 5, 145–160. <https://doi.org/10.1016/j.trpro.2015.01.002>
- Alqahtani, T. (2025). Recent Trends in the Public Acceptance of Autonomous Vehicles: A Review. In *Vehicles* (Vol. 7, Issue 2). Multidisciplinary Digital Publishing Institute (MDPI). <https://doi.org/10.3390/vehicles7020045>
- Anderson, J. M. ., Kalra, Nidhi., Stanley, K. D. ., Sorensen, Paul., & Oluwatola, O. A. . (2016). *Autonomous vehicle technology : a guide for policymakers*. Rand Corporation.
- Bansal, P., Kockelman, K. M., & Singh, A. (2016). Assessing public opinions of and interest in new vehicle technologies: An Austin perspective. *Transportation Research Part C: Emerging Technologies*, 67, 1–14. <https://doi.org/10.1016/j.trc.2016.01.019>
- Chao, E. L. (2017). *Introductory message*. In *National Highway Traffic Safety Administration, \*Automated driving systems 2.0: A vision for safety\* (p. i)*. U.S. Department of Transportation. [https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0\\_090617\\_v9a\\_tag.pdf](https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf)
- Clark, B., Parkhurst, G., & Ricci, M. (2016). *Introducing Driverless Cars to UK Roads WORK PACKAGE 5.1 Deliverable D1 Understanding the Socioeconomic Adoption Scenarios for Autonomous Vehicles: A Literature Review*. <https://uwe-repository.worktribe.com/output/917906>
- Dai, J., Wang, X. C., Ma, W., & Li, R. (2023). Future transport vision propensity segments: A latent class analysis of autonomous taxi market. *Transportation Research Part A: Policy and Practice*, 173. <https://doi.org/10.1016/j.tra.2023.103699>
- Das, S., Dutta, A., & Fitzpatrick, K. (2020). Technological perception on autonomous vehicles: perspectives of the non-motorists. *Technology Analysis and Strategic Management*, 32(11), 1335–1352. <https://doi.org/10.1080/09537325.2020.1768235>
- Daziano, R. A., Sarrias, M., & Leard, B. (2017). Are consumers willing to pay to let cars drive for them? Analyzing response to autonomous vehicles. *Transportation Research Part C: Emerging Technologies*, 78, 150–164. <https://doi.org/10.1016/j.trc.2017.03.003>
- Ehsani, J. P., Michael, J. P., & MacKENZIE, E. J. (2023). The Future of Road Safety: Challenges and Opportunities. *Milbank Quarterly*, 101, 613–636. <https://doi.org/10.1111/1468-0009.12644>
- Elliott, D., Keen, W., & Miao, L. (2019). Recent advances in connected and automated vehicles. In *Journal of Traffic and Transportation Engineering (English Edition)* (Vol. 6, Issue 2, pp. 109–131). Chang'an University. <https://doi.org/10.1016/j.jtte.2018.09.005>
- Gkartzonikas, C., & Gkritza, K. (2019). What have we learned? A review of stated preference and choice studies on autonomous vehicles. *Transportation Research Part C: Emerging Technologies*, 98, 323–337. <https://doi.org/10.1016/j.trc.2018.12.003>
- Ha, T., Kim, S., Seo, D., & Lee, S. (2020). Effects of explanation types and perceived risk on trust in autonomous vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour*, 73, 271–280. <https://doi.org/10.1016/j.trf.2020.06.021>
- Harrow, D., Gheerawo, R., Phillips, D., & Ramster, G. (2018). Understanding how attitudes towards autonomous vehicles can shape the design of cities. *Proceedings of the Institution of Civil Engineers: Municipal Engineer*, 171(1), 31–40. <https://doi.org/10.1680/jmuen.16.00066>
- Hilgartner, K., & Granig, P. (2020). Public perception of autonomous vehicles: A qualitative study based on interviews after riding an autonomous shuttle. *Transportation Research Part F: Traffic Psychology and Behaviour*, 72, 226–243. <https://doi.org/10.1016/j.trf.2020.05.012>
- Howard, D., & Dai, D. (2014). Public perceptions of self-driving cars: The case of Berkeley, California. *Transportation Research Board 93rd Annual Meeting, Washington, DC, USA: The National Academies of Sciences, Engineering, and Medicine*, 14, 4502, 1–16. <https://trid.trb.org/View/1289421>
- Hulse, L. M., Xie, H., & Galea, E. R. (2018). Perceptions of autonomous vehicles: Relationships with road users, risk, gender and age. *Safety Science*, 102, 1–13. <https://doi.org/10.1016/j.ssci.2017.10.001>
- Hussain, Q., Alhajyaseen, W. K. M., Adnan, M., Almallah, M., Almukdad, A., & Alqaradawi, M. (2021). Autonomous vehicles between anticipation and apprehension: Investigations through safety and security perceptions. *Transport Policy*, 110, 440–451. <https://doi.org/10.1016/j.tranpol.2021.07.001>
- ITF. (2024). *“Korea: Road Safety Country Profile 2023”*, OECD Publishing, Paris.
- Krizsik, N., & Sipos, T. (2023). Social Perception of Autonomous Vehicles. *Periodica Polytechnica Transportation Engineering*, 51(2), 133–139. <https://doi.org/10.3311/PPtr.20228>
- Kyriakidis, M., Happee, R., & De Winter, J. C. F. (2015). Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. *Transportation Research Part F: Traffic Psychology and Behaviour*, 32, 127–140. <https://doi.org/10.1016/j.trf.2015.04.014>
- Lazányi, K. (2023). Perceived Risks of Autonomous Vehicles. *Risks*, 11(2). <https://doi.org/10.3390/risks11020026>
- Li, J., Hu, Z., & Liu, L. (2023). A survey on public acceptance of automated vehicles across COVID-19 pandemic periods in China. *IATSS Research*, 47(4), 482–490. <https://doi.org/10.1016/j.iatssr.2023.10.002>
- Liljamo, T., Liimatainen, H., & Pöllänen, M. (2018). Attitudes and concerns on automated vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour*, 59, 24–44. <https://doi.org/10.1016/j.trf.2018.08.010>
- Litman, T. (2020). *Autonomous vehicle implementation predictions: Implications for transport planning*. Victoria Transport Policy Institute. [www.vtpi.org/avip.docx](http://www.vtpi.org/avip.docx)
- Liu, H., Yang, R., Wang, L., & Liu, P. (2019). Evaluating Initial Public Acceptance of Highly and Fully Autonomous Vehicles. *International Journal of Human-Computer Interaction*, 35(11), 919–931. <https://doi.org/10.1080/10447318.2018.1561791>
- Milakis, D., Snelder, M., Van Arem, B., Van Wee, B., Homem, G., & Correia, A. (2017). Development and transport implications of automated vehicles in the Netherlands: scenarios for 2030 and 2050. *EJTIR Issue*, 17(1), 63–85.
- Mircea, I.-I., Vlad, C.-S., Ivascu, L., & Roşca, E. (2025). Exploring Demographic Influences on Public Perception and Adoption of Autonomous Vehicles: An Empirical Perspective. *Proceedings of the International Conference on Business Excellence*, 19(1), 27–36. <https://doi.org/10.2478/picbe-2025-0006>

- Moody, J., Bailey, N., & Zhao, J. (2020). Public perceptions of autonomous vehicle safety: An international comparison. *Safety Science*, 121, 634–650. <https://doi.org/10.1016/j.ssci.2019.07.022>
- Othman, K. (2021). Public acceptance and perception of autonomous vehicles: a comprehensive review. *AI and Ethics*, 1(3), 355–387. <https://doi.org/10.1007/s43681-021-00041-8>
- Parekh, D., Poddar, N., Rajpurkar, A., Chahal, M., Kumar, N., Joshi, G. P., & Cho, W. (2022). A Review on Autonomous Vehicles: Progress, Methods and Challenges. *Electronics (Switzerland)*, 11(14). <https://doi.org/10.3390/electronics11142162>
- Quartulli, A. M., Casley, S. V., & Jardim, A. S. (2013). *A Study of Public Acceptance of Autonomous Cars Interactive Qualifying Project. Dissertation: Worcester Polytechnic Institute.*
- Schoettle, B., & Sivak, M. (2014). A survey of public opinion about connected vehicles in the U.S., the U.K., and Australia, 2014 International Conference on Connected Vehicles and Expo (ICCVE), Vienna, Austria, 2014, pp. 687-692, doi: [10.1109/ICCVE.2014.7297637](https://doi.org/10.1109/ICCVE.2014.7297637).
- Shin, J., Bhat, C. R., You, D., Garikapati, V. M., & Pendyala, R. M. (2015). Consumer preferences and willingness to pay for advanced vehicle technology options and fuel types. *Transportation Research Part C: Emerging Technologies*, 60, 511–524. <https://doi.org/10.1016/j.trc.2015.10.003>
- Stoma, M., Dudziak, A., Caban, J., & Drożdziel, P. (2021). The future of autonomous vehicles in the opinion of automotive market users. *Energies*, 14(16). <https://doi.org/10.3390/en14164777>
- Tennant, C., Stares, S., & Howard, S. (2019). Public discomfort at the prospect of autonomous vehicles: Building on previous surveys to measure attitudes in 11 countries. *Transportation Research Part F: Traffic Psychology and Behaviour*, 64, 98–118. <https://doi.org/10.1016/j.trf.2019.04.017>
- Thomas, E., McCrudden, C., Wharton, Z., & Behera, A. (2020). Perception of autonomous vehicles by the modern society: A survey. *IET Intelligent Transport Systems*, 14(10), 1228–1239. <https://doi.org/10.1049/iet-its.2019.0703>
- Vinkhuyzen, E., & Cefkin, M. (2016). Developing Socially Acceptable Autonomous Vehicles. *Ethnographic Praxis in Industry Conference Proceedings*, 522–534. <https://www.epicpeople.org>
- Woldeamanuel, M., & Nguyen, D. (2018). Perceived benefits and concerns of autonomous vehicles: An exploratory study of millennials' sentiments of an emerging market. *Research in Transportation Economics*, 71, 44–53. <https://doi.org/10.1016/j.retrec.2018.06.006>
- Xu, X., & Fan, C. K. (2019). Autonomous vehicles, risk perceptions and insurance demand: An individual survey in China. *Transportation Research Part A: Policy and Practice*, 124, 549–556. <https://doi.org/10.1016/j.tra.2018.04.009>
- Yuen, K. F., Wong, Y. D., Ma, F., & Wang, X. (2020). The determinants of public acceptance of autonomous vehicles: An innovation diffusion perspective. *Journal of Cleaner Production*, 270. <https://doi.org/10.1016/j.jclepro.2020.121904>