Fuzzy-AHP를 이용한 화물자동차의 교통안전 대책에 관한 연구

A Study on the Safety Policies of Truck Traffic Using Fuzzy-AHP

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요 약

최근 화물자동차 통행량이 증가함에 따라 도로가 더욱 혼잡해지고 사고 위험도도 높아지고 있는 추세이다. 화물자동차로 인한 교통사고 치사율은 승용차와 승합차에 비해 약 2~3배로 높은 상황으로 화물자동차 교통안전에 대한 대책 마련이 시급한 상황이다. 기존 연구들이 대부분 교통사고에 영향을 미치는 요인 분석에 집중하였다면, 본 연구에서는 운전자 설문조사 및 인터뷰, 관련 연구 등을 토대로 화물자동차의 교통안전을 위한 대책을 제시하였다. Fuzzy-AHP 방법론을 활용하여 안전대책 항목을 대분류 4개, 소분류 12개로 설정하고, 항목 간의 우선순위를 평가하였다. 분석결과, 화물자동차 운전자의 근무환경 개선이 가장 중요한 것으로 도출되었으며, 도로 교통환경 개선이 그 뒤를 이었다. 세부적으로는 화물자동차 운임제도 개선, 운전자의 충분한 휴식 보장, 도로변 불법 주정차 단속 강화 등이 시급한 것으로 나타났다. 본 연구는 향후 지속적 증가한 화물자동차 통행에 대비한 안전정책 마련을 위해 활용될 수 있을 것으로 기대된다.

핵심어 : 화물자동차 교통안전, 안전대책, Fuzzy-AHP, 우선순위 분석

ABSTRACT

With the increase of truck traffic, roads are becoming more congested and the risk of accidents is also increasing. Since the fatality rate of traffic accidents caused by trucks is about 2 to 3 times higher than that of passenger cars and buses, it is urgent to prepare policies for truck traffic safety. While most of the previous studies focused on factor analysis that contributes to traffic accidents, this study presented traffic safety policies (4 major-criteria and 12 sub-criteria) for trucks through driver interviews and previous studies. Then, the priority of the policies was evaluated by using Fuzzy-AHP. As a result, the improvement of truck drivers' working environment was evaluated as the most important criteria, and followed by the improvement of road traffic conditions. In detail, there is an urgent need to improve the freight car fare system, ensure sufficient rest for drivers, and strengthen the crackdown of illegal parking and stopping along roads. This study is expected to be usefully utilized in preparing traffic flow safety policies in preparation for the continuous increase of truck traffic.

Key words : Truck traffic safety, Safety policy, Fuzzy-AHP, Priority analysis

Ⅰ. Introduction

With economic growth, the Korean freight transport market has been developed rapidly. As 90% of the freight takes place in the road sector, the truck traffic volume has increased continuously. According to KTDB (Korea Transport Data Base), The O/D traffic volume of trucks increased from 4.45 million in 2017 to 4.46 million in 2020. With the increase of truck transportation, the problem of truck traffic safety has become an inevitable social issue. Compared to other vehicle types, truck traffic accident has a high risk of personal injury (Lee et al., 2016). The fatality rate(number of deaths per 100 traffic accidents) of truck accidents in Korea shows 2.79 in 2019, which was much higher than that of other vehicle types (bus: 1.47, passenger car: 1.04). Since Korea's traffic safety index (number of deaths due to traffic accidents per 100 thousand population) was at a low level (29th, 2018) among the 36 OECD (Organisation for Economic Co-operation and Development) countries (KoROAD, 2021), the Korean government is contemplating various policies to prevent the traffic accidents such as the policy of 'Safety Speed 50-30' and 'Rest time guarantee of truck drivers'. However, it is necessary to prepare safety policies efficiently.

Previous studies in truck traffic accidents mostly focused on verifying which factors contribute to the traffic accidents. The ADT(Average Daily Traffic)(Lee et al., 1998; Park et al., 2007; Park et al., 2013; Castillo-Manzano et al., 2016), number of lanes(Lee et al., 1998; Kim et al., 2012; Park et al., 2013), slope(Kim et al., 2000; Park et al., 2007), climatic conditions(Lee et al., 2000; Lankarani et al., 2014; Hammad et al., 2019), etc were mentioned as the impact factors frequently. Some researchers suggested preventive measures based on the factor analysis results. Chae and Ko(2008) identified the causes of truck accidents through truck operation status and survey and suggested improvement measures such as improvement of drowsy driving, improvement of speeding driving, and improvement of overload driving. Choi et al.(2014) applied a binary logistic regression technique to identify causal factors affecting truck crash severity on highways under normal and adverse weather conditions and presented that the variable speed limit (VSL) strategy and the improvement of lighting conditions should be considered for truck traffic safety on the highways. Yoo and Kim(2018) analyzed the characteristics of truck traffic accidents and stated that improvement policies should include sufficient rest to prevent overwork and drowsy driving, and the establishment of advanced vehicle safety devices to prevent dangerous driving. Similar to the above studies, many studies suggest truck traffic safety policies through factors analysis of truck traffic accidents. However, most studies focus on factors that show statistically significant results, the researches engaged in systematic safety policies of truck traffic are insufficient.

There are two studies were found as the representative studies which have discussed the truck traffic safety policies deeply. Chae(2007) analyzed the prevention for accidents of heavy-duty trucks and proposed 2 parts (employer and publication) for preventing the accidents. Adequate rest time, installation of advanced IT technology, more convenient working conditions for truck drivers were suggested. Lee et al.(2016) presented the truck traffic safety policies in 4 parts. First, the transportation companies have responsibilities to promote the mandatory recruitment of traffic safety management personnel and endeavor to guarantee mandatory breaks after continuous driving. Second, the realization of an overloaded crackdown system and reinforced punishment for drivers and shippers needed to be implemented. It is also necessary to actively introduce and review the implementation of the on-road inspection system to improve the effectiveness of road control and administrative execution. Third, there is necessary to enhance the education programs for drivers who have experienced traffic accidents and elderly drivers

at truck drivers' oligopoly. Additionally, special aptitude tests for traffic accidents, repeat violators of traffic safety laws, and elderly truck drivers should be diversified. Fourth, specific regulations on the age of the trucks should be introduced. Deteriorated trucks are likely to experience serious problems such as braking disorders in emergencies. Also, the scope of trucks subject to mandatory attachment to rear reflectors should be expanded due to a large number of nighttime operations.

The previous studies mostly focused on the factor analysis of truck traffic accidents and presented the safety policies based on the significant factors. However, there is insufficient research to comprehensively present safety policies that can improve truck traffic safety from an expert's perspective. In addition, the government is preparing many systems for truck traffic safety, and it will be necessary to compare and analyze the importance of safety measures in the implementation of the system. This study reviews domestic truck traffic safety policies widely and analyzes priorities among truck traffic safety policies by conducting Fuzzy-AHP (Analytic Hierarchy Process) for experts. This study can be utilized as a meaningful reference for drivers, employers, and government institutions in establishing strategies to improve truck traffic safety and prepare excellent traffic environments in the future.

Ⅱ. Korean Truck Traffic Accident Statistics and Policies

1. Korean traffic safety

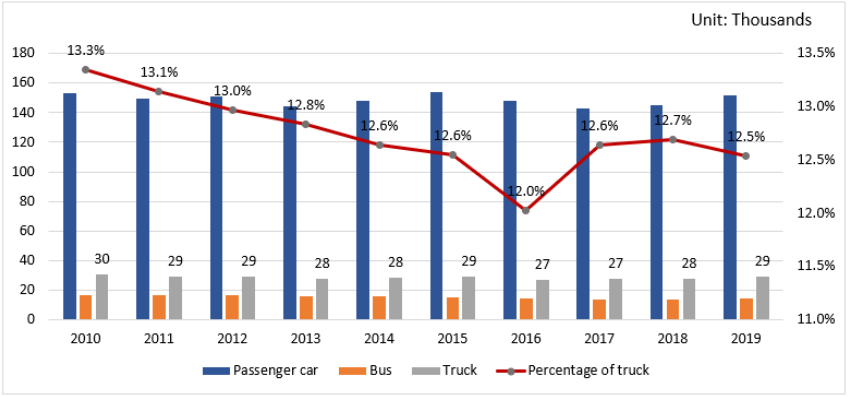
According to the National Police Agency of Korea, among OECD countries in 2019, the number of deaths in traffic accidents per 10,000 automobiles in Korea was 1.2, which was the same as the United States. However, this index was four times higher than Sweden's 0.3. The number of deaths per 100,000 people caused by traffic accidents in Korea was 6.5, higher than the OECD average of 5.2, and 2.4 times higher than Sweden's 2.2. It can be found that Korea has more serious traffic safety problems than other developed countries <Table 1>.

<Table 1> Traffic safety status in major OECD countries (2019)

Section	Korea	UK	Germany	United States	France	Australia	Sweden	Japan	OECD average
The number of deaths in traffic accidents per 10,000 automobiles	1.2	0.5	0.5	1.2	0.7	0.8	0.3	0.4	0.9
The number of deaths per 100,000 people caused by traffic accidents	6.5	2.7	3.6	11.0	5.0	4.7	2.2	3.1	5.2

Source: National Police Agency, 2020

Traffic accidents were mostly caused by passenger cars. According to the data analysis of recent decade, the number of traffic accidents caused by passenger car has not appeared to be decreasing. The number of truck traffic accidents did not show a decreasing trend either. Furthermore, the percentage of truck traffic accidents in 2010 was 13.3% the highest during the past decade. In 2016, it had dropped to the lowest by 12.0%. Nevertheless, it increased from 2017 rapidly. Overall, the percentage of truck traffic accidents seems between 12.5% and 13.0% <Fig. 1>.



<Fig. 1> Traffic Accidents Trend

Source: KoROAD, 2020

2. Truck safety policies

Recognizing the importance of traffic safety, the Korean government has made great efforts. According to the news release of public institutions, truck safety policies currently in effect can be divided into three categories. The first is to strengthen the crackdown and punishment for illegal behaviors, the second is to foster a safe driving culture for truck drivers, and the third is to improve the working environment. The crackdown and punishment for illegal behaviors such as the non-installation of speed limiters and defective loading are being strengthened. Fines are imposed on trucks that violate habitual violations and are temporarily excluded from the late-night discount on highways. Fostering a safe driving culture for truck drivers is mainly implemented through the improvement of education programs and safety campaigns. Incentives such as rewards and insurance premium discounts are provided to excellent drivers for safe driving. The improvement of the work environment for truck drivers is representative such as the regulation to take a 15-minute break after two consecutive hours of driving to ensure the driver's rest time, strengthen vehicle safety inspections, and improve the safety fare system.

In addition to the current policies, the government is also establishing plans for future truck traffic safety with high technology devices. For example, the government is planning to install an advanced overload control system that applies AI technology to highways in stages. By 2024, it is planned to be installed on all highways across the country. In addition, it plans to expand 60 sleeping lounges in service areas and garages by 2023 for truck drivers to get enough rest. It is planning to test drive a detection sensor device that can warn trucks of drowsy driving in 2022. It can be seen that truck traffic safety measures are gradually shifting from strengthening crackdown on illegal activities to promoting driver convenience.

Ⅲ. Fuzzy-AHP Methodology

The Analytic Hierarchy Process (AHP) is a powerful method to solve complex decision problems. Any complex problem can be decomposed into several sub-problems using AHP in terms of hierarchical levels where each level represents a set of criteria or attributes relative to each sub-problem (Sun, 2010). The AHP method is a multicriteria

method of analysis based on an additive weighting process, in which several relevant attributes are represented through their relative importance. AHP has been extensively applied by academics and professionals, mainly in engineering applications involving financial decisions associated with non-financial attributes (Saaty, 1996). Through AHP, the importance of several attributes is obtained from a process of paired comparison, in which the relevance of the attributes or categories of drivers of intangible assets is matched two-on-two in a hierarchic structure.

However, the AHP method creates and deals with a very unbalanced scale of judgment and does not take into account the uncertainty associated with the mapping of human judgment to a number by natural language (Sun, 2010). Even if a certain number is the same among decision-makers, it is unable to treat that the opinions of actual decision-makers are the same. Therefore, when using the hierarchical analysis method, the problem of being unable to handle ambiguity and uncertainty due to limitations of mathematical theory as well as inaccuracy of expression caused by the limitation of the expression method cannot be avoided. Therefore, there is a need for a method that can systematically reflect ambiguity and uncertainty in the decision-making process. To overcome these problems, several researchers integrate fuzzy theory with AHP to improve the uncertainty. Buckley(1985) used the evolutionary algorithm to calculate the weights with the triangular fuzzy numbers (Fig. 2). The fuzzy AHP is based on the triangular fuzzy numbers and confidence index with a geometric mean approach to determine the weights for evaluative elements.

The fuzzy number can be calculated as follows:

- Addition of the fuzzy number $\oplus$:

$$\widetilde{A_1} \oplus \widetilde{A_2} = (l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad \cdots\cdots (1)$$

where $\widetilde{A_1}$ is the first fuzzy set 1, and $\widetilde{A_2}$ is the second fuzzy set.

- Multiplication of the fuzzy number $\otimes$:

$$\widetilde{A_1} \otimes \widetilde{A_2} = (l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 l_2, m_1 m_2, u_1 u_2) \text{ for } l_1, l_2, m_1, m_2, u_1, u_2 > 0 \quad \cdots\cdots (2)$$

- Subtraction of the fuzzy number $\ominus$:

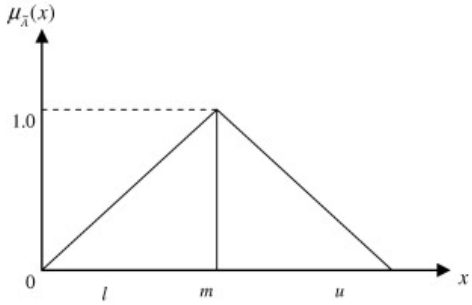
$$\widetilde{A_1} \ominus \widetilde{A_2} = (l_1, m_1, u_1) \ominus (l_2, m_2, u_2) = (l_1 - l_2, m_1 - m_2, u_1 - u_2) \quad \cdots\cdots (3)$$

- Division of a fuzzy number $\oslash$:

$$\widetilde{A_1} \oslash \widetilde{A_2} = \frac{(l_1, m_1, u_1)}{(l_2, m_2, u_2)} = \left(\frac{l_1}{l_2}, \frac{m_1}{m_2}, \frac{u_1}{u_2}\right) \text{ for } l_1, l_2, m_1, m_2, u_1, u_2 > 0 \quad \cdots\cdots (4)$$

- Reciprocal of the fuzzy number:

$$\widetilde{A}^{-1} = (l_1, m_1, u_1)^{-1} = \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right) \text{ for } l_1, l_2, m_1, m_2, u_1, u_2 > 0 \quad \cdots\cdots (5)$$



<Fig. 2> Triangular fuzzy number

The Fuzzy-AHP analysis includes the following steps:

(Step 1) Construct pairwise comparison matrices among all the elements/criteria in the dimensions of the hierarchy system. Assign linguistic terms to the pairwise comparisons by asking which is the more important of each two dimensions, as the following matrix $\widetilde{A}$, and a 9-item ranking scale is suggested as <Table 2>.

$$\widetilde{A}=\begin{bmatrix} 1 & \widetilde{a_{12}} & \cdots & \widetilde{a_{1n}} \\ 1/\widetilde{a_{12}} & 1 & \cdots & \widetilde{a_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\widetilde{a_{1n}} & 1/\widetilde{a_{2n}} & \cdots & 1 \end{bmatrix} \quad \cdots\cdots (6)$$

$$where \quad \widetilde{a}_{ij}=\left\{\widetilde{9}^{-1},\widetilde{8}^{-1},\widetilde{7}^{-1},\widetilde{6}^{-1},\widetilde{5}^{-1},\widetilde{4}^{-1},\widetilde{3}^{-1},\widetilde{2}^{-1},\widetilde{1}^{-1},\widetilde{1},\widetilde{2},\widetilde{3},\widetilde{4},\widetilde{5},\widetilde{6},\widetilde{7},\widetilde{8},\widetilde{9}\right\}$$

<Table 2> Numerical rating in Fuzzy-AHP method

Meaning	AHP Scale	Triangular Fuzzy-AHP Scale
Equal	1	1, 1, 1
Weak advantage	2	1, 2, 3
Not bad	3	2, 3, 4
Preferable	4	3, 4, 5
Good	5	4, 5, 6
Fairly good	6	5, 6, 7
Very good	7	6, 7, 8
Absolute	8	7, 8, 9
Perfect	9	9, 9, 9

(Step 2) Use a geometric mean technique to define the fuzzy geometric mean and fuzzy weights of each criterion;

$$\widetilde{r_i}=(\widetilde{a_{i1}}\otimes\cdots\otimes\widetilde{a_{ij}}\otimes\cdots\otimes\widetilde{a_{\in}})^{1/n} \quad \cdots\cdots (7)$$

$$\widetilde{w_i}=\widetilde{r_i}\oplus\left[\widetilde{r_1}\oplus\cdots\oplus\widetilde{r_i}\oplus\cdots\oplus\widetilde{r_n}\right]^{1/n} \quad \cdots\cdots (8)$$

Where $\widetilde{a}_{ij}$ is fuzzy comparison value of dimension i to criterion j, thus, $\widetilde{r}_i$ is a geometric mean of fuzzy comparison value of criterion to each criterion, $\widetilde{w}_i$ is the fuzzy weight of the i^{th} criterion, can be indicated by a TFN, $\widetilde{w}_i=(lw_i,mw_i,uw_i)$. The lw_i, mw_i, and uw_i stand for the lower, middle, and upper values of the fuzzy weight of the i^{th} dimension.

(Step 3) The priority weight of the options derived from the pairwise comparison matrix is calculated by the following equation;

$$\widetilde{A_w}=\lambda_{\max}\widetilde{w}, \quad \widetilde{w}=(\widetilde{w}_1,\widetilde{w}_2,\cdots\widetilde{w}_n)^T \quad \cdots\cdots (9)$$

where $\widetilde{A}$ is a dimensional comparison matrix, $\lambda_{\max}$ is the largest eigenvalue of $\widetilde{A}$ and $\widetilde{w}$ is the eigenvector corresponding to $\widetilde{A}$.

(Step 4) In AHP, a consistency index (CI) is defined to measure the inconsistencies in the pairwise comparison matrix $\widetilde{A}$;

$$CI. = \frac{\lambda_{\max} - n}{n-1} \quad \cdots\cdots (10)$$

Accordingly, the consistency ratio $CR.$ is used to measure the degree of $CI.$ by the following equation:

$$CR. = \frac{CI.}{RI.} \quad \cdots\cdots (11)$$

In order to determine the inconsistency, RI (Random Index) is required. This study presents a RI by an order of 1~15 as <Table 3>. If $CR.$ < 0.10, the inconsistency degree of the comparison matrix $\widetilde{A}$ is considered acceptable and the eigenvector $\widetilde{w}$ is used as the weighting vector after normalization. Otherwise, the comparison matrix would need to be adjusted.

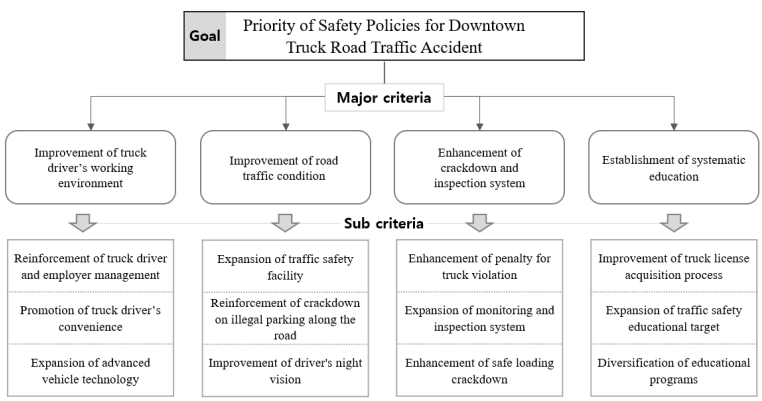
<Table 3> Random Index

Order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49	1.52	1.54	1.56	1.58	1.59

Ⅳ. Priority Analysis of Truck Traffic Safety Policies

1. Fuzzy-AHP structure

This study presents the safety policies for truck traffic into 4 major criteria and 12 sub-criteria. For the selection of factors, 4 major criteria were first determined through prior research. The appropriateness of the 4 major criteria was secured through expert interviews. In addition, the setting of sub-criteria was carried out by considering truck drivers' survey and previous studies comprehensively. For example, in the driver survey, 'Reinforcement of crackdown on illegal parking along the road' was given as a necessary factor. Furthermore, during the investigation process of Fuzzy-AHP, the pieces of advice of experts were conflicted. Through this process, the appropriateness of the survey items was secured. The Fuzzy-AHP structure is shown as <Fig. 3>: (1) Improvement of truck driver's working environment; (2) Improvement of road traffic condition; (3) Enhancement of crackdown and inspection system; (4) Establishment of systematic education.



<Fig. 3> Fuzzy-AHP structure

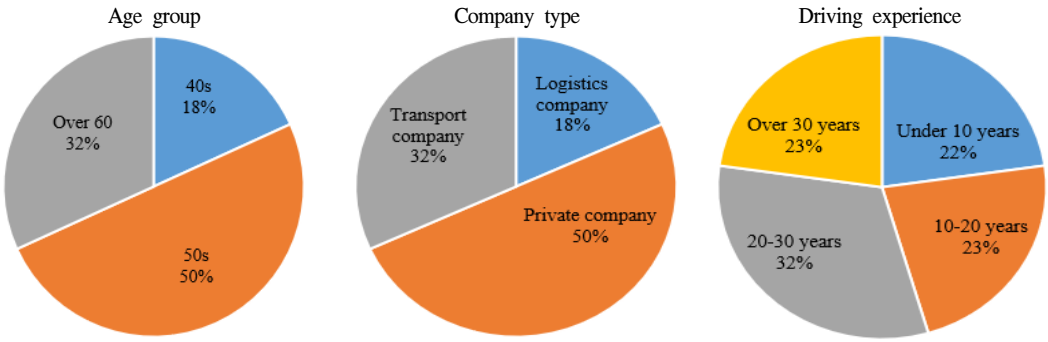
Some of the criteria such as ‘Reinforcement of truck driver and employer management’, ‘Promotion of truck driver’s convenience’, ‘Expansion of advanced vehicle technology’, ‘Expansion of traffic safety facility’, etc. have been suggested based on the literature review (Table 4). However, it is necessary to suggest improvement plans related to the causes of truck traffic accidents to ensure the rationality of the Fuzzy-AHP criteria. Therefore, this study surveyed truck drivers who caused traffic accidents and reflected the survey results in the Fuzzy-AHP criteria.

<Table 4> Definition of criteria

Sub-criteria	Reference	Definition
Reinforcement of truck driver and employer management	Chae(2007) Lee et al.(2016)	• Expanding the incentives (e.g., tax reduction, bonus) for employers and drivers with excellent safety traffic (no accidents & no violations) (Status: maximum 5 million won in prize money for excellent truck drivers) • Enhancing the monitoring of schedule to secure that truck drivers obey the regulation of continuous driving time (15-minute break for 2 hours continuous driving)
Promotion of truck driver’s convenience	Chae(2007) Lee et al.(2016)	• Expanding the convenient facilities (e.g., rest areas, truck parking lots) to reduce driver fatigue • Installing a truck-only lane on important logistics connecting road (arterial road and service road)
Expansion of advanced vehicle technology	Lee et al.(2016)	• Expanding the prevalence of advanced safety devices such as driver state warning (DSW), lane departure warning system, and driving recorder (DTG)
Expansion of traffic safety facility	Chae(2007) Park et al.(2007) Lee et al.(2016)	• Installing warning signs, antislip, and lane painting in hazardous truck traffic areas
Reinforcement of crackdown on illegal parking along the road	Driver survey	• Reinforcing the parking and stopping control in the areas with congested traffic (e.g., round-trip two lanes, intersections)
Improvement of driver’s night vision	Driver survey Lee et al.(2016)	• Promoting the replacement of high-illumination streetlights for obsolete streetlights • Installing high-brightness reflective signs for hazardous areas such as intersections
Enhancement of penalty for truck violation	Chae(2007) Lee et al.(2016)	• Enhancing the penalties (fines and demerit) for violations of truck traffic laws.
Expansion of monitoring and inspection system	Lee et al.(2016)	• Investing in radar trap and patrol police the road with heavy truck traffic
Enhancement of safe loading crackdown	Lee et al.(2016)	• Reinforcing the inspections for dangerous behaviors such as overloading and irrational load-fixing
Improvement of truck license acquisition process	Chae(2007) Lee et al.(2016)	• Strengthening the traffic safety education in the process of obtaining a driver’s license
Expansion of traffic safety educational target	Lee et al.(2016)	• Mandatory traffic safety education for drivers with less than 40 points due to violations of general traffic laws and accidents
Diversification of educational programs	Driver survey Chae(2007) Lee et al.(2016)	• Promoting the diversification of training programs according to driver characteristics (e.g., inexperienced driver, Accident Hazard driver, habitual violator, older driver)

A total of 22 truck drivers who took the education of driving in Korea Transportation Safety Authority on the 30th of March, the 26th of April, and the 8th of June in 2021 were surveyed. All of the 22 drivers were male,

50% of the drivers were in the 50s, 50% of drivers were working in a private company. The max, min, and average driving experience were 35 years, 4 years, and 20 years <Fig. 4>.



<Fig. 4> Driver personal information

There were 7 fatal, 9 seriously injured, and 6 slightly injured accidents in the total 22 surveyed accidents. The driving experience, continuous driving time, and the behavior causes were conducted whether affecting the severity of truck traffic accidents. In terms of driving experience, the drivers with driving experience under 10 years had 3 fatal and 2 seriously injured without slightly injured accidents. Compare to other groups, it suggested that inexperienced truck drivers are more likely to cause fatal accidents. In the continuous driving time part, with the continuous driving time growth, the proportions of fatal and seriously injured accidents increase (Table 5).

In the 22 accidents, ‘Personal careless driving’ was indicated as the main cause by 12 drivers. Forward and backward distraction, such as using a mobile phone while driving, always leads to serious traffic accidents. 4 drivers claimed that the main cause was the difficulty in ensuring the visual distance in the nighttime. Due to the narrower range of vision, especially on unlighted roads, drivers can only see the range of the headlights 100m upward and 40m downward which makes it late to find pedestrians or dangerous objects (Road Traffic Authority Driver’s License Examination Office). Other causes of fatal accidents were ‘Drowsiness/fatigue driving due to heavy work’ and ‘Lack of awareness of related traffic regulation’.

Several implications can be drawn from the results of the survey of truck drivers who have experienced traffic accidents. Based on the implications, the Fuzzy-AHP investigation criteria could be supplemented. A differentiated education program should be prepared to improve the traffic safety of drivers who have short driving experience. In addition, the need for improvement measures is also explained because there are many cases where it is difficult to secure visibility due to illegal parking on the side of the road in the investigation, which causes traffic accidents. Personal careless driving and difficulty in securing visibility during night driving are investigated as major causes, so it will be necessary to promote educational programs that can improve awareness of safe driving culture and installation of facilities that can provide convenience for night driving. Through these implications, the Fuzzy-AHP investigation criteria of this study were further reinforced.

<Table 5> Main causes of truck accidents

Section		Severity of accidents						Total
		Fatal		Seriously injured		Slightly injured		
Driving experience	Under 10 years	3	60%	2	40%	0	0%	5
	10-19 years	1	20%	3	60%	1	20%	5
	20-29 years	1	14%	3	43%	3	43%	7
	Over 30 years	2	40%	1	20%	2	40%	5
Total		7	32%	9	41%	6	27%	22
Continuous driving time	Under 1 hour	2	22%	3	33%	4	44%	9
	1-2 hours	2	33%	3	50%	1	17%	6
	Over 2 hours	3	43%	3	43%	1	14%	7
Total		7	32%	9	41%	6	27%	22
Behavior causes	Personal careless driving	3	25%	6	50%	3	25%	12
	Invisible at night	2	50%	0	0%	2	50%	4
	Drowsiness/fatigue driving due to heavy work	1	33%	1	33%	1	33%	3
	Lack of awareness of related traffic regulation	1	33%	2	67%	0	0%	3
Total		7	32%	9	41%	6	27%	22

2. Fuzzy-AHP analysis result

Fuzzy-AHP surveys were implemented to 16 experts including 4 managers of the transport company (experience of over 15 years), 6 truck drivers (experience of over 15 years), 4 professors (experience of over 20 years), 2 traffic safety authority staff (experience of over 10 years) from 20 April to 14 May 2021. The average experience of the experts is over 20 years which ensures that the result is reliable. In order to ensure the consistency of the questionnaire, a re-examination of the questionnaire with a consistency index higher than 0.10 was requested during the survey process. The detailed result of inconsistency is shown as in <Table 6>.

<Table 6> Inconsistency result

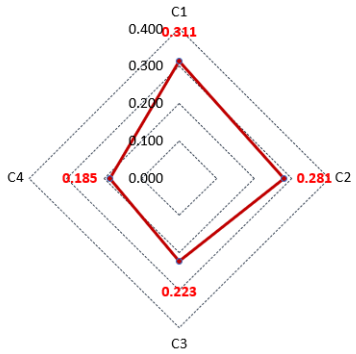
Experts	Manager				Truck driver						Professor				TS staff		Combined
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Inconsistencies	0.05	0.07	0.07	0.01	0.09	0.09	0.10	0.04	0.02	0.04	0.06	0.03	0.05	0.08	0.09	0.07	0.002

1) Main criteria

According to the opinion of 16 experts, in the major criteria (Table 7), ‘Improvement of truck drivers’ working environment’ (0.311) is the most important criteria. ‘Improvement of road traffic conditions’ shows an importance index of 0.281 and ranks 2nd important criteria. ‘Enhancement of crackdown and inspection system’ (0.223) and ‘Establishment of systematic education’ (0.185) are evaluated as the less important criteria. To improve truck traffic safety in Korea, truck drivers’ working environment and road traffic conditions should be improved fundamentally.

<Table 7> Fuzzy-AHP result of major criteria

Inconsistency: 0.001

Major criteria		Importance	
C1	Improvement of truck drivers' working environment	0.311	
C2	Improvement of road traffic conditions	0.281	
C3	Enhancement of crackdown and inspection system	0.223	
C4	Establishment of systematic education	0.185	
Total		1	

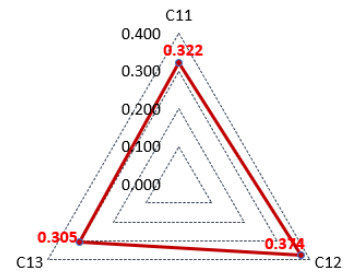
2) sub-criteria

- Improvement of truck drivers' working environment

In the local importance of 'Improvement of truck drivers' working environment', 'Promotion of truck drivers' convenience' is analyzed as the most important sub-criteria of 0.374. 'Reinforcement of truck driver and employer management' (0.322) ranks 2nd. 'Expansion of advanced vehicle technology' (0.305) is the least important sub-criteria. Expanding the convenient facilities (e.g., rest areas, truck parking lots) to reduce driver fatigue has to be promoted urgently.

<Table 8> Fuzzy-AHP result of sub-criteria.1

Inconsistency: 0.001

Sub-criteria		Importance	
C11	Reinforcement of truck driver and employer management	0.322	
C12	Promotion of truck drivers' convenience	0.374	
C13	Expansion of advanced vehicle technology	0.305	
Total		1	

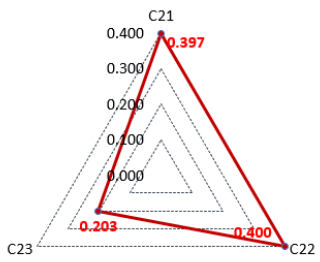
- Improvement of road traffic conditions

In the 'Improvement of road traffic conditions' section, 'Reinforcement of crackdown on illegal parking along the road' (0.400) is carried out as the most important sub-criteria. ' Expansion of traffic safety facility' presents a similar number of 0.397. 'Improvement of drivers' night vision' (0.203) has low importance comparatively. The illegal parking and stopping in the areas with congested traffic (e.g., round-trip two lanes, intersections) obscure the

drivers' sight which has a high probability of making pedestrian accidents. So that reinforcement of crackdown on illegal parking along the road can improve traffic safety. Also, installing warning signs, antislip, and lane painting in hazardous truck traffic areas has to be promoted, either.

<Table 9> Fuzzy-AHP result of sub-criteria.2

Inconsistency: 0.008

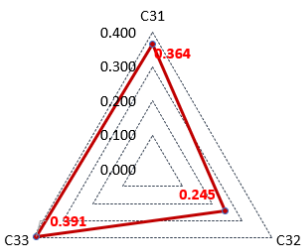
Sub-criteria		Importance	
C21	Expansion of traffic safety facility	0.397	
C22	Reinforcement of crackdown on illegal parking along the road	0.400	
C23	Improvement of drivers' night vision	0.203	
Total		1	

- Enhancement of crackdown and inspection system

An important order of 'Enhancement of safe loading crackdown' (0.391), 'Enhancement of penalty for truck violation' (0.364), and 'Expansion of monitoring and inspection system' (0.245) is presented in the part of 'Enhancement of crackdown and inspection system'. Trucks can cause serious accidents due to falling objects when overloading and irrational load-fixing. Enhancement of safe loading crackdowns can prevent truck traffic accidents.

<Table 10> Fuzzy-AHP result of sub-criteria.3

Inconsistency: 0.001

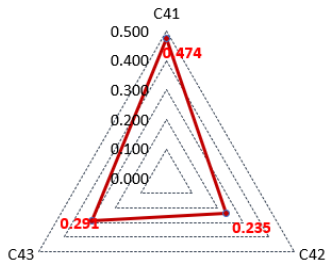
Sub-criteria		Importance	
C31	Enhancement of penalty for truck violation	0.364	
C32	Expansion of monitoring and inspection system	0.245	
C33	Enhancement of safe loading crackdown	0.391	
Total		1	

- Establishment of systematic education

In the local importance of 'Establishment of systematic education', 'Improvement of truck license acquisition process' is analyzed as the most important subcriteria of 0.474. 'Diversification of educational programs' (0.291) and 'Expansion of traffic safety educational target' (0.235) are less important sub-criteria. According to the result, strengthening traffic safety education in the process of obtaining a driver's license is necessary to be improved to prevent truck traffic accidents.

<Table 11> Fuzzy-AHP result of sub-criteria.4

Inconsistency: 0.002

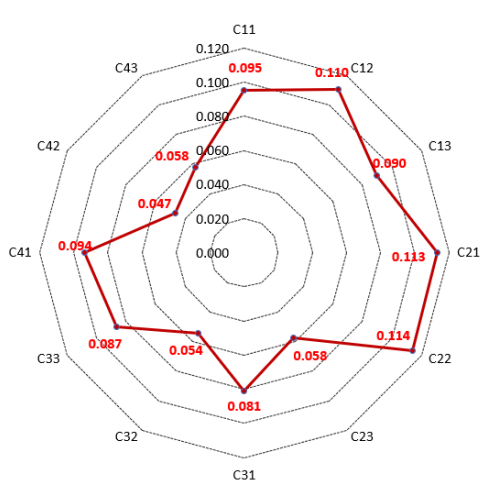
Sub-criteria		Importance	
C41	Improvement of truck license acquisition process	0.474	
C42	Expansion of traffic safety educational target	0.235	
C43	Diversification of educational programs	0.291	
Total		1	

3) Global priority result

The global priority of sub-criteria is as below. ‘Reinforcement of crackdown on illegal parking along the road’ (0.114) has the highest priority followed by ‘Expansion of traffic safety facility’ (0.113), ‘Promotion of truck drivers’ convenience’ (0.110). ‘Reinforcement of truck driver and employer management’ (0.095), and ‘Improvement of truck license acquisition process’ (0.094). In contrast, ‘Diversification of educational programs’ (0.058), ‘Improvement of drivers’ night vision’ (0.054), and ‘Expansion of traffic safety educational target’ (0.047) are suggested as having low priority. A lot of effort is required to secure truck traffic safety. However, according to the results derived from the AHP analysis, it is necessary to prioritize improving the drivers’ working conditions and road traffic environment.

<Table 12> Fuzzy-AHP result of global importance

Sub-criteria		Importance (rank)	
C11	Reinforcement of truck driver and employer management	0.095	(4)
C12	Promotion of truck drivers’ convenience	0.110	(3)
C13	Expansion of advanced vehicle technology	0.090	(6)
C21	Expansion of traffic safety facility	0.113	(2)
C22	Reinforcement of crackdown on illegal parking along the road	0.114	(1)
C23	Improvement of drivers’ night vision	0.058	(9)
C31	Enhancement of penalty for truck violation	0.081	(8)
C32	Expansion of monitoring and inspection system	0.054	(11)
C33	Enhancement of safe loading crackdown	0.087	(7)
C41	Improvement of truck license acquisition process	0.094	(5)
C42	Expansion of traffic safety educational target	0.047	(12)
C43	Diversification of educational programs	0.058	(10)
Total		1.000	

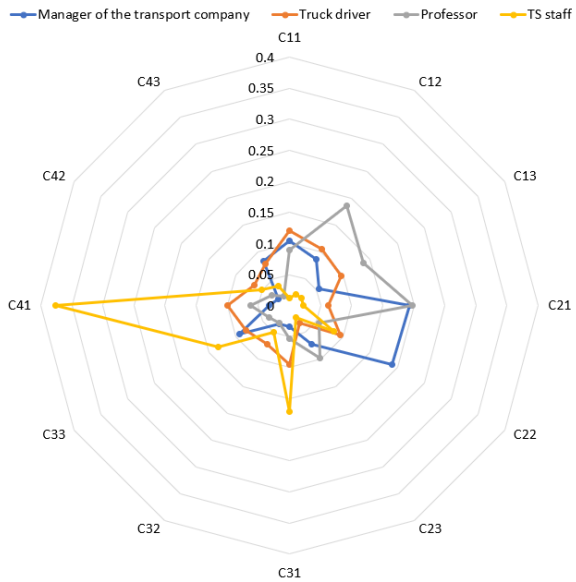


Inconsistency: 0.002

4) Comparison between groups

By grouping the experts in this study, the priority results of truck safety policies were further compared and analyzed. Through <Fig. 5>, it can be confirmed that the evaluation results of the TS staff are different from other groups. The TS staff gave the highest priority to the 'Improvement of truck license acquisition process'. However, there is a limitation that only two experts were surveyed. According to <Table 13>, the managers of the transport company and the professors evaluated 'Expansion of traffic safety facility' as the most important factor. And it can be seen that the parts corresponding to 'Improvement of road traffic conditions' and 'Improvement of truck drivers' working environment' are relatively important for both groups. For truck drivers, 'Reinforcement of truck driver and employer management' was analyzed as the most important factor, and the evaluation of 'Improvement of truck drivers' working environment' was generally high.

Due to the characteristics of the job, the priority evaluation results between groups are different. Workers in the field of safety education are more probably to regard education-related policies as important policies, and truck drivers will place more importance on improving the working environment. Nevertheless, the managers of the transport company and the professors suggested 'Improvement of road traffic conditions' and 'Improvement of truck drivers' working environment' as important policy directions. Recently, the government is also shifting to promoting driver convenience rather than strengthening enforcement to improve traffic safety, and this is in line with the results presented in this study.



<Fig. 5> Comparison between groups

However, since the TS staff has fewer people than other groups, this study recalculated the overall results by standardizing the survey results for each group. The results are similar to the results before standardization, as 'Improvement of truck drivers' working environment' and 'Improvement of road traffic conditions' are important major criteria. In the sub-criteria, 'Promotion of truck drivers' convenience' was the most important, followed by

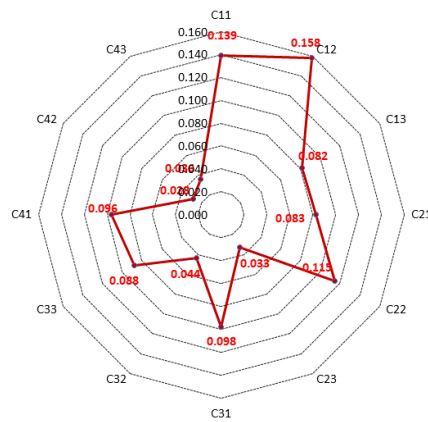
'Reinforcement of truck driver and employer management' and 'Reinforcement of crackdown on illegal parking along the road'. It can be found that the 'Expansion of traffic safety facility' has significantly decreased. The detailed results are shown in <Table 14> below.

<Table 13> Comparison between groups

Sub-criteria		Manager of the transport company (4 experts)		Truck driver (6 experts)		Professor (4 experts)		TS staff (2 experts)	
C11	Reinforcement of truck driver and employer management	0.105	(3)	0.121	(1)	0.090	(5)	0.012	(12)
C12	Promotion of truck drivers' convenience	0.086	(5)	0.105	(2)	0.185	(2)	0.021	(11)
C13	Expansion of advanced vehicle technology	0.055	(8)	0.096	(4)	0.138	(3)	0.023	(8)
C21	Expansion of traffic safety facility	0.194	(1)	0.062	(11)	0.198	(1)	0.022	(9)
C22	Reinforcement of crackdown on illegal parking along the road	0.191	(2)	0.095	(5)	0.055	(7)	0.083	(4)
C23	Improvement of drivers' night vision	0.072	(7)	0.032	(12)	0.098	(4)	0.022	(9)
C31	Enhancement of penalty for truck violation	0.034	(9)	0.095	(5)	0.054	(8)	0.171	(2)
C32	Expansion of monitoring and inspection system	0.034	(9)	0.071	(9)	0.032	(11)	0.050	(6)
C33	Enhancement of safe loading crackdown	0.093	(4)	0.081	(7)	0.038	(9)	0.133	(3)
C41	Improvement of truck license acquisition process	0.033	(11)	0.100	(3)	0.063	(6)	0.376	(1)
C42	Expansion of traffic safety educational target	0.020	(12)	0.065	(10)	0.033	(10)	0.051	(5)
C43	Diversification of educational programs	0.083	(6)	0.078	(8)	0.017	(12)	0.037	(7)
Total		1.000		1.000		1.000		1.000	

<Table 14> Fuzzy-AHP result of global importance (standardization)

Sub-criteria		Importance (rank)	
C11	Reinforcement of truck driver and employer management	0.139	(2)
C12	Promotion of truck drivers' convenience	0.158	(1)
C13	Expansion of advanced vehicle technology	0.082	(8)
C21	Expansion of traffic safety facility	0.083	(7)
C22	Reinforcement of crackdown on illegal parking along the road	0.115	(3)
C23	Improvement of drivers' night vision	0.033	(11)
C31	Enhancement of penalty for truck violation	0.098	(4)
C32	Expansion of monitoring and inspection system	0.044	(9)
C33	Enhancement of safe loading crackdown	0.088	(6)
C41	Improvement of truck license acquisition process	0.096	(5)
C42	Expansion of traffic safety educational target	0.028	(12)
C43	Diversification of educational programs	0.036	(10)
Total		1.000	



Inconsistency: 0.001

Ⅴ. Conclusion

This study synthesized the safety policies for truck traffic and conduct their importance by the Fuzzy-AHP method. First of all, it can be judged that it is more important to improve truck drivers' working environment and road traffic conditions rather than the improvement in terms of education and crackdown/inspection enforcement. As emphasized in the study of Lee et al.(2016), drivers' awareness of safe driving can be enhanced by improving the working conditions or work environment of truck transport. The income of a truck driver depends on the driving time, distance and load. To generate a large amount of income, continuous driving hours are often not observed. Cooperation between companies and drivers is necessary to improve the working environment. Also, truck drivers are more difficult to drive due to the size and weight of the truck body. So truck drivers experience significantly higher driving fatigue than passenger car drivers. Yoo and Kim(2018) pointed out that the drowsy driving of truck drivers is fatal, and to improve this, it is important not only to get enough rest but also to provide driver convenience by installing advanced digital devices in trucks. Installation of vehicle driving assistance devices to reduce driving fatigue of truck drivers must be promoted emergency. In January 2022, the government announced measures to strengthen traffic safety for commercial vehicles, and major measures for truck traffic safety include providing sufficient resting facilities and time for drivers, installing advanced devices that provide convenience to drivers, enhancing safety inspection of old trucks, and using AI technology for crackdown systems. The analysis results of this study also explain that it is better to encourage drivers to drive safely by promoting driver convenience through environmental improvement than to passively obey drivers for truck traffic safety.

Considering the analysis results and practical feasibility, the present study suggests the guidelines for safe truck traffic as follows. The management of transport companies and truck drivers should be strengthened. To prevent drowsy driving and speeding, it is necessary to reinforce the inspection of truck drivers' compliance with the break time. Currently, truck drivers have to take a 15-minute break after 2 hours of continuous driving. However, many drivers seem to violate this. Therefore, to prevent overwork to the truck drivers, continuously monitoring the transport companies and utilizing Digital Tacho Graph (DTG: A device that stores driving information such as vehicle speed, acceleration, location, and travel distance) on the truck vehicles are required. Since the submission of the data recorded by the DTG has not been realized widely, it is required to reinforce the management of data submission from the transport companies and drivers. In addition, safety checks should be carried out in parallel for businesses whose vehicles are suspected of running overtime. Furthermore, selecting excellent companies and drivers that comply with traffic laws to increase drivers' awareness of safe driving through the benefits such as discounts on insurance premiums and tax reductions.

Also, driving convenience should be provided to truck drivers. Here, it can be divided into two categories. One is to ensure sufficient resting space for truck drivers. Since truck drivers have more driving fatigue than other vehicles, there is a high demand for rest facilities. The government must secure truck rest stops not only on highways but also within cities. The other one is installing additional convenience facilities in the trucks to help drivers' driving. Driver State Warning (DSW) is a device that monitors vehicle driving data in the drivers' face in real-time and sends an alarm when it detects negligence or abnormal conditions. The camera attached to the vehicle calculates the number of times the driver blinks, yawns, and closes. Through this, the drivers' fatigue and drowsiness are identified. Since this function was applied to the bus operated as a shuttle bus at the time of the

Pyeongchang 2018 Olympics, there is a need to promote the mandatory settlement of trucks in the future.

Illegal parking and stopping along the road are known to cause many problems in terms of road traffic safety. It increases traffic congestion, accidents, poor living conditions and easily causes pedestrian accidents. The crackdown on illegal parking and stopping along the road must be strengthened to create a traffic environment by CCTV installation expanding and administrative punishment strengthening.

In summary, a truck traffic accident is a complex problem in current society, and the fatality rate of truck traffic accidents is higher than other types of vehicles. To ensure traffic safety, all members of society should do their best, drivers and pedestrians should always follow the traffic rules and be responsible for keeping safe traffic for themselves and others. Transport companies have to observe the regulations on the rational distribution of working time, and actively cooperate with relevant departments in the inspection. Public institutes should pay more attention to improving the traffic environment to prevent accidents. As the issue of truck traffic safety grows, this paper can be used as a reference when establishing traffic safety policies. However, the small number of participants in the safety education group compared to other groups is a limitation of this study. The research can be improved by recruiting sufficient survey participants in the future.

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