IDENTIFYING RELATIONSHIPS BETWEEN SEVERE CRASH FREQUENCY AND CHARACTERISTICS OF OLD INDUSTRIAL COMPLEXES

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ABSTRACT

As industrial complexes that have been constructed to promote remarkable industrial and economic development in Korea have been aging, a variety of problems have risen. One of the problems is the human and/or property losses caused by traffic crashes occurred within industrial complexes. The purpose of this study is to identify a relationship between characteristics of old industrial complexes operated for more than 20 years and frequency of fatal and major injured crashes. The traffic accident data of each old industrial complex from 2011 to 2015 were collected from the Road Traffic Authority. For the analysis, a negative binomial regression model was estimated with a total of six independent variables representing the characteristics of industrial complexes and a dependent variable, frequency of severe crashes. Four variables were found to be statistically significant: type of industrial complex, location of industrial complex, number of tenant companies per square meter, and national industrial complex in the capital area. The results show that old industrial complexes that are vulnerable in terms of traffic safety are those that are large-scale complexes with many tenant companies, and are located outside the capital area. Therefore, while the Ministry of Land, Infrastructure, and Transport implements large regeneration projects for old industrial complexes, consuming massive amounts of the national revenue, the findings described here need to be considered when determining appropriate industrial complexes. In particular, old industrial complexes outside the capital area seem to more urgently require investments in the road infrastructure and efficient traffic management.

KEYWORDS
Severe crashes, Industrial complexes, Negative binomial regression model

INTRODUCTION

The Korean War, which broke out in 1950, caused enormous social and economic damage to Korea, nationwide. Since the 1960s, the Korean government has resolutely pushed ahead with economic development plans in order to recover from the devastation and to revive the collapsed economy. In this context, full-scale policies for industrialization began to be implemented. These efforts resulted in the remarkable industrial and economic development around Seoul, which is known as the “Miracle on the Han River.” One of the driving forces of the achievements is to

construct and manage industrial complexes, which are located over different regions (*1*, *2*).

An initial industrial complex focused on a factory site, which offered a minimum support facility. On the other hand, as new industrial locations and development policies have been implemented since 2000s, industrial complexes have become more complex. In addition to factory sites, they are connected to the knowledge-based industry, and include ICT-related facilities, data processing facilities, distribution facilities, residences for staff, and cultural, medical, tour, sports, and welfare facility services for users (*3*-*5*).

The construction of an industrial complex has many merits. First, an industrial site equipped with an infrastructure and that offers tax and financial benefits can reduce the initial investment costs of companies. Second, a business cluster formed in a complex may create synergy effects, which support the manufacturing activities of companies. Third, at a national level, the collective placement of factories promotes efficient land use, which reduces social and environmental costs (*6*). Thus, industrial complexes have become important in national economic policies around the world. According to the national statistics related to industrial complexes, as of 2016, Korea had 1,158 industrial complexes, of which 445 were built more than 20 years ago, and so are classified as old *(7)*.

However, along with these positive effects, there are still many problems, including an aging infrastructure and a degraded environment caused by development. In particular, industrial complexes that were constructed in the early 1960s have become less competitive because of the aging road infrastructure, which also presents a threat to safety. In addition, as old industrial complexes become incorporated into an expanding city, this causes environmental and traffic problems, as well as conflicts with local residents. Furthermore, the drastic increase in the number of cars has resulted in significant parking problems within complexes since the 1990s (*8*-*10*).

In addition, nearby traffic systems, including access roads to industrial complexes, are frequently congested with commuters, which yields congestion costs. However, the industrial site development plan and the basic industrial site management plan do not include alternative traffic links or concrete solutions. As a result, roads inside and outside industrial complexes become congested with the usual people/freight traffic directly related to the complex. Accordingly, efficient traffic management is difficult to implement, increasing the likelihood of traffic accidents (*11*).

In 2014, the Korea Transportation Safety Authority analyzed traffic accidents that occurred over a three-year period (2010–2012) in 18 old national industrial complexes. It was reported that the fatality rate of the accidents was about 1.7 times the national average (*12*). According to the statistics of traffic accidents provided by the Traffic Accident Analysis System (TAAS) of the Road Traffic Authority, 73,681 traffic accidents occurred over the five years from 2011 to 2015 in old industrial complexes. This is about 3.1 times higher than the number of accidents in “non-old” industrial complexes (23,912 crashes). If these figures are calculated for each complex, the gap becomes more remarkable. With regard to the annual average number of traffic accidents per complex, each complex in the old group had 33.12 traffic accidents per year, which is about 13.2 times the average value (about 2.47) of the non-old group. The old industrial complexes also

have far more accidents that result in death or serious injury than do the non-old complexes. Old industrial complexes have an average of 1.1 fatal accidents per year, which is about 1.8 times higher than in non-old industrial complexes (0.62)(*13*).

Although old industrial complexes are vulnerable to traffic accidents, few improvement projects have been implemented to investigate and solve the safety problems in a comprehensive way. Accordingly, those who work in these complexes are exposed to a hazardous environment, which requires urgent attention. Unfortunately, less research associated with traffic accidents in industrial complexes were found (*14*). The main objective of this research is to examine the relationship between the characteristics of each old complex and severe crashes occurred in old industrial complexes in order to improve highway safety in old industrial complexes,

KOREAN INDUSTRIAL COMPLEXES: AN OVERVIEW

An industrial complex is an area of land designated and developed according to a comprehensive plan. These complexes offer factory sites and facilities related to the ICT and knowledge industry, as well as resource storage and educational, data-processing, and distribution facilities. Industrial complexes aim to improve the functions of these facilities and to provide collective residential, cultural, medical, tourist, sports, and welfare facilities for employees and users. These complexes are designated and notified according to the Industrial Sites and Development Act (2009). Korea's first industrial complex was the Ulsan industrial center (now Ulsan national industrial complex), constructed in February 1962. The industrial complexes of Korea were planned and constructed according to the government-led economic development plan, which was implemented to help the devastated economy to recover and to help people escape from the severe poverty caused by the Korean War. The Ulsan national industrial complex was initially led by oil refinery and fertilizer plants, but then grew significantly as petrochemical plants and car factories were included(*4*).

The Industrial Sites and Development Act classifies four main types of industrial complexes. A national industrial complex fosters key national industries and advanced scientific and technological industries (*5*). These complexes also aim to develop regions that are underdeveloped in industrial terms or that extend over more than two jurisdictions. A general industrial complex promotes the regional distribution of industries and local economies. An urban high-tech industrial complex is located in an urban region in order to foster and develop knowledge, cultural, ICT, and other high-tech industries. Lastly, an agricultural-industrial complex attracts and promotes industries that can help residents of agriculture and fishing villages to increase their income.

According to the 2016 Status of the National Statistical Industrial Park, as of December 2016, a total of 1,158 industrial complexes had been constructed around the country. This represents a 137% increase from the number of 488 in March 2001, and an increase of about 9.1% per year. The 1,158 industrial complexes comprise 42 national industrial complexes (3.6%), 627 general industrial complexes (54.2%), 21 urban high-tech industrial complexes (1.8%), and 468 agricultural-industrial complexes (40.4%). Thus, most of these are general or agricultural-industrial complexes (*7*).

A total of 92,165 companies have moved into industrial complexes, which represents an increase of about 8% since 2015. Among the companies, 49,350 companies (53.3%) have moved into national industrial complexes, 36,086 companies (39.0%) have moved into general industrial complexes, 260 companies (0.3%) have moved into urban high-tech industrial complexes, and 6,919 companies (7.4%) have moved into agricultural-industrial complexes. These figures show that although there are relatively few national industrial complexes, they accommodate more than half the companies in all complexes.

Analysis of traffic accidents by type of industrial complex

Table 1 compares the numbers of traffic accidents occurred in industrial complexes from 2011 to 2015, using data from the road traffic accident database provided by the Road Traffic Authority (*15*). The accidents are compared at three levels: national and general industrial complexes, old and non-old industrial complexes (the latter includes all complexes except old complexes), and capital (Seoul, Incheon, and Gyeonggi-do) and non-capital areas.

TABLE 1 Comparison of Accident Frequencies between Old and Non-old Industrial Complexes

Year	Type	Region	Non-old Industrial Complex			Old Industrial Complex			(B) / (A)
			Number of Industrial Complex	Total number of crashes	Average number of crashes (A)	No. of Industrial Complex	Total number of crashes	Average number of crashes (B)	
2011	NIC	Capital	5	96	19.2	7	5,149	735.6	38.3
		Non-capital	21	651	31.0	16	5,798	362.4	11.7
	GIC	Capital	87	1,136	13.1	22	718	32.6	2.5
		Non-capital	268	2,575	9.6	43	2,837	66.0	6.9
2012	NIC	Capital	5	112	22.4	7	5,211	744.4	33.2
		Non-capital	24	760	31.7	16	5,837	364.8	11.5
	GIC	Capital	83	1,062	12.8	20	805	40.3	3.1
		Non-capital	268	2,683	10.0	44	2,904	66.0	6.6
2013	NIC	Capital	5	109	21.8	7	4,974	710.6	32.6
		Non-capital	23	751	32.7	16	5,595	349.7	10.7
	GIC	Capital	89	1,171	13.2	22	785	35.7	2.7
		Non-capital	280	2,626	9.4	45	2,809	62.4	6.6
2014	NIC	Capital	5	117	23.4	7	5,502	786.0	33.6
		Non-	23	837	36.4	16	5,756	359.8	9.9

Year	Type	Region	Non-old Industrial Complex			Old Industrial Complex			(B) / (A)
			Number of Industrial Complex	Total number of crashes	Average number of crashes (A)	No. of Industrial Complex	Total number of crashes	Average number of crashes (B)	
		capital							
	GIC	Capital	89	1,275	14.3	23	840	36.5	2.6
		Non-capital	268	2,782	10.4	44	2791	63.4	6.1
2015	NIC	Capital	5	162	32.4	7	6,096	870.9	26.9
		Non-capital	24	786	32.8	16	5,691	355.7	10.8
	GIC	Capital	91	1,435	15.8	23	855	37.2	2.4
		Non-capital	269	2,786	10.4	44	2,728	62.0	6.0
Total	NIC	Capital	25	596	23.8	35	26,932	769.5	32.3
		Non-capital	115	3,785	32.9	80	28,677	358.5	10.9
	GIC	Capital	439	6,079	13.8	110	4,003	36.4	2.6
		Non-capital	1353	13,452	9.9	220	14,069	64.0	6.5

Note: NIC: National Industrial Complex, GIC: General Industrial Complex

A simple comparison of the average number of accidents between old and non-old industrial complexes shows that old industrial complexes had between twice and 38 times as many accidents as did non-old complexes. More specifically, in the case of the non-old industrial complexes, a comparison between national and general industrial complexes in the capital area shows more accidents occurred in the national industrial complexes, on average. Among the national and general industrial complexes outside the capital area, national industrial complexes have more accidents than general complexes do, but the gap is larger than that in the capital area.

The statistics for the old industrial complexes are not that different to those of the non-old complexes. However, traffic accidents in national industrial complexes occurred between 10 and 20 times as often as in general complexes. In addition, old national industrial complexes in the capital area recorded a much larger average number of traffic accidents than complexes in the non-capital area did. On the other hand, the old general industrial complexes in the non-capital area showed a larger average number of accidents than those in the capital area.

DATA COLLECTION AND DESCRIPTION

Data for this research are divided into two types: the characteristics of old industrial complexes and data related to traffic accidents in each old industrial complex. The first type of data are extracted from the GIS-based industrial complex boundary layer, provided by the Industrial Sites Information Center of the Korea Research Institute for Human Settlements (KRIHS). For the

analysis, original data related to the characteristics of old industrial complexes were converted into five variables: type of industrial complex, geographical location, size of city where the industrial complex is located, and the numbers of tenant companies and employers per square meter. The type of industrial complex, geographical location, and size of a city are binary variables, whereas the numbers of tenant companies and employers per square meter are continuous variables. Among the four types of industrial complexes, only national and general industrial complexes are used in the analysis, because they were the focus of the project to regenerate and revitalize old industrial complexes. The geographical locations are divided into the capital area including Seoul, Incheon, and Gyeonggi-do, and the remaining area. In terms of size, cities are classified as metropolitan cities, with a population of more than one million, and all remaining cities.

It was initially assumed that the number of traffic accidents might be closely linked to the size of an industrial complex. Accordingly, the initial stage of the analysis was devoted to constructing a model by setting the designated area of each complex as a parameter. However, no significant result was found. This might be due to the fact that there is the difference between the designated area and the actual developed area of each industrial complex. Thus, the numbers of tenant companies and employers per square meter were used, because these reflect real conditions more accurately.

The traffic accident data for each old industrial complex were collected from the TAAS of the Road Traffic Authority. Data for five years, from 2011 to 2015, were used in the analysis. This research aims to identify the characteristics of old industrial complexes, where many traffic accidents result in death or serious injury, and, thus to determine which complexes urgently require an active regeneration project. As such, the number of accidents, including cases resulting in death or serious injury, is used as a dependent variable.

Table 2 presents basic explanations of each variable used in the analysis. A total of 87 old industrial complexes were surveyed for the analysis. The average number of severe crashes for the five years was 4,966, or about 57 cases per complex. The 87 old industrial complexes include 23 national industrial complexes (26.4%), and 23 complexes located in the capital area, representing nearly a third of the total number. In addition, 26 old industrial complexes are located in cities with a population of over one million. Thus, most of the analyzed complexes are located in a small or medium-sized city. The average number of tenant companies per square meter is 0.231, and the average number of employers per square meter is 5.996.

TABLE 2 Descriptive Statistics of Variables Used in the Analysis

Variables	Description	Mean	S.D.	Max	Min
SEVERE_CRA	Frequency of fatal and major injured crashes occurred within a 500m boundary of old industrial complexes	57.080	125.73	946	0
TYPE	Industrial complex type (1=National industrial complex, 0=otherwise)	0.264	0.443	1	0
LOC	Location of industrial complex (1=Seoul metropolitan area including City of Seoul, City of Incheon and Gyeonggi	0.333	0.474	1	0

Variables	Description	Mean	S.D.	Max	Min
	Province, 0=otherwise)				
SIZE	City size of industrial complex (1=population over 1 million people, 0=otherwise)	0.299	0.460	1	0
NCOM	Number of companies per ㎡ in a complex	0.231	0.543	4.458	0.0001
NWOR	Number of employees per ㎡ in a complex	5.996	10.498	82.74	0.104
TYPE*LOC	Interaction term between TYPE and LOC (1=National industrial complex located in Seoul metropolitan area, 0=otherwise)	0.080	0.274	1	0

ANALYSIS RESULTS

The purpose of this research is to clarify the relationship between the characteristics of old industrial complexes and the traffic accidents that occur in these complexes that result in at least serious injury. Six variables representing the characteristics of old industrial complexes were used as independent variables. The number of accidents resulting in death or serious injury in 2015 is set as a dependent variable.

For the analysis, a negative binomial regression model was employed since the dependent variable is count data. As shown in Table 3, four variables were found to be statistically significant at the 95% significance level: type of industrial complex, location of industrial complex, number of tenant companies per square meter, and national industrial complex in the capital area. In addition, an overdispersion parameter, α, were found to be significant, indicating that the industrial complex crash data are better fitted with a negative binomial model rather than a Poisson model.

TABLE 3 Estimation Results

Variables	Coefficient	Standard Error	P-value
Constant	2.788	0.248	0.000
TYPE	1.798	0.326	0.000
LOC	-1.062	0.330	0.001
SIZE	0.489	0.271	0.071
NWOR	-0.024	0.042	0.571
NCOM	1.261	0.606	0.037
TYPE*LOC	1.595	0.581	0.006
α	1.192	0.170	0.000

The results indicate that among the old industrial complexes, national complexes have a larger number of serious accidents than general complexes do. As mentioned above, this appears to be because national industrial complexes typically have many wide and straight roads. Thus, speeding occurs frequently, and many accidents are caused by traffic signal violations and occur at crossroads (*12*).

The old industrial complexes were found to be negatively related to serious accidents. This means that the old industrial complexes in the capital area had fewer serious accidents than those located outside the capital area. This result may be attributed to the fact that the old industrial complexes in the capital area have maintained the road infrastructure relatively well or travel speeds within them are not fast enough to cause serious accidents. It can also suggest that the old industrial complex has larger number of average traffic accidents than the non-old industrial complex but is not linked to relatively serious accidents.

The number of tenant companies per square meter is positively related to the number of accidents resulting in serious injury or death. This indicates that among the same types of industrial complexes, those that are densely developed and, thus, have a greater number of tenant companies, experience higher numbers of serious accidents. In addition, according to the research of the Korea Research Institute for Human Settlements (KRIHS), since a small-scale industrial complex with few tenant companies tends to follow a minimum standard of infrastructure, the problem of traffic congestion occurs relatively easily, which may be inferred to increase the number of traffic accidents (*16*).

The size of the area where an industrial complex is located is significantly related to the number of accidents resulting in serious injury or death at the 90% significance level. This could be because an old industrial complex located in a metropolitan city, which has a population of over one million, has actively utilized nearby land, which translates into a significant number of people and vehicles and, hence, traffic. This results in a more frequent incidence of serious accidents. This can also be understood as a transformation of the problem of old industrial complexes that were previously located near a city, but are now incorporated into the city, into a problem of traffic safety (*9*).

The variable denoting a national industrial complex located in the capital area is shown to have a positive relationship with the number of accidents resulting in serious injury or death. However, because this variable adjusts the degree of influence on the type and location of an industrial complex, the significance of the regression coefficient itself is not significant.

CONCLUSIONS

Since the 1960s, the Korean government has pushed ahead with economic development plans and, thus, full-scale policies for industrialization. Such efforts resulted in the remarkable industrial and economic development around Seoul, which is often called “Miracle on the Han River.” One of the key driving forces of this achievement is the concentrated construction of industrial complexes in different regions.

However, industrial complexes, along with their positive effects, also cause problems, such as an aging infrastructure and a degraded environment due to reckless development. In particular, the aging road infrastructure not only weakens the competitiveness of the complexes, but also threatens people’s safety. In addition, as an old industrial complex becomes incorporated into an expanding city, this causes environmental and traffic problems, as well as conflicts with local residents.

However, although old industrial complexes are vulnerable to traffic accidents, few improvement projects have been implemented to investigate and solve these safety problems in a comprehensive way. Accordingly, in order to improve the traffic safety in old industrial complexes, the main objective of this research is to examine the relationship between the characteristics of each old complex and the traffic accidents that occur in the complexes that cause at least serious injury.

Data on the characteristics of old industrial complexes were extracted from the GIS-based industrial complex information system, provided by the Industrial Sites Information Center of the Korea Research Institute for Human Settlements (KRIHS). The analysis data were constructed by arranging the parameters denoting the characteristics of old industrial complexes into five categories: type of industrial complex, geographical location, size of the city where an industrial complex is located, and the numbers of tenant companies and employers per square meter.

The traffic accident data of each old industrial complex were collected from the TAAS of the Road Traffic Authority. The data of five years, from 2011 to 2015, were used for the analysis. This research aimed to identify the characteristics of old industrial complexes, where many traffic accidents occur that result in death or serious injury and, thus, to determine which complexes urgently require an active regeneration project. Therefore, the number of accidents resulting in death or serious injury was used as a dependent variable.

Among the independent variables, being a national industrial complex, the number of tenant companies per square meter, and being incorporated into a metropolitan city were found to influence the incidence of traffic accidents resulting in death or serious injury, which is a characteristic of old industrial complexes. Among the old industrial complexes, national complexes had a larger number of serious accident than did general complexes. This may be because national industrial complexes typically have many wide and straight roads. As a result, speeding occurs frequently, and many accidents are caused by traffic signal violations and occur at crossroads. The number of tenant companies per square meter was found to have a positive relationship with the number of accidents resulting in serious injury or death. This indicates that even among the same types of industrial complexes, those that have been densely developed and, hence, have a greater number of tenant companies, experience higher numbers of serious accidents. Finally, because old industrial complexes located in a metropolitan city, which has a population of over one million, have actively utilized nearby land, there is more traffic, which results in an increased incidence of serious accidents. This can also be understood as the transformation of the problem of old industrial complexes that were located near a city, but have now been incorporated into the city, into a problem of traffic safety.

The results show that old industrial complexes that are vulnerable in terms of traffic safety are those that are large-scale complexes with many tenant companies, and are located outside the capital area. Therefore, while the Ministry of Land, Infrastructure, and Transport implements large regeneration projects for old industrial complexes, consuming massive amounts of the national revenue, the findings described here need to be considered when determining appropriate industrial complexes. In particular, old industrial complexes outside the capital area seem to more urgently require investments in the road infrastructure and efficient traffic management.

ACKNOWLEDGMENT

This paper was written as a part of a R&D project on “Development of Road Infrastructure Efficiency and Environmental Performance Improvement Technologies for Decrepit Industrial Complex (2/5)” sponsored by the Korea Agency for Infrastructure Technology Advancement(KAIA). The authors would like to thank everyone who provided assistance to this study.

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