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Investigating Driver Preferences for Traffic Information Using Digital Signage and Road Surface Holograms

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ABSTRACT

This study investigates road users' information preferences to enhance traffic information provision strategies. Traditional road signs primarily convey static information like speed limits and restricted areas. However, smart street poles now offer the capability to collect real-time road conditions and deliver dynamic traffic updates promptly. Leveraging these smart poles allows for more effective and tailored information delivery strategies. The research examines three types of media for information dissemination: digital signage, road surface hologram, and a combination of both. Additionally, it surveys road users' preferences for information delivery methods, including text, graphics, or a mixture, based on the type of information. Conjoint analysis of 220 responses reveals essential attributes influencing users when they receive information. The findings indicate that a majority of road users prefer a blend of digital signage and road surface holograms, with a notable preference among younger individuals for digital signage. For road surface holograms, the favored approach involves a mix of text and graphics. This study lays the foundation for user-centric information strategies, offering insights into tailoring approaches based on the type of information and user preferences.

1. Introduction

Numerous countries worldwide are leveraging information and communication technology (ICT) to develop road infrastructure, aiming to alleviate traffic congestion, enhance road infrastructure, and address urban challenges. For instance, Valencia, Spain has implemented wireless sensor-equipped poles for traffic data collection and management, employing processes encompassing data collection, storage, processing, and dissemination (Pla-Castells et al., 2015). Similarly, Nigeria has adopted ICT-integrated road infrastructure to mitigate urban congestion issues (Nwankwo et al., 2019).

In this evolving era of smart city development, optimizing road infrastructure through ICT has become a global imperative. Anticipated as fundamental components of smart cities, smart street poles are poised to offer electric vehicle charging, urban environment and noise data collection, public Wi-Fi, CCTV surveillance, and 5G communication modules (Seoul Digital Foundation, 2021). Smart street poles, a fundamental component of this transformation, have transcended their conventional role as mere street lights. They now integrate cutting-edge technologies to collect real-time data on road and traffic environments.

Traditionally, street lights served merely as illumination for roads, with initial smart pole iterations primarily focused on optimizing electricity efficiency through collective control (Putra and Wibisono, 2021). Researchers have pioneered autonomous brightness control systems by implementing smart street poles in smart cities, effectively managing multiple lights via a single server (Müllner and Riener, 2011; Magno et al., 2014; Kokilavani and Malathi, 2017; Gagliardi et al., 2020). The subsequent evolution of smart street poles involves the amalgamation of street lighting and data collection capabilities for road environment detection. In South Korea, extensive research has been undertaken, particularly in integrating diverse ICT technologies into smart street poles, where road environment sensing and information delivery methods synergize with existing street lights. A salient distinction of the smart street poles addressed in this study from conventional smart poles lies in their dual role as street lights and road signs.

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These smart street poles are fortified with multifaceted technologies enabling the collection of multisensory environmental data, incident detection, and road condition monitoring. They consist of two principal components: a device for gathering road and traffic environment data (e.g., accidents, congestion, road icing, traffic volume, pedestrian paths, vehicle movement, direction, and speed) and an information provision mechanism for disseminating pertinent data via digital signage and road surface holograms (Kim et al., 2021).

Effective policy formulation encompasses deliberations on the nature and manner of information dissemination, warranting careful consideration of road user satisfaction and preferences. In this context, road users exhibit varied satisfaction levels contingent on attributes like efficiency, reliability, and comprehensibility (LaMondia et al., 2008; Hong et al., 2010). Crucially, a proficient traffic information delivery strategy is imperative for effective traffic management. Moreover, recognizing the individual variability in processing traffic information based on personal traits, such as travel characteristics, is vital (Wade et al., 1991; Wardman et al., 1996; Ko and Choi, 2012).

The realm of traffic information encompasses static and dynamic information categories. Static information entails immobile data encompassing road infrastructure, facilities, and details of road. In contrast, dynamic information pertains to hazardous situations or the presence of perilous elements that could potentially engender unsafe driving conditions. Particularly, dynamic information can result in complex decision making regarding a driver's trip within a traffic network because the reactivity between the two types of information differs (Yim et al., 2002; Muizelaar and Van Arem, 2007; Marchal and Palma, 2008).

To investigate road users' preferences concerning information provision methods, a conjoint analysis is conducted. This approach has gained prominence for optimizing user benefits prior to system, product, and service implementations (Krantz and Tversky, 1971). Sutterer et al. (2007) underscored the significance of accommodating user demands and expectations to enhance the acceptability of novel services and applications, emphasizing the potential to refine acceptability through the analysis of user preferences.

This study delves into the nuanced preferences of road users regarding information provision methods, aiming to bridge the gap between advanced technology and user satisfaction. Understanding these preferences is vital for tailoring efficient traffic information dissemination strategies. Contribution of this study lies in discerning the distinctions in user preferences across diverse information types and provision methods facilitated by smart street poles. Road signs provide drivers with static information based solely on road geometrical aspects. Conversely, while Variable Message Signs (VMS) can disseminate a wealth of information, their utility is constrained by installation limitations. In contrast, smart street poles encompass the dual functionalities of road signs and VMS. By employing conjoint analysis, this research identifies and ranks driver preferences across nine distinct scenarios, integrating road holograms. While previous studies predominantly examined preferences for road signs, VMS, and information types in isolation due to limitations in installation and technology, this study endeavors to comprehend driver preferences holistically by integrating these facets.

2. Literature Review

The integration of Information and Communication Technology (ICT) into road infrastructure has demonstrated positive impacts on economic growth and environmental sustainability (Jafri et al., 2021). ICT-enabled infrastructure comprises a combination of sensors, control units, wireless communication devices, and operational platforms (Buchholz et al., 2020). In the context of traffic management, this encompasses a wide array of components such as traffic control centers, real-time traffic data collection and provisioning, VMS installations, parking space management systems, systems for curbing illegal parking, parking guidance solutions, and traffic signal systems (Bakogiannis et al., 2019).

Various types of information and their expression formats significantly influence a driver's route preference and comprehension of information (Wardman et al., 1997; Peeta and Pasupathy, 2000; Tsirimpa and Polydoropoulou, 2009; Richard and Barros, 2010; Park and Moon, 2011; Ma et al., 2020). Numerous studies have consistently highlighted the substantial impact of different information types. Wardman et al. (1997) presented information in three different formats via VMS to road users, combining accident and congestion information, and analyzed information understandability and preference by assessing road users' route alterations. Peeta and Pasupathy (2000) investigated user preferences, capturing changes in route selection rates influenced by the type and combination of accident, detour, and delay information conveyed through VMS. They constructed a decision logit model for route choice. Ma et al. (2020) found a significant impact of information types through a stated preference survey of Beijing drivers. Consistently, previous research has demonstrated that user behavior tends to shift in response to different types of information.

Walton et al. (2009) delved into the information requirements of arterial road users, encompassing both the type and format of information most valuable to drivers, transit riders, and pedestrians. They discovered that drivers and transit riders benefit from real-time traffic information delivered via VMS and radio, whereas pedestrians find cellular phone-based information more useful. This emphasizes the distinct user reactions depending on the provision medium. Wang et al. (2009) noted varying driver responses to different information technologies, with radio-delivered transportation information demonstrating the most substantial association with travel route changes. Notably, there is a paucity of studies focusing on the type of information provision device, particularly road holograms. However, it is noteworthy that road holograms have been practically implemented, particularly at crosswalks and predominantly during evening hours. This practical utilization underscores the need for further research in this area.

Prior research has consistently highlighted the significance of presentation formats to drivers. Kim (2010) examined drivers' visual preferences for VMS expression formats to optimize their effects. Among various forms, 67% of respondents in a survey preferred information conveyed through text. Similarly, Park et al. (2009) conducted a user preference survey on simple information delivery encompassing warnings and instructional information, using various visual formats like pictures and shapes. Most users exhibited a preference for simple speed information, while the simultaneous presentation of text and shapes with flickering was the most favored information provision method.

Furthermore, drivers' preferences for information expression methods differ depending on the type of information. Zhao et al. (2019) conducted a stated preference survey to analyze drivers' preferences for various combinations of information types and presentation forms, encompassing congestion, delay, and route guidance information, as well as textual and graphical presentation. Their results demonstrated that respondents favored delay information presented using both text and shapes, whereas congestion information presented solely in text form garnered the least preference. Yeon et al. (2008) explored drivers' preferences regarding VMS message expression forms and proposed message design and operational strategies. In a survey involving 40 individuals, they investigated preferences for text and shape combinations, fonts, information content, and styles. The findings revealed a preference for strategies that conveyed instructional information on driver behavior and road conditions, excluding natural disasters.

Summarizing previous research underscores the critical importance of information type, information provision medium, and format of information to drivers. These attributes have been explored in isolation, with researchers discerning conditions that impact driver responses individually. However, few studies have undertaken the simultaneous consideration of these conditions. Addressing this gap, this study concurrently tackles these variables and analyzes user preferences concerning information receipt and presentation methods.

Preference analysis is commonly used for product and service feedback (Kelly and Teevan, 2003) but can also be applied to product and service development. Keinonen (1997) asserts that heightened preference levels correlate with increased system and product usage frequency. Notably, high user preference does not necessarily equate to superior product performance; nonetheless, consumer preference is pivotal in designing products (Bailey, 1993; Dillon, 2001; Bartuskova and Kerjcar, 2013).

3. Methodology

3.1 Survey Design

In this study, the preference analysis is conducted for determining user’s preference of information provision. Preference analysis is commonly used for product and service feedback (Kelly and Teevan, 2003) but can also be applied to product and service development. Keinonen (1997) asserts that heightened preference levels correlate with increased system and product usage frequency. Although high user preference doesn't guarantee superior product performance, consumer preference plays a crucial role in shaping product design (Bailey, 1993; Dillon, 2001; Bartuskova and Krejcar, 2013). The preference survey regarding information type, device type, and format was conducted through an online interview format using convenience sampling, necessitated by the challenges posed by COVID-19. While convenience sampling is cost-effective and straightforward, it may lack sample representativeness and introduce bias. To mitigate these discrepancies, efforts were made to ensure fairness in the sample.

In general, conjoint analysis is used to analyze the attribute preference of products and services. The number of attributes and levels is important when setting the profiles, which are the core elements of conjoint analysis. An excessively large choice set can be burdensome for respondents, and if a choice set of the desired size cannot be configured, it will be difficult to apply in reality because the researcher cannot form a specific size of the selection set (McCullough, 2002). Accordingly, this study adopted a conjoint approach using a balanced incomplete block design (BIBD). BIBD increases the precision of the study because balancing and replication reduce standard deviation or variability (Cox, 1958). Also, it can save the respondent's time and improve the reliability of the result (Rink, 1987).

A conjoint survey was conducted involving 358 drivers aged 20 to 60, over five days from November 2 to 6, 2021. The survey consisted of three parts: socioeconomic indicators and basic information (e.g., age, gender, average income, driving frequency, and trip purpose), preferences for media and expression format within static information, and preferences for media and expression format within dynamic information (see Appendix). The survey was structured in the form of ranking responses for given scenarios and consisted of four types of inquiries. Prior to the survey, respondents were exposed to video content explaining information delivery through smart street poles, allowing them to base their responses on an understanding of the technology.

In this study, we designed and analyzed a survey to identify user preferences for various types and methods of information applicable to smart street poles. The information technology devices on a smart street pole encompass digital signage and road surface hologram. Conjoint analysis was performed by selecting important attributes of information provision media and preferences.

3.2 Data

After excluding surveys with inappropriate responses and insincere answers, a total of 220 collected surveys were used as final data. The first step of define the inappropriate survey was to separate drivers and non-drivers and exclude non-drivers or if driving less than once per week. Second way is to present same combination of profiles in duplicate, and if the ranking for the query is different, that survey is judged to be inappropriate.

In the context of determining an appropriate sample size, McCullough (2002) suggested that a minimum of 75 samples

Table 1. Road User Characteristics from Survey Data

Variable		Male	Female	% of Male	% of Female	Work	Non-work	% of Work	% of Non-work
Age	20s	46	23	66.7	33.3	37	32	53.6	46.4
	30s	37	29	56.1	43.9	34	32	51.5	48.5
	40s	41	25	62.1	37.9	29	37	43.9	56.1
	50s and over	11	8	57.9	42.1	13	6	68.4	31.6
	Total	135	85	61.4	38.6	114	106	51.8	48.2

per level is necessary. Similarly, Marshall et al. (2010) indicated that studies employing conjoint analysis, especially in the healthcare field, typically utilize 100 to 300 respondents. Given this guidance, the sample size of 220 in this study was deemed appropriate. Nundy et al. (2022) calculate the sample size for estimating using the Eq. (1) most widely used formula to determine the sample size. In this study the adequate sample size is calculated over 170 samples with a 95% confidence level, p = 0.5, d = 7.5%. The process of determining the sample size prior to conducting a survey is important, and in this study, the minimum number of sample was satisfied by applying the criteria above.

Upon analyzing the data, it was found that 61.36% (135 respondents) were male, and 38.64% (85 respondents) were female. Examining the distribution by age groups, the highest number of participants belonged to the 20s age group. However, the number of participants in their 20s, 30s, and 40s was nearly equal. Notably, in the 20 – 29 age group, the gender distribution was not uniform, primarily due to a higher number of males in their 20s who reported driving compared to females. Regarding the purpose of travel, 51.8% of respondents reported work-related trips, while 48.2% reported non-work-related trips. Individuals in their 40s had a higher proportion of non-work-related trips compared to work-related trips, whereas other age groups exhibited a higher ratio of work-related trips. Specific sample distributions are detailed in Table 1.

$$n \geq Z^2 * \frac{p(1-p)}{d^2} \tag{1}$$

3.3 Analysis Methodology

Conjoint analysis effectively predicts the probability that a user will select a service or product by analyzing consumer responses and then estimating the usefulness value perceived by a consumer for each attribute and level (Green and Srinivasan, 1990). Before proceeding with a detailed survey, researchers configure profiles of attributes and levels to allow consumers to rate or select rankings or grades for the profiles (Boyle et al., 2001). Several studies have employed conjoint analysis to investigate user preferences regarding traffic information. For example, Ko et al. (2013) surveyed the preferred content and expression methods of traffic information; users received real-time traffic information through various media, such as VMS. The survey involved conjoint analysis, and a total of 18 profiles were configured by setting five attributes. Most users preferred information provided via voice. In terms of the type of information, they favored active behavior information (Kim, 2012).

In summary, a conjoint analysis was designed to identify preference rankings for profiles extracted through orthogonal planning, resulting in nine profiles configured. However, surveying preference rankings by providing all nine profiles may confuse respondents due to the many response choices. In this study, profiles of conjoint make up a substantial number of questionnaires, whereas using BIBD can help solve the problem of congestion arising from the number of questionnaires.

Therefore, a BIBD was applied by encompassing specific profiles in choice sets; this enables the same number of profiles to be included in all choice sets, and each profile is used the same number of times. Accordingly, BIBD was configured as follows.

$$r \cdot n = n_b \cdot r_b\,, \tag{2}$$

$$n(r_b - 1) = n_b(r-1), r \leq n_b\,, \tag{3}$$

where r is the total number of profiles, n_b is the number of choice sets, and r_b is the number of profiles encompassed in each choice set. The Eqs. (2) and (3) means: 1) Each profile has to encompass one choice set; 2) Each profile contains exactly n choice set; 3) Any r profiles are simultaneously included in the n_b choice sets.

3.4 Analytical Approach

The relevant attributes and levels for the conjoint analysis pertaining to the implementation of smart poles were identified through a qualitative process. To establish these attributes, an extensive literature review was conducted to pinpoint the key attributes of traffic information from the perspective of road users. Given the limited empirical evidence on traffic information provision through smart poles, studies focusing on VMS were also taken into account.

From the comprehensive review of various literature sources, critical factors in providing traffic information were identified to be the type of information and the mode of provision. Factors such as font size and color were deliberately excluded from the analysis, with emphasis placed on the utilization of various media as a factor in the survey design.

To align the survey with the study's objectives, two separate surveys were conducted based on the type of information being provided: static and dynamic. Combinations of information provision methods were defined as factors, and the method of providing each media type (graph or text) was set as a detailed level for the survey. Furthermore, recognizing that user priorities vary depending on the type of information (static and dynamic),

Table 2. Attributes and Corresponding Levels

Variable		Attribute	Level
Information Provision	Static Information	Media	Digital signage, Road hologram, Both
		Digital Signage	Text, Graph, Text + Graph
		Road Hologram	Text, Graph, Text + Graph
	Dynamic Information	Media	Digital Signage, Road hologram, Mixed
		Digital Signage	Text, Graph, Text + Graph
		Road Hologram	Text, Graph, Text + Graph

surveys were conducted to analyze users' preferences accordingly.

Based on findings from the literature review, the following considerations were incorporated:

1. Driver preferences differ between dynamic information (accidents, sudden events, warnings) and static information (simple information).
2. Driver preferences differ depending on the medium through which information is provided.
3. Driver preferences differ depending on the combination of information provision methods (text, graph, mixed)

In Table 2, the final attributes and levels used for the conjoint analysis are presented. The survey commenced by providing respondents with a brief explanation and visuals incorporating the changes before and after the introduction of smart poles (refer to Fig. 1). The survey was conducted separately for static and dynamic information, preceded by an explanation of both types of information. Traffic information was categorized into situations where the driver's attention is required due to external factors and where it is not. Static information denotes stationary information such as road structure, facilities, and trip methods, while dynamic information refers to risky situations or the appearance of dangerous objects necessitating the driver's reaction to avoid hazardous driving problems (see Fig. 2).

Fig. 1. Differences before and after the Introduction of Smart Pole

Fig. 2. Current Signs: (a) Signs for Static Information in Korea, (b) Signs for Dynamic Information in Korea

Additionally, the current road signs providing static and dynamic information were showcased to respondents. Subsequently, respondents were presented with nine conjoint alternative sets, derived using an orthogonality test within 27 ($3 \times 3 \times 3$) combinations of attribute levels. They were then asked to rank these sets in order of preference. Consequently, respondents ranked the nine profiles based on whether static or dynamic information was provided.

The extracted alternatives had three profiles for each type of media (road surface hologram alone, digital signage alone, and a mixture of digital signage and road surface hologram). Then, each media type was further classified into information delivery technology (text, graphics, text + graphics). Accordingly, it is possible to understand which information-providing media road users prefer and through which information-providing method has high utility. The profiles in the survey were provided in the surveyed images of an intersection in Fig. 3.

4. Model Estimation Results

This study conducted a conjoint analysis separately for both static and dynamic information. In the following section, relative importance and added value utility are estimated for each attribute level based on the preference rankings for the profiles within static information. In this context, importance refers to the comparison of the difference between the maximum and minimum added values at the level within the attributes; attributes with higher importance do not necessarily have a higher preference. High importance indicates that the relevant factor is key in selecting alternatives. Since Pearson's R was greater than 0.9, and Kendall's Tau was higher than 0.7 for all analysis results, the model fit and the validity of the profiles are satisfied in the following analyses. Green and Srinivasan (1990) asserted the studies used a variety of reliability measures, such as Pearsonian product moment correlations and the median reliability of correlation is about 0.75.

4.1 Result of Conjoint Analysis on Gender

Table 3 shows the summary statistics for respondents' preferences by gender in the type of information. Irrespective of gender, the importance ranking consistently placed "Provision method of road hologram" as the most crucial attribute, with a preference for utilizing both road hologram and digital signage. For males, attribute importance rankings remained relatively consistent

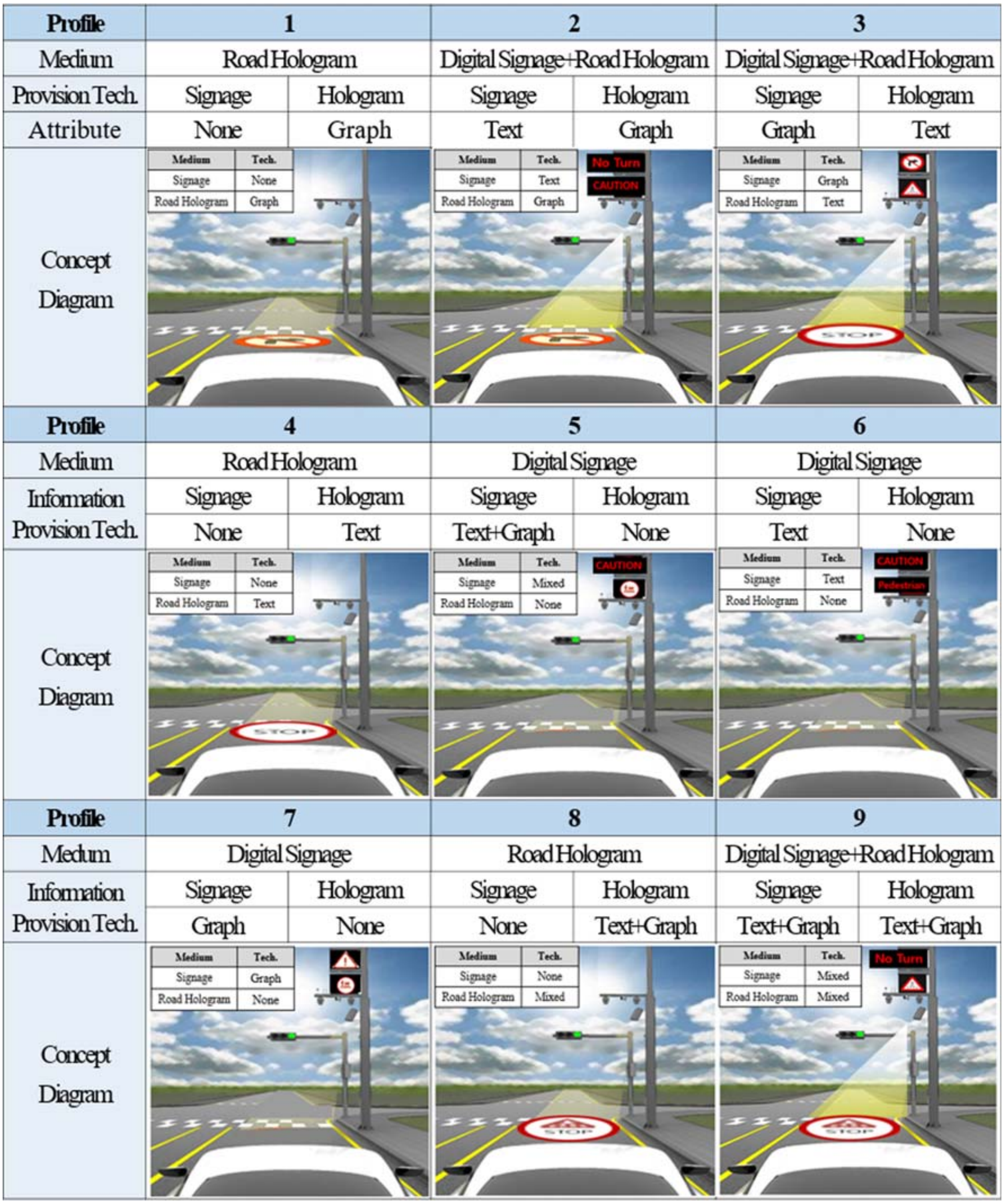

Fig. 3. Example Profiles for Conjoint Analysis for a Simulated Image of an Intersection

across information types, favoring media that combine text and graph elements within digital signage and road hologram.

Among females, although the importance rankings matched, differences emerged in the "Provision method of digital signage". Additionally, females exhibited a preference for graph-based digital signage when presented with static information. In contrast, for dynamic information, they preferred a blend of text and graph. Both males and females preferred the simultaneous provision of digital signage and road hologram across scenarios. In particular, female's preference was higher than that of male's. This is similar to the result of previous studies showing that females are more sensitive to information and risk situations and have a higher preference for media with a large amount of dynamic information (Peeta et al., 2000; Ma et al., 2014, 2020).

4.2 Result of Conjoint Analysis on Age

It can be seen from the data in Table 4 that respondents are segmented based on age, with the division set at the 40s threshold, denoting those over 40 as "senior" and those below 40 as "junior" for convenience. The response to signs while driving is affected

Table 3. Results from the Conjoint Analysis on Gender

Attribute	Level	Gender							
		Static Information				Dynamic Information			
		Male		Female		Male		Female	
		Importance	Utility	Importance	Utility	Importance	Utility	Importance	Utility
Provision Method of Digital Signage	Text	18.77	-0.658	23.44	-0.834	18.61	-0.547	18.97	-0.642
	Graph		0.314		0.437		0.169		0.244
	Text + Graph		0.344		0.397		0.379		0.397
Provision Method of Road Hologram	Text	41.47	-1.323	41.32	-1.324	41.79	-1.308	41.73	-1.371
	Graph		0.430		0.409		0.537		0.456
	Text + Graph		0.892		0.915		0.771		0.915
Information Provision Medium	Digital signage	39.76	0.626	35.24	0.590	39.60	0.507	39.30	0.472
	Road hologram		-1.374		-1.250		-1.239		-1.312
	Using both		0.749		0.660		0.732		0.841
Correlation Coefficient	Pearson's R	0.931(0.000)		0.926(0.000)		0.928(0.000)		0.928(0.000)	
	Kendal's Tau	0.778(0.002)		0.778(0.000)		0.722(0.003)		0.778(0.002)	

Table 4. Results from the Conjoint Analysis on Age

Attribute	Level	Age							
		Static Information				Dynamic Information			
		Under 40s		40s or more		Under 40s		40s or more	
		Importance	Utility	Importance	Utility	Importance	Utility	Importance	Utility
Provision Method of Digital Signage	Text	19.18	-0.667	24.72	-0.825	17.95	-0.584	20.18	-0.584
	Graph		0.394		0.308		0.217		0.167
	Text + Graph		0.273		0.517		0.367		0.416
Provision Method of Road Hologram	Text	44.92	-1.457	33.09	-1.102	43.21	-1.418	39.22	-1.190
	Graph		0.431		0.408		0.547		0.436
	Text + Graph		1.027		0.683		0.871		0.754
Information Provision Medium	Digital signage	35.90	0.693	42.19	0.477	38.84	0.530	40.60	0.432
	Road hologram		-1.292		-1.383		-1.294		-1.222
	Using both		0.599		0.906		0.764		0.790
Correlation Coefficient	Pearson's R	0.950(0.000)		0.890(0.001)		0.956(0.000)		0.868(0.001)	
	Kendal's Tau	0.889(0.000)		0.667(0.006)		0.780(0.000)		0.667(0.006)	

by age, Wardman et al. (1997) announced there was a statistically significant tendency for response VMS and signs under 35 years. Ma et al. (2014) and Peeta et al. (2000) also analyzed the differences in responsiveness to VMS based on the age of 45 and 40. In this study, it is necessary to classify age based on previous studies, and 40 years was set as the standard.

While the importance ranking by information type remains consistent, the order of attribute importance varies by age group. Among juniors, distinct preferences for the Information provision medium were observed based on the information type. They preferred exclusive provision of digital signage for static information but preferred the simultaneous provision of digital signage and road hologram for dynamic information. Additionally, when receiving static information through digital signage, they preferred graph-only presentation; however, for dynamic information, they preferred a format combining text and graph.

In contrast, seniors exhibited a more consistent pattern regardless of information type. They preferred the combined usage of digital signage and road hologram as the information provision medium and preferred the expression involving both text and graph. The most notable age-related discrepancy pertained to the provision of static information. Juniors preferred the exclusive use of digital signage displaying only graphs, whereas seniors favored a hybrid format combining text and graph for both digital signage and road hologram. This result supports the prior studies showing that older people are sensitive to information, and therefore, it is believed that they prefer media that provide a variety of information (Wardman et al., 1997; Peeta et al., 2000).

Table 5. Results from the Conjoint Analysis on Trip Purpose

Attribute	Level	Trip purpose							
		Static Information				Dynamic Information			
		Work		Non-work		Work		Non-work	
		Importance	Utility	Importance	Utility	Importance	Utility	Importance	Utility
Provision Method of Digital Signage	Text	21.28	-0.713	20.01	-0.739	21.06	-0.650	16.66	-0.522
	Graph		0.372		0.352		0.221		0.176
	Text + Graph		0.341		0.387		0.429		0.346
Provision Method of Road Hologram	Text	40.65	-1.184	42.05	-1.452	39.96	-1.273	43.41	-1.388
	Graph		0.297		0.539		0.498		0.513
	Text + Graph		0.888		0.913		0.775		0.875
Information Provision Medium	digital signage	38.06	0.605	37.94	0.618	38.98	0.466	39.93	0.519
	road hologram		-1.273		-1.376		-1.232		-1.300
	Using both		0.668		0.758		0.765		0.782
Correlation Coefficient	Pearson's R	0.904(0.000)		0.948(0.000)		0.920(0.000)		0.935(0.000)	
	Kendal's Tau	0.778(0.002)		0.778(0.002)		0.778(0.000)		0.778(0.002)	

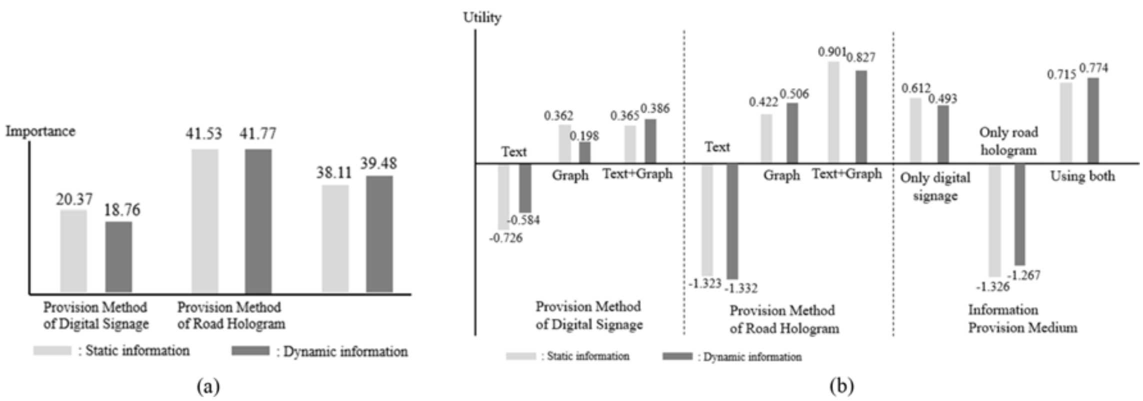

Fig. 4. Results from the Conjoint Analysis: (a) Importance of Attribute, (b) Utility of Levels

4.3 Result of Conjoint Analysis on Trip Purpose

As shown in Table 5, when receiving static information, the preference for media remains the same for trip purposes categorized as "work" and "non-work": both digital signage and road hologram are favored. However, the preference difference is more pronounced for the "non-work" category. For "work" trips, the difference in preference between the sole use of digital signage and the combined use of both media is less significant. This is similar to the result from Ma et al. (2020)'s study that people who know their way around well are less sensitive to information. Also, differences are observed in the expression way of digital signage. For "work" trips, there is a stronger preference for graphs, while for "non-work" trips, a preference for a combination of text and graphs is more prominent.

Regarding dynamic information, the preference pattern for "work" and "non-work" trips exhibits a similar trend. The information provision medium is favored when both digital signage and road hologram are used together, and the preference leans towards the presentation of information in a mixed form of text and graphs. However, the difference between digital signage and mixed medium in work trips is particularly large, and it can be assumed that work trips react sensitively to dynamic information due to their sensitivity to travel time during commuting (Lai and Wong, 2000).

4.4 Preference Difference according to Static/Dynamic Information Type

User preferences for each characteristic of static and dynamic information are shown in Fig. 4. Fig. 4 shows an insignificant difference in preference between digital signage alone and a combination of digital signage and road surface hologram for static information; however, the preference for the combination of media is higher for dynamic information. The attribute preference for digital signage was the highest when static information was provided using a combination of text and graphics, regardless of gender. This indicates that users wish to receive more detailed information regarding dynamic information but prefer graphics, as in existing traffic signs when provided with static information. In contrast, the preference for a combination of media information was higher for road surface holograms among all users; the

Table 6. Results from the Conjoint Analysis of Information Type: Results from Conjoint Analysis for Both Static and Dynamic Information

Attribute	Level	Gender				Age				Trip Purpose			
		Static Information		Dynamic Information		Static Information		Dynamic Information		Static Information		Dynamic Information	
		Male	Female	Male	Female	Under 40s	40s or more	Under 40s	40s or more	Work	Non-work	Work	Non-work
Provision Method of Digital Signage	Text	-0.658	-0.834	-0.547	-0.642	-0.667	-0.825	-0.584	-0.584	-0.713	-0.739	-0.650	-0.522
	Graph	0.314	0.437	0.169	0.244	0.394	0.308	0.217	0.167	0.372	0.352	0.221	0.176
	Text + Graph	0.344	0.397	0.379	0.397	0.273	0.517	0.367	0.416	0.341	0.387	0.429	0.346
Provision Method of Road Hologram	Text	-1.323	-1.324	-1.308	-1.371	-1.457	-1.102	-1.418	-1.190	-1.184	-1.452	-1.273	-1.388
	Graph	0.430	0.409	0.537	0.456	0.431	0.408	0.547	0.436	0.297	0.539	0.498	0.513
	Text + Graph	0.892	0.915	0.771	0.915	1.027	0.683	0.871	0.754	0.888	0.913	0.775	0.875
Information Provision Medium	Digital signage	0.626	0.590	0.507	0.472	0.693	0.477	0.530	0.432	0.605	0.618	0.466	0.519
	Road hologram	-1.374	-1.250	-1.239	-1.312	-1.292	-1.383	-1.294	-1.222	-1.273	-1.376	-1.232	-1.300
	Using both	0.749	0.660	0.732	0.841	0.599	0.906	0.764	0.790	0.668	0.758	0.765	0.782

overall preference was similar or lower for dynamic information than static information. The preference rankings for information provision media did not vary between user characteristics for either static or dynamic information, and only a minor difference in the utility value was observed.

4.5 Traffic Information Provision Measure Considering User Preference on Information

As inferred from the preceding discourse, the diversification in driver attribute preferences becomes apparent contingent upon the type of the conveyed information (See Table 6). In instances of dynamic information provisioning, a consistent pattern emerges across all instances: a discernible predilection towards the simultaneous conveyance of textual and graphical data via both road hologram and digital signage mediums. This finding aligns with previous studies which indicated that drivers prefer receiving traffic information related to specific situations, such as abnormal traffic conditions, using a combination of text and graphical elements (Park et al., 2009; Zhao et al., 2019). Additionally, similar to Zhao et al. (2019), a lower preference for information composed solely of text was observed. Furthermore, this study reflects a preference for road hologram, indicating that the preference for road hologram-based information provision is lower than traditional text-based VMS.

In contrast, when receiving static information, variations in preference are observed in both the information provision medium and the provision method of digital signage. Among the group under the age of 40, a preference was observed for receiving information solely through digital signage, with a particular inclination towards graph-only information provision within the digital signage framework. Furthermore, female drivers and those engaged in work-related trips similarly exhibited a preference for exclusive graph-based information provision. This preference is indicative of a propensity towards simplified modes of information dissemination within the static information domain.

These findings engender the paramount importance of customizing information dissemination methodologies consonant with content characteristics and target demographics, thereby harmonizing with the distinctive preferences of diverse driver cohorts across specific situational contexts.

5. Conclusions

Traffic information helps drivers make decisions regarding trip planning, detour routes, and emergency responses. Traffic information provision strategies have become extremely varied due to advancements in related technologies such as smart street poles. Thus, traffic information can now be delivered in diverse forms, including holograms. In this study, we examined user preferences according to user characteristics (gender, age, trip purpose) by performing a conjoint analysis on traffic information using digital signage and road surface holograms, which is a new type of information provision media. Furthermore, information is distinguished into static and dynamic information, as the information required in general situations differs from unexpected situations, such as the appearance of dangerous objects. An analysis was performed by dividing the types of information according to these situations.

Based on user characteristics, the conjoint analysis revealed a prevailing preference for a combined approach involving digital signage and road surface holograms, featuring both text and graph formats in most cases. However, certain distinctions were identified in specific cases, particularly concerning situations where static information was provided. Notably, disparities emerged in the provision device choice under the “under 40s” demographic, with a preference for graph-based expression via digital signage. Similarly, variations were evident in the provision method of digital signage, particularly among female participants, those under 40 years old, and individuals on work-related trips, who favored the graph format.

These findings have revealed that preferences for information vary based on the type of information and the characteristics of the drivers. This underscores the inefficiency of employing a standardized information delivery approach in transportation systems, emphasizing the need to adopt diverse information provision methods based on the nature of the information. When delivering dynamic information, road operators can enhance the effectiveness of information dissemination by offering a combination of digital signage and road holograms, presented in both text and graph formats. This conjecturally aligns with the idea that drivers seek more specific information in unusual road situations.

Also, the noteworthy preference for utilizing road holograms should not be overlooked. With the exception of a case: under 40s in static information, a majority of scenarios demonstrated a preference for combining road holograms with digital signage, rather than relying solely on digital signage. However, the solitary preference for road hologram usage alone was notably low, with an evident inclination toward the combined approach involving both text and graph formats. These outcomes underscore the necessity for research into information provision using road holograms, a previously underutilized information provision device. The implications of these findings emphasize the value of utilizing road holograms for information provision and underscore the need for further investigation in this relatively unexplored area.

Through the result of study, future traffic information system should be capable of providing information tailored to individual preferences and characteristics considering the significant diversity in driver preferences. Depending on the characteristics of age, gender, and driving purpose, it may be difficult to apply customized changes to the information provision method in real time in the actual road environment. However, as revealed in this study, differences in road users' information preferences for dynamic and static situations may be applicable. In a general road environment, an information provision method that reflects the characteristics of static information is used, and when an accident or incident occurs on the road, a strategy can be adopted to change the information provision method within the area of influence.

A significant contribution of this study is that we estimated a driver's preference function for various media for both static and dynamic information based on preference data obtained through a conjoint analysis, and developed operation plans based on the results. However, the current study has some limitations and conducted a preference survey for selected information types in a large framework; therefore, a follow-up study is required. First, driver's preference on information may change depending on circumstances; time of day, weather abnormality, under interrupted flow or uninterrupted flow, number of lanes, regional characteristics. The specific analysis in each of the aforementioned situations is an important point that should be analyzed although not covered in this study. Thus, future research might explore a more detailed environment before introducing the proposed operation plans with different road characteristics. Another limitation of this study lies in the composition of the sample. In future research, addressing this is vital. When introducing new technology for information dissemination, future studies should meticulously craft a sample that truly mirrors the population, ensuring a lack of bias. Understanding that user characteristics can vary significantly based on the introduction area of the technology, upcoming research must take this variability into account and tailor the study accordingly. While our study provided valuable insights through a simulated setting, it's crucial to conduct real-world testing to validate the findings. This would involve deploying smart street poles with the preferred information provision methods and assessing driver satisfaction and safety outcomes. Real-world testing can help bridge the gap between simulated experiments and practical implementation.

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Appendix

Static Information

Static information refers to the conventional road signs seen in daily life, conveying details about road structures, facilities, and navigation methods. This encompasses **structural information** such as tunnels and bridges, navigational instructions like one-way traffic and no-left-turn signs, and cautionary notices such as alerts for school zones.

Static information corresponds to the familiar traffic safety signs we encounter, conveying information that remains **constant** and **unchanging**.

The approaches for providing static information can be categorized broadly into three combinations: hologram alone, signage alone, and a combination of hologram and signage. These approaches offer information through text-based, shape-based, and combined text-and-shape methods. Please select the combinations below in order of their ease of comprehension and preference.

Question 1.

Please select the preferred order among the **medium of providing static information**

[Road Hologram] **[Digital Signage]** **[Road holgram + Digital Signage]**

Question 2.

Please select the preferred order among the **expression format by road hologram**

[Graph]

[Text]

[Graph+Text]

Question 3.

Please select the preferred order among the **expression format by digital signage**

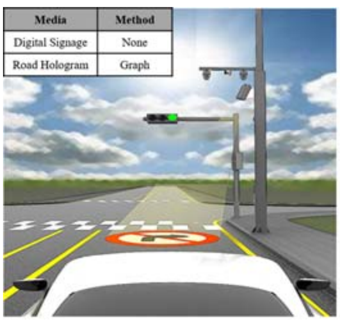
[Graph]

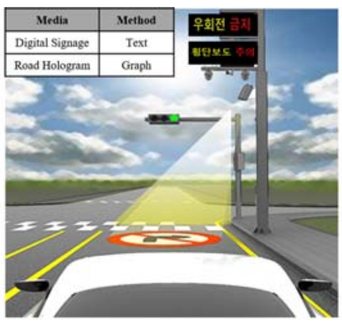
[Text]

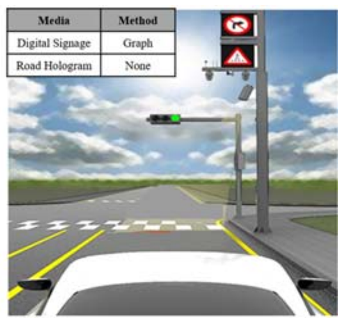
[Graph+Text]

Question 4-1.

Please select the preferred order among the **Picture**

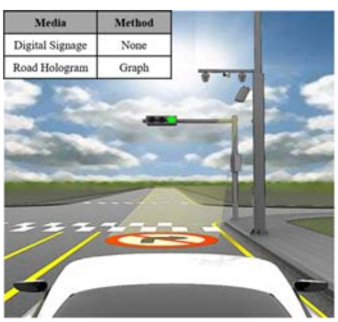


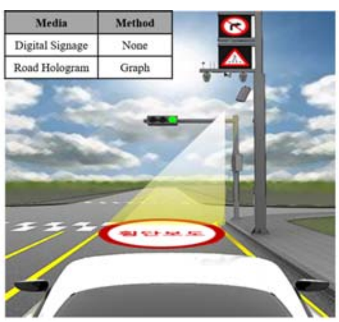




Question 4-2.

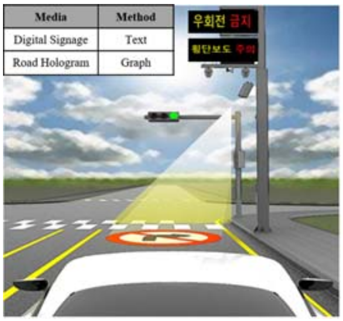
Please select the preferred order among the **Picture**





Question 4-3.

Please select the preferred order among the **Picture**



Question 4-4.

Please select the preferred order among the **Picture**