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Transport Management Characteristics of Urban Hazardous Material Handling Business Entities

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Abstract: In order to minimize the occurrence of large-scale accidents resulting from the transportation of hazardous materials (HAZMAT) on urban roadways, a system to monitor freight vehicle movements in real-time is being implemented. Although monitoring systems are in place, no prioritization strategy has been prepared for the selection of vehicles by the companies handling HAZMAT. Therefore, this study aims to analyze the factors affecting the level of transport management of HAZMAT handling business entities such as the freight, shipping, and vehicle characteristics, and suggests directions for effective policy enforcement of HAZMAT vehicle monitoring strategies. In this study, nation-wide survey data on the logistics status of HAZMAT handling business entities were collected, and the influence of such business entities according to their level of transport management was derived using an ordered logit model. Implications were obtained through statistical analysis of the transport management behavior of urban hazardous material handling business entities. In the future, it is necessary to study empirical methods for setting priorities based on the survey data of the entire population of HAZMAT transport vehicles.

Keywords: hazardous materials; monitoring system; nation-wide survey data; ordered logit; business entities

1. Introduction

Urban freight generation is continuously increasing due to rising economic growth, increased international trade, expanded online transactions, advances in technology, and increased efficiency of transportation systems. The quantity of urban freight that is transported using several transportation modes is also increasing, and considerations in the freight transport process are gradually changing from cost to service factors such as travel time, punctuality, safety, and eco-friendliness. Owing to regional economic growth and the expansion of related industrial areas, the producers, managers, and consumers of hazardous materials (HAZMAT), as well as their types and sizes, are gradually increasing. Moreover, the scope and scale of HAZMAT handling business entities and transport vehicles are slowly expanding, and their management targets are expanding [1]. When accidents related to HAZMAT that occurred from 2004 to 2013 in the four main stages of production, namely manufacturing, storage, transport, and processing, were analyzed, it was identified that approximately twice as many accidents occurred in the transport stage alone compared to those that occurred in the manufacturing, storage, and processing stages [2]. In addition, it was found that the accident rate and fatality of HAZMAT transport vehicles were respectively 11% and 22% higher than those of vehicles not carrying such materials [3]. Since the amount of HAZMAT being transported, along with the seriousness of HAZMAT related accidents both continue to increase, HAZMAT transportation safety issues continue to gain attention among researchers and practitioners.

In many countries, including South Korea, the importance of managing the transportation of HAZMAT has been recognized through experience and from research results related to accidents involving HAZMAT transport vehicles, and countless safety and accident response measures have been prepared for business entities and vehicles that handle and transport HAZMAT. As part of policies related to transport management, a HAZMAT transport monitoring system has been implemented to integrate and manage the individual transport data of freight vehicles, to monitor vehicle travel paths in real-time, and to minimize HAZMAT vehicle-involved accidents and damages resulting from them. According to the results of a study, the implementation of the vehicle monitoring system reduced traffic accidents by approximately 20% [4]. Despite this benefit, there is a lack of detailed consideration concerning the setting of a criterion for the installation of devices in selected HAZMAT transporting trucks. Prior to the implementation of the monitoring system, more detailed management is required through close cooperation between policymakers, the monitoring system developers, and HAZMAT transport researchers. It is necessary to set priorities for the selection of vehicles from HAZMAT handling business entities for monitoring, while considering the limited budget of the individual firms. Monitoring must be performed in stages by selecting HAZMAT vehicles through the identification of the characteristics of HAZMAT handling business entities, such as the size of business, HAZMAT types, outsourcing, shipment volumes, shipment frequency, shipment index, vehicle types, and safety management programs. Currently, there are not many empirical studies on the transport management characteristics of HAZMAT handling business entities operating in urban areas, and HAZMAT transport monitoring systems in use were not derived based on the sufficient theoretical and empirical examination of the targets to be monitored.

Based on this background, this study aims to analyze the influential factors according to the level of transport management of HAZMAT handling business entities considering the general, shipment, vehicle, transport, and product characteristics, and to propose a direction for the effective implementation of HAZMAT vehicle monitoring systems. To this end, the survey data on the logistics status of HAZMAT handling business entities were used, and the influence of such business entities according to their level of transport management was derived using an ordered logit model.

The contents of this paper are as follows. In Section 2, the status of previous studies related to this study and that of the HAZMAT transport monitoring system are reviewed. The research methodology is described in Section 3. In Section 4, the survey data on the logistics status of HAZMAT handling business entities are introduced, and a basic analysis of the survey data is conducted. In Section 5, the estimation results according to the set variables are examined. Finally, in Section 6, conclusions are drawn, and future research projects are presented.

2. Literature Reviews

2.1. Insights from the Previous Studies

In previous studies, research areas on HAZMAT transport are primarily classified into risk assessment, transport path, location, and network design [5–8]. Even though HAZMAT transport monitoring has emerged as an essential issue, currently there are not many studies focused on it. Also, studies on the transport management characteristics, according to the HAZMAT handling business entities, are not enough partly due to limited data collection. On the other hand, many studies have been conducted focusing on the traffic accident characteristics of HAZMAT handling business entities. In this chapter, previous studies related to HAZMAT transport monitoring and traffic accident characteristics of HAZMAT handling business entities are examined. The implications drawn from the previous studies are identified and summarized.

Studies regarding HAZMAT transport monitoring have mentioned the importance of introducing the monitoring system in HAZMAT transport vehicles. Studies from the United States and European countries have emphasized that the HAZMAT transport monitoring system is a policy alternative required to promote active information exchange among producers, transport managers, and safety

personnel, to minimize damage in the event of HAZMAT transport accidents, and to prepare for terrorist threats [9–11]. Tatarinov and Krsanov [12] proposed a low-cost monitoring system that unites Information Technology (IT) tools such as GPS and Google maps, among others, to solve the problem of responsiveness after accidents involving HAZMAT vehicles occur. The architecture of the proposed system also takes into consideration distinctive features of emergency situations, which provides decision-makers with real-time information for making management decisions and emergency responses, and in turn leads to the reduction in loss of lives and damage caused to properties in the event of an accident.

There are not many empirical cases in which the effect of implementing HAZMAT transport monitoring was analyzed. However, the few that have been studied have proposed specific frameworks that can be used to develop appropriate policies to ensure the safety of HAZMAT transport. A case study conducted in the Netherlands investigated accident reduction resulting from the installation of vehicle tracking devices using a sample of 840 vehicles classified into 11 vehicle types. Although traffic accident reduction was slightly different depending on vehicle type, the overall effect was found to be significant due to monitoring [4]. From some studies on the HAZMAT transport monitoring system, related systems have been implemented in many countries of late with the advancement of IT. The monitoring system is considered as an essential factor for the management, operation, and evaluation of HAZMAT transport, indicating that the intervention of central and local governments, and the cooperation between system developers and traffic researchers are essential. Zhao et al. [13] studied and identified a rising trend in HAZMAT truck accidents in China. To counter the increasing trend, they applied an unsupervised framework to analyze HAZMAT truck trips and to provide adequate decision-making support for policymakers in terms of HAZMAT transportation. To build a HAZMAT planning aid system that provides valuable data to urban planners and decision-makers, Cherradi et al. [14] proposed an environmental information system that captures transportation dynamics, visualization, analysis, and evaluation of HAZMAT risk using wireless technology and real-time intelligent sensors. The proposed system operates over a cloud environment, providing services such as pre-transportation, routing, GIS-based monitoring and tracking, data collection, substance and risk knowledge, transport documentation, historical information sharing, alert, and query information. The data collection solution facilitated real-time data transfer between vehicles and IT infrastructure. Also, with the aid of a pgRouting bi-directional A* algorithm, the least risky routes are identified for HAZMAT shipments.

In the area of transport monitoring, study results showed that management and supervision under the intervention of central and local governments, among freight owners, transport companies, and central and local governments, are significantly useful for ensuring traffic safety [15,16]. Also, the literature on HAZMAT transport monitoring has emphasized that the system's data are also required to acquire detailed information on before and after accident situations. To achieve this, cooperation between system developers and accident analysts is required [17,18]. Besides, most recent studies selected technical transport management tracking combined with IT as a significant evaluation factor in terms of the management, operation, and evaluation of HAZMAT transport. Although there are differences in terms of the choice of factors depending on researchers, the importance of the transport management tracking factor has been stressed along with factors such as transportation mode and path selection, transport permits, HAZMAT monitoring, violations, penalties, certificates related to HAZMAT transport, safety of delivery sites, transport capability evaluation, and cooperation among various management entities [19–21].

Studies on the accident characteristic of HAZMAT handling business entities mostly estimated models using either data of transport companies or survey data of business entities [22,23]. Poisson regression analysis [22], negative binomial regression analysis [3], and Mann Whitney test [23] were among the methodologies frequently used. Different market segmentation strategies were employed, depending on the studies. Comparisons were made between business entities that transport HAZMAT and those that do not [3,22], between large business entities with more than

250 employees and small business entities, and between companies with a HAZMAT transport ratio of over 50% based on their shipment volume and those with a ratio lower than 50% [23]. Several variables such as the number of employees, the operation period of the business entity, safety cost, availability of safety manager, availability of accident prevention program, accident status, compliance with regulations, monitoring device operation, accident registration, HAZMAT items being transported, travel distance, vehicle industry, the ratio of commercial freight vehicles, and contract and consignment operation status for freight vehicles were used in models considering the general, shipment, vehicle, and transport characteristics of business entities [22,23]. Also, there was a study that used the shipment frequency, the shipment region, the consignee's industry, the value per ton, and the freight vehicle ownership as variables [24].

The research results showed that many vehicles managed by HAZMAT handling business entities were involved in accidents. Business entities that transport HAZMAT exhibited an 11% higher accident rate and a 22% higher fatality compared to those that do not [22]. The number of traffic accidents decreased as the size of the business entity increased [22,23]. As the size of the business entity increased, the accident rate also decreased as a result of the stable employment of drivers due to stable funds, transport equipment maintenance, and vehicle replacement cycle [25,26]. It was also found that large business entities were making more efforts in terms of safety. These large business entities focused on carrying out monitoring operations using monitoring devices, registering accidents when they occur, employing safety managers, and running accident prevention programs [23].

From the literature, it was found that fewer accidents occurred when HAZMAT transport business entities have consignment arrangements or have long-term contracts for freight vehicle operation. In addition, it was found that the accident rate was higher for long-distance transport vehicles, tank truck vehicles (among the vehicle types), and gas and flammable liquids (among the HAZMAT types). Some studies identified factors that led to the reduction of the clearance time of accidents involving HAZMAT freight vehicles that transport HAZMAT on highways. In a recent study, weather conditions, loading capacity, accident types, and accident status were found to be significant factors. Further, directions for responding to accidents were presented [27].

Upon examining previous studies, it was found that those focused on transport management characteristics were not enough even though there were some studies on accident attributes according to the characteristics of HAZMAT handling business entities. Moreover, while governments and companies frequently monitored the transport of HAZMAT due to the recent developments in IT, empirical analysis-based studies using survey data concerning the logistics status of HAZMAT handling business entities that could be used to determine priorities and setting monitoring targets are limited. As such, in this study, the characteristics of urban HAZMAT business entities according to the HAZMAT level of transport managements were analyzed, and empirical analysis was conducted so that the results could be referred to for the selection of the priorities for HAZMAT transport monitoring business entities and vehicles.

2.2. HAZMAT Transport Management System in South Korea

The Government of South Korea prepared a HAZMAT transport monitoring system because the management system in the transport process was not enough even though people's awareness of safety with regards to HAZMAT was high. Among the accidents related to HAZMAT, the accident that attracted people's attention the most was a hydrofluoric acid leakage that occurred in Gumi along the highway in Gyeongsangbuk-do in September 2012. As a result of the leakage, five people died, and 18 firefighters, together with some 12,000 people, sustained several degrees of injuries. This accident prompted the Government to design a system for monitoring the entire transport process by installing terminals in each HAZMAT transport vehicle so that accidents that may occur during the transportation process could be accurately responded to and rapidly dealt with [28].

The goals of the HAZMAT transport management system is to efficiently check and drastically reduce the frequency of HAZMAT vehicle-related transport incidents, respond to disasters promptly

and accurately by strengthening social safety nets, and to consider the users' convenience and management efficiency by providing information in real-time and reinforcing management. Another crucial goal is to help in responding promptly to accidents or providing support when the abnormal operation of a HAZMAT vehicle is detected. Based on this system, the Government launched the "HAZMAT transport safety management center," where it oversees the transport management process. Through the HAZMAT transport management center, it is possible to monitor the types of HAZMAT, the maximum loading capacity, installation, and management of vehicles using the installed devices.

With these goals and plans for HAZMAT management, the Government also established long-term plans through in-depth discussions on the risks of HAZMAT and the importance of its management as of 2013 with stakeholders. The system was constructed, and a pilot project was initiated using 300 test vehicles in 2018. Currently (during 2019), the monitoring functions and information linkage services are being upgraded. New functions will be developed, and a system for sharing and analyzing the collected information will be established in 2020. A transport management monitoring system will be constructed by 2021 and will be stabilized by monitoring 15,000 freight vehicles [28].

Table 1 shows the criteria for monitoring HAZMAT transportation in South Korea. The HAZMAT classification was based on HAZMATs, designated wastes, hazardous chemicals, and high-pressure gases. The HAZMATs include commonly used gasoline, diesel, and kerosene, and the designated wastes refer to liquids such as waste acid and oil, which are meant to be thrown away after use. Hazardous chemicals comprise chemicals such as sulfuric acid, hydrochloric acid, and nitric acid that are harmful or likely to be harmful to human health or the environment. High-pressure gases were grouped into flammable gases and toxic gases that are harmful to human health.

Table 1. Domestic targets for HAZMAT transport management (Article 2.2 of the Enforcement Regulations of the Framework Act on Logistics Policies).

HAZMAT Classification		Maximum Loading Capacity	Related Ministries
HAZMAT (Flammable liquids: Gasoline, diesel, kerosene, etc.)		Over 10,000 L	National Fire Agency; Korea Fire Institute
Designated waste (Liquids including waste acid, waste oil, and waste synthetic resin)		Over 10,000 kg	Ministry of Environment; Korea Environment Corporation
Hazardous chemicals (Sulfuric acid, hydrochloric acid, nitric acid, etc.)		Over 5000 kg	Ministry of Environment; National Institute of Chemical Safety
High–pressure gas	Flammable gas (LPG, LNG, hydrogen, etc.)	Over 6000 kg	Ministry of Trade, Industry and Energy; Korea Gas Safety Corporation
	Toxic gas (Hydrogen fluoride, hydrogen chloride, etc.)	Over 2000 kg	

Under these schemes, the criteria for monitoring the transport and management of HAZMAT in South Korea are set based on the HAZMAT classification and the maximum loading capacity. It shows that, currently, there is no detailed strategy that considers the characteristics of business entities.

3. Methodology

3.1. Model Setting

The purpose of this study is to analyze the relationship between the characteristics of business entities and the level of transport management of HAZMAT handling business entities. For the attribute variables of business entities, the survey data on HAZMAT handling business entities collected by the Korea Transport Institute in 2017 were utilized. The survey items were classified into general, shipment,

vehicle, transport, and product characteristics, considering the characteristics of business entities. From the survey data, independent variables used for the analysis were determined. The dependent variable was created by defining the level of transport management. The classification was performed by selecting statistically significant variables from the surveyed items through correlations.

Based on the survey items on HAZMAT handling business entities, HAZMAT transport management can be divided into three types. The first is pre-management, which is meant to prevent accidents by designating a path in advance. The second is in-transit management in which the vehicle reports its status in real-time or while transporting HAZMAT. The last is post-management in which information, such as the travel path and transport time, is recorded and collected upon the completion of transport. In total, there were 503 business entities surveyed across the country.

First, in the case of the dependent variable, four levels of HAZMAT transport management were defined as shown in Table 2. Considering that the accident risk is high during transport due to the nature of HAZMAT, all levels, except for level 1, were divided based on the business entities. Level 1 refers to business entities that do not consider performing pre-management, in-transit management, and post-management. Level 2 represents those that perform only in-transit management in real-time, and level 3 refers to those that perform at least two processes, that is, pre-management along with in-transit management or post-management along with in-transit management. Finally, level 4 represents business entities that manage HAZMAT transportation in all three processes.

Table 2. Definition of the ordered dependent variable based on the levels of HAZMAT transport management.

Category	Pre-Management	In-Transit Management	Post-Management
Level 1	-	-	-
Level 2	-	●	-
Level 3	●[1]	●	-
	-	●	●
Level 4	●	●	●

[1] ● represents the type of management activities carried out the HAZMAT business entities.

From the surveyed items, the independent variables were created and classified mainly into general, shipment, vehicle, and transport characteristics. The general characteristics refer to the general variables such as the industry of the business entity, HAZMAT type being handled, number of employees, and annual sales of the business entities. The shipment characteristics include the total annual shipment volume, the number of monthly shipments, and the use of third-party logistics. In terms of transport characteristics, the total number of daily consignees, total travel distance, ownership of management manuals, the entity responsible for transport, and the use of third-party logistics were designated as variables. In terms of vehicle characteristics, the number of vehicles owned by the business entity and the use of vehicles is included. Finally, in the product characteristics category, six materials, including gunpowder, gas, flammable liquids, and combustible solids, were selected as primary HAZMATs.

Each independent variable can be classified as the representative attribute of HAZMAT handling business entities. Variables determined not to be significant were removed after completing the statistical verification procedures.

3.2. Model Estimation Method

In this study, an ordinal logistic regression model was applied considering the ordered nature of the dependent variable. For a binary dependent variable (y = 0, 1), the general logit and probit models are applicable. In case there are more levels of the dependent variable, using a general regression model may cause errors. Therefore, to obtain accurate estimation results, an ordinal logistic model capable of analyzing data with an ordered dependent variable was applied. The proportional odds

model can be used to explain ordered dependent variables. This model can be analyzed by expressing it as a generalized linear model. Generalized linear models can be used in a wide range of applications, and the basic model is given by the following equation [28,29];

$$\text{link}(\gamma_i) = \theta_i - [\beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k] \quad (1)$$

where link denotes a link function, and γ_i is the cumulative probability for the i-th category. θ_i represents the intercept term for the first i-th category. $\beta_1, \ldots \beta_k$ are the regression coefficients whereas $x_1, \ldots x_k$ are k independent variables.

To treat the ordered logit model in the same manner as the general regression equation, the relationships between the ordered dependent variable and the independent variables can be seen as follows:

$$y^* = \sum_{k=1}^{K} \beta_k x_k + \varepsilon \quad (2)$$

where y* is an unobservable response variable, and provides a criterion for respondents to select an observable response y. In other words, when there are j responses (y) that can be selected by respondents, their probabilities can be represented in a sequence [30].

Logit transformation for ordinal data can be achieved through adjacent category logit transformation, continuous ratio logit transformation, and cumulative logit transformation. In this study, the cumulative logit model was selected by determining that the same effect can be assumed on the cumulative logit transformation of individual categories considering the order of the independent variables. The cumulative logit distribution function uses the inverse function as the link function, and the basic model is as follows [31,32]:

$$\text{Prob}(\text{y} \le \text{j}) = \text{Prob}\left(y^* \le \mu_j\right) = F\left(\mu_j - \sum_{k=1}^{K} \beta_k x_k\right) = L\left(\mu_j - \sum_{k=1}^{K} \beta_k x_k\right) = \frac{e^{\mu_i - \sum_{k=1}^{K} \beta_k x_k}}{1 + e^{\mu_i - \sum_{k=1}^{K} \beta_k x_k}} \quad (3)$$

In the case of the ordered logit model, the explanatory variable can be interpreted as a log-odds value. This value represents the degree of accident occurrence of the corresponding independent variable when other variables are fixed. It is mainly expressed by the odds ratio. The odds ratio refers to the ratio of the probability that an accident will occur to the probability that it will not, and it can be seen as equal to exp(β) depending on the calculation. In other words, whether each independent variable has a positive effect, and their occurrence probabilities as the level of HAZMAT transport management increases can be analyzed. When the probability that an accident will occur is assumed as and the probability that it will not occur is assumed as P_0, the odds ratio can be expressed as follows:

$$Odds\ Ratio = \frac{\frac{P_1}{(1-P_1)}}{\frac{P_0}{(1-P_0)}} = \frac{LOGIT\ P_1}{LOGIT\ P_0} \quad (4)$$

4. Survey Data Collection

The data of the survey on HAZMAT handling business entities, which were collected in May 2017, were used for this study. The survey targeted 503 sample business entities across South Korea that deal with nine different kinds of HAZMATs. Basic statistical analysis was conducted, and models were derived focusing on the business entities that handle the transportation of HAZMAT in cities. Table 3 summarizes the data used in this study.

Table 3. Summary statistics based on hazardous materials (HAZMAT) handling business entities segregated by level of transport management.

Category		Variable	Unit	Level 1 (%)	Level 2 (%)	Level 3 (%)	Level 4 (%)
Ordinal type	Dependent	Level of transport management	Entities	42	24	64	99
Continuous type (average)	General	Number of employees	Persons	42.4	60.8	63.4	69.7
		Area mainly used	m^2	2218.9	1132.6	1260.0	2385.1
	Transport	Number of daily consignees (destinations)	Companies	2.5	1.9	5.2	4.3
		Total travel distance	km/day	606.8	1063.9	609.8	644.4
	Vehicle	Number of vehicles owned	Vehicles	9.9	11.5	12.0	13.4
	Shipment	Total annual shipment volume	Tons	14,828.4	31,912.7	65,259.7	87,502.2
		Annual shipment volume of HAZMATs	Tons	3818.8	29,028.0	10,123.1	31,679.8
		Proportion of HAZMAT shipment volume	%	0.51	0.61	0.58	0.62
		Total number of monthly shipments	Cases	45.1	105.8	141.1	132.4
		Total monthly shipment days	Days	11.5	13.7	18.2	17.0
[1] Nominal type	General	Business entity location	(1: city, 2: non-city)	27(16.7)	17(10.5)	43(26.5)	75(46.3)
		Industry code	(1: manufacturing, 2: others)	19(13.1)	14(9.7)	41(28.3)	71(49.0)
		Annual sales	(1:0.5 bil. or less, 2: over 0.5 bil.)	3(14.3)	2(9.5)	3(14.3)	13(61.9)
	Transport	Manual ownership	(1: owned, 2: not owned)	21(11.9)	14(8)	55(31.3)	86(48.9)
		Transport management entity	(1: business entity, 2: transport company)	16(13.9)	7(6.1)	38(33.0)	54(47.0)
		Use of third-party logistics	(1: yes, 2: no)	29(21.5)	17(12.6)	29(21.5)	60(44.4)
	Vehicle	Use of vehicles	(1: non-commercial, 2: commercial)	10(10.8)	6(6.5)	35(37.6)	42(45.2)
	Product	Gunpowder	(1: handled, 2: not handled)	1(10.0)	0(0.0)	3(30.0)	6(60.0)
		Gases	(1: handled, 2: not handled)	2(6.3)	4(12.5)	9(28.1)	17(53.1)
		Flammable liquids	(1: handled, 2: not handled)	23(20.0)	13(11.3)	33(28.7)	46(40.0)
		Combustible solids/pyrophoric materials	(1: handled, 2: not handled)	3(23.1)	1(7.7)	5(38.5)	4(30.8)
		Oxidizing materials	(1: handled, 2: not handled)	4(25.0)	0(0.0)	6(37.5)	6(37.5)
		Toxic/infectious materials	(1: handled, 2: not handled)	2(22.2)	2(22.2)	1(11.1)	4(44.4)

[1] For all variables, basic statistics results in the nominal type category are presented based on option "1".

The total number of business entities that were selected from the total sample was 229. These 229 business entities were those whose HAZMAT transportation management levels corresponded to the categorical levels described in Table 2. The business entities that cannot be placed under any of the categories were excluded from the analysis. Among them, 42 (18.3%) belonged to level 1, which is referred from Table 2, 24 (10.5%) belonged to level 2, 64 (27.9%) matched level 3, and 99 (43.2%) of the business entities had a management level of 4. The independent variables were divided into continuous and nominal types depending on their value. The continuous-type variables, such as the number of employees, the number of vehicles owned, and the total annual shipment volume, were found to increase as the level of transport management increased. While the average number of employees in business entities that belonged to level 1 was only 42.4, that of business entities that belonged to level 4 was as high as 69.7.

The total shipment volume, annual shipment volume of HAZMAT, and the number of shipments, which represent shipment characteristics, also increased as the level of transport management increased. Specifically, in the case of the total annual shipment volume, the business entities that belonged to level 1 shipped 14,828.4 tons while those that belonged to level 4 shipped 87,502.2, which is 5.9 times higher than those that belonged to level 1. It was also found that business entities with high HAZMAT shipment volumes generally exhibited a high level of transport management.

The nominal-type independent variables were also classified into general, transport, vehicle, and product characteristics. The variables in the general category include the business entity's location, industry code, and annual sales. Variables for manual ownership, transport management entity, and use of third-party logistics were also considered in the analysis. For instance, the business entities that owned manuals for responding to accidents during transport exhibited high transport management levels. The use of commercial vehicles was also considered, and each HAZMAT item to be transported was applied to figure out their relationship with the transportation management level. Among the six HAZMAT items, the variable for flammable liquids had the highest transport ratio, and 40% of them were associated with business entities that have transport management level 4.

Finally, when the underlying statistics were analyzed based on HAZMAT products, the number of business entities that handled flammable liquids was found to be the largest. The distribution of the business entities that performed no transport management and those that observed all levels of transport management functions were not significantly different depending on the product type. In the case of flammable liquids, however, the proportion of business entities with transport management level 4 was approximately twice as high as that of business entities with transport management level 1.

Consequently, the primary analysis showed that the level of transport management increased as the size of the business entity, and the shipment volume increased. Also, it was identified that the level of transport management increased as the business entity directly performed the transport management, and in business entities that owned manuals. In addition, items such as the shipment volume, industry, ownership of transport management manuals, and transport responsibilities resulted in significant differences in transport management.

5. Results

A model was constructed to predict the probability of the level of transport management according to the characteristics of HAZMAT handling business entities. Table 4 shows the results of the ordered logit model.

Table 4. Ordered logit model estimation results by level of transport management.

Category		β	Std. Error	Wald	Sig.	Odds Ratio	95% Confidence Interval	
							Lower Bound	Upper Bound
	Transport management 1→2	0.245	0.483	0.258	0.612	-	−0.702	1.193
	Transport management 2→3	0.823	0.478	2.962	0.085	-	−0.114	1.760
	Transport management 3→4	1.838 ***	0.484	14.397	0.000	-	0.889	2.788
General characteristics	Business entity location (city)	0.350 *	0.206	2.884	0.089	1.419	−0.054	0.754
	Industry (manufacturing)	0.589 ***	0.198	8.858	0.003	1.801	0.201	0.976
	Number of employees (200 or less)	0.367	0.357	1.058	0.304	1.443	−0.332	1.066
	Annual sales (0.5 bil. or less)	0.672 *	0.376	3.204	0.073	1.959	−0.064	1.408
Shipment characteristics	Monthly shipment days	0.018 *	0.011	2.736	0.098	1.019	−0.003	0.040
	Proportion of HAZMAT shipment volume	0.134	0.225	0.356	0.551	1.144	−0.307	0.575
Transport characteristics	Manual ownership (owned)	0.967 ***	0.208	21.538	0.000	2.630	0.559	1.376
	Transport management entity (business entity)	0.310	0.248	1.569	0.210	1.364	−0.175	0.796
Product characteristics	Flammable liquids (handled)	−0.356 *	0.202	3.116	0.078	0.701	−0.751	0.039
	Combustible/pyrophoric materials (handled)	−0.782 **	0.397	3.874	0.049	0.458	−1.560	−0.003
	Oxidizing materials (handled)	−0.655 *	0.362	3.262	0.071	0.520	−1.365	0.056
Vehicle characteristics	Use of vehicles (non-commercial)	−0.064	0.260	0.061	0.805	0.938	−0.574	0.446
MF test	Chi-square	46.028						
	df	12						
	p-value	<0.001						
TPL test	Chi-square	32.425						
	df	24						
	p-value	0.117						
Log likelihood		514.056						
ρ^2(Nagelkerke)		0.198						

*** means *p*-value < 0.01, ** means *p*-value < 0.05, * means *p*-value < 0.1.

First, the model fitness test (MF test) and parallelism test (TPL test), which evaluate the overall suitability of the model, were examined. The overall significance level was found to be less than 0.001, indicating that the model was appropriate at the 99% confidence level. In addition, ρ^2, which represents the explanatory power of the model was 0.198. In general, a logistic model is deemed sufficiently explainable when the value of ρ^2 is between 0.2 and 0.4. It is judged that the constructed model has an appropriate explanatory power, since its likelihood is close to 0.2.

An assumption of the ordinal logistic model is that each independent variable should have the same impact when the dependent variable increases by one unit. The TPL test is required to examine whether this assumption is met. The results of the TPL test showed that the underlying assumption could be satisfied if the significance probability is higher than 0.05. If it is lower than 0.05, the basic assumption would be violated, and techniques other than the ordinal logistic model must be considered. The significance probability of the constructed model was estimated at 0.117. Therefore, the underlying assumption was met, and the analysis with the ordinal logistic model was deemed appropriate.

The odds ratio was available as an explanatory index and can be used to have a closer look at the results of the model. From the general characteristics, the location of the business entity and the industry were found to be significant. For the variable of the business entity location, the estimated coefficient was positive, and the value of the odds ratio was 1.419. This observation means that if the business entity is in a city instead of the periphery of the city, the probability that the level of transport management will become higher increases by 1.419 times. For the variable related to the industry, the odds ratio was 1.801. This result can be explained as the probability that the level of transport management will become higher and increase by 1.801 times if the industry is into manufacturing rather than wholesale. The variable for annual sales was significant at a 90% confidence level, and the odds ratio indicated that the HAZMAT transport management level of the business entities increases by 1.959 times when the annual sales are 0.5 billion or less.

In the case of the shipment characteristics, several variables were analyzed, but the variable for the monthly shipment days was the most significant. The odds ratio of the monthly shipment days variable was 1.019, indicating that the level of transport management is more likely to increase as the number of shipment days increases. Again, considering the transport characteristics, it was found that the level of transport management is higher if transport management manuals are owned. The odds ratio was 2.630, which was higher compared to that of other independent variables. This result indicates that owning such manuals significantly affects the level of transport management. This outcome is naturally expected since manuals are items to be prepared and utilized by business entities for pre-management purposes.

When the model was analyzed for each HAZMAT type, three materials were found to be significant among the six products that were studied. All the flammable liquids, combustible/pyrophoric materials, and oxidizing materials exhibited negative coefficient signs. These results show that the handling of such materials negatively affects the level of transport management. The odds ratio of flammable liquids was 0.701, indicating that the probability of performing transport management by level decreases by 0.299 times as flammable liquids increase by each unit. The odds ratio of combustible/pyrophoric materials was 0.458, and that of oxidizing materials was 0.520. In the same manner, this indicates that the probability of performing transport management by level decreases by 0.542 times for combustible/pyrophoric materials and by 0.480 times for oxidizing materials. In other words, these results imply that the level of transport management is not high, and transport management is not properly performed for business entities that handle these materials.

From the analysis, the main results obtained are as follows. In terms of the general characteristics of HAZMAT handling business entities, it was found that the level of transport management was high when the business entities are in urban cities, and when the industry was manufacturing-oriented. With regards to the shipment characteristics, the level of transport management increased as monthly shipment days increased. Regarding the transport characteristics, the ownership of transport management manuals by business entities was found to be closely related to the level of transport

management. Concerning the product characteristics, it was found that the impact of handling HAZMAT on the increase in the level of transport management was not significant.

For governments to effectively support and manage the HAZMAT transport monitoring system, its implementation must be performed in stages considering the constraints of their budgets, as emphasized above. Therefore, it is necessary to consider and reflect the sizes and transport characteristics of business entities.

6. Conclusions

The criteria for transport management, however, are classified only by the maximum loading capacity and HAZMAT type. To date, in setting appropriate criteria, researchers have not considered including the characteristics of business entities and the transport and vehicle characteristics. In addition, vehicles for which transport management is planned are usually fixed at certain times due to the limited budget of many governments. It is necessary to place priorities on the management criteria. However, a review of the literature on the transportation and management of HAZMAT shows that discussions among policymakers, system managers, and traffic experts were not enough. Therefore, this study aimed to perform an empirical analysis of these items using the data of the survey on HAZMAT handling business entities.

In this study, the responses grouped into pre-management, in-transit management, and post-management were defined as four management levels, and an ordinal logistic model was employed with independent variables that considered the characteristics of business entities. From the results of the analysis, the suitability of the overall model was investigated. Generally, it was found that the level of transport management was likely to increase as the independent variables increase.

The main results obtained through model estimation are as follows. The level of transport management was found to be high when business entities were in urban cities, and when the industry was manufacturing-oriented. Furthermore, the level of transport management increased as shipment days increased, and the ownership of transport management manuals by business entities was identified to be closely associated with the level of transport management. However, in regards to the product characteristics, it was shown that the impact of handling HAZMAT on the increment of the level of transport management was not significant.

The priorities, according to this study, are as follows. First, priority should be given to freight vehicles belonging to companies with a low level of transport management or business entities that do not perform pre-management, in-transit management, and post-management. Second, a higher priority must be given to the freight vehicles of small and local business entities with insufficient safety programs (such as education using transport management manuals and driver training) due to the burden of safety-related cost and the relative shortage of IT tools and infrastructure and management personnel. Third, among the business entities of the same size, priority should be given to those with high shipment frequency, longer shipment days, and higher HAZMAT handling rates. Finally, business entities with many freight vehicles or those handling flammable, combustible, and oxidizing materials should be monitored.

In this study, implications were drawn through the analysis of the transport management behavior of HAZMAT handling business entities. In the future, it is necessary to study more empirical methods for setting priorities based on the data obtained from the entire HAZMAT transport vehicle population. Moreover, empirical studies using the data obtained before and after the actual monitoring of HAZMAT transport vehicles and studies geared at identifying the entire population of HAZMAT handling business entities and transport companies need to be conducted. Finally, studies on the priorities of transport management and the cooperative relationships among policymakers, system managers, traffic experts, business entity operators, and transporters who are related to the HAZMAT transport monitoring system will also be required.

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