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Exposure to Fear: Changes in Travel Behavior During MERS Outbreak in Seoul

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Abstract

Disaster management teams could learn much from the Middle East Respiratory Syndrome (MERS) outbreak in South Korea in 2015. The virus outbreak provoked public fear, which resulted in a mass reduction in transit use in the Seoul Metropolitan Area (SMA). Its effect differed among socioeconomic groups and geographical areas. A typical way to analyze this is to associate individual reactions to the disaster with socioeconomic characteristics. However, a more structured approach, which considers behavioral characteristics resulting from the societal position of an individual, would identify the basic reason for such associations. The study hypothesized that the degree of fixity that individuals have in their daily life may elucidate these associations. When fear is prevalent, people having the flexibility to change their lifestyle will make more changes in daily activities and travels. The study examined the influence of public fear of a pandemic disease on travel behavior and the effect of life fixity on individual response to the fear. To this end, smart card data of transit use and changes in travel behavior during the MERS period were examined. The study found that fear was powerful and influenced travel behavior differently depending on life fixity levels and regional characteristics.

Keywords: *MERS, disaster management, travel behavior, fear, life fixity*

1. Introduction

On May 20, 2015, the Middle East Respiratory Syndrome (MERS) outbreak was reported in South Korea. The disease is a viral respiratory illness that is new to humans and can cause the development of severe acute respiratory illness (Centers for Disease Control and Prevention, 2015), with a death rate of nearly 20%. Fear of the disease was prevalent in South Korea, particularly in the Seoul Metropolitan Area (SMA), which is a high-density populated area with more than 20 million people. The fear was pandemic, and people refrained from normal daily activities such as going out. The first patient affected by the disease was reported by the news media to the public on May 20, 2015, and the number of patients increased every day. The central government did not release information on the hospitals treating the affected patients to the public (Newsweek, 2015). Fear exponentially grew among the citizens because the disease was known to be contagious, and the hospitals where the patients were being treated were not known by the public. Dozens of new patients affected by the disease were identified, and the number of people who self-quarantined to avoid exposure to the disease exceeded 1,000 on June 3, 2015. The central government of South Korea officially released information on the (potentially) affected hospitals on June 7, 2015. However, fear was already widespread, and there were concerns about the possibility of community infection. The pandemic level was gradually reduced toward the end of June since the number of those isolated was greatly reduced around the middle of June. Most people returned to their normal daily activities from the beginning of July.

For disaster management purposes, policy measures should take into account different possible outcomes for the same source of risk, depending on the group of people and characteristics of the area at risk. The experience with MERS revealed that different aspects of the social system should be improved for better safety at the national and community levels. Although the disease was proven to be not very contagious at the community level, disaster management should take into account not only the effect of the disease in a medical context but also the effect of fear. Fear can manifest when there is insufficient information. As the World Health Organization (WHO) pointed out when it started its investigation in Korea on June 9, 2015, the central government failed to appropriately provide information on the

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disease (Yonhap News, 2015), and public fear was centered on disease hotspots, followed by the overestimation of the contagiousness of the disease. The study focused on differences in the influence of fear between different people and different areas when there is a high level of fear. Some people may feel more fearful than others may. Certain incidents may cause more fear among people than other incidents. Some areas may be affected more so than other areas.

The response of the public to fear typically results in changes in travel behavior, and transportation-related disaster management should identify the different types and degrees of behavioral changes between various focus groups. Choi *et al.* (2014) studied the influence of social changes on travel behavior in South Korea. They analyzed household travel survey data over eight years from 2002 to 2010 and found that the temporal and spatial characteristics of changes in travel behavior were associated with socioeconomic or regional characteristics and travel characteristics. Elias *et al*. (2013) studied the factors that affect travel behavior when there are terror threats. They used an ordered logit model showing that fear and risk perception are important for understanding travel when under terror threats in two cities in Israel. Women were found to be more sensitive to fear, and their travel behavior was affected more substantially. People preferred cars the most, followed by taxis when they do not use buses. Wen *et al.* (2005) analyzed the influence of SARS (Severe Acute Respiratory Syndrome) on Chinese consumer behavior and their leisure travel. The results revealed that SARS greatly affected the daily life of people and played a role in changing tour choices and travel patterns. Women and lower education groups were affected more than other groups. Liu *et al*. (2011) examined the effect of SARS on air travel in U.S., China, Hong Kong, and Taiwan using the ARIMA model. Worldwide fear negatively affected air travel among those countries; however, fear of the risk was perceived differently between countries, thus reflecting different life styles. Fenichel *et al.* (2013) examined the hypothesis that individuals practice a voluntary action of defense when there is a risk of contagious disease. They tested the hypothesis by assessing the number of passengers who gave up air travel because of concerns of being infected by the contagious disease. The results revealed that people took self-defensive action against the contagious disease; however, this did not seem to be in accordance with risk level. Rittichainuwat and Chakraborty (2009) studied the effect of both terror and disease threats on hospitality business in Thailand. They found that seasoned travelers were less fearful of disease and terror threats in general; nevertheless, certain fatal diseases such as SARS strongly influenced the travel behavior of visitors. Keane (1998) more directly focused on fear itself when analyzing the behavior of women. The research found that women's fear of crime restricted their movement, and the number of alternative options was increased when fear was eliminated. Finally, Church *et al.* (2000) reported a similar finding, suggesting that the exclusion from fear is a category of social exclusion. They claimed that social characteristics, gender, and the use of public space and transportation affect the fear of public spaces.

These studies contributed to the analysis of the association between threats or risks and activity behavior. They found that general behavior and particularly travel behavior are affected by threats, and the degree of influence depends on socioeconomic groups and other factors. Nevertheless, a more in-depth investigation is required to reveal why different socioeconomic characteristics and other factors result in different degrees of behavioral changes given the same threats or risks. This study aimed to initiate the discussion on why and how socioeconomic characteristics affect travel behavior differently in our daily lives. To this end, this study analyzed a large data set of transit (bus and subway) use and revealed the differences in travel behavior among different social and geographical groups. In addition, the cause of such differences was further investigated. We concluded with a summary of the findings and discussion of further research direction.

2. Research Concept

The study proposed the life fixity concept to understand the differences in travel behavior among different groups of people and geographical areas. As discussed previously, existing studies have investigated the association between socioeconomic characteristics and behavioral changes when under threats and risks. However, the suggested causal relationship typically lacks a basic explanation of why such an association has been built. We hypothesized that a conceptual device of activity-based approach is required to provide an in-depth and more transferable reasoning of the association between the two. Life fixity is the opposite of the flexibility or degree of freedom to change the details of daily life. It can be defined as the degree of difficulty to change the details of daily life. If a typical day is full of mandatory responsibilities, the person would have no other choice but to perform all activities as scheduled. Therefore, his/her daily schedule is not sensitive to any demands for change. This reasoning is in line with the notion of time geography (Pred, 1977, 1981a, 1981b), from which activity-based transportation studies were initiated (Ettema and Timmermans, 1997). Travel is derived from activity participation; thus, any change in travel behavior would be affected by the degree of life fixity. If one's daily life is extremely fixed, changes in travel behavior will not occur.

The current study demonstrated that life fixity largely determines the strength of the association between socioeconomic or other factors and behavioral changes when under threats and risks. We did not intend to provide a rigorous definition of life fixity nor measure the degree of fixity of individual groups or geographical areas. Rather, this study attempted to perform activity-based reasoning to explain the different travel behavior in response to the same external influences and further open the possibility of other explanations.

As a case study on the role of life fixity in behavioral change, the study analyzed the influence of contagious disease on changes in travel behavior. The recent outbreak of MERS in South Korea is a suitable case to examine the role of life fixity. The disease caused a great deal of fear rather than medical fatalities at the societal level. The actual contagious rate of MERS was proven to be much lower than that of other well-known pandemic diseases such as SARS. Nevertheless, South Korea went into a state of panic in May and June 2015 because of fear. Public fear had a strong mental influence on everyone, forcing them to dramatically change their normal daily activities to alternatives that may be safer. Nevertheless, the degree of change was not the same between different people. People considerably altered their daily activities if they could easily make such changes. Those who were not able to make such changes easily because of the strong fixity in daily life did not alter their daily activities as much as they might have wanted.

The study did not directly measure the life fixity of an individual; instead, average land price was used in the measurements. We hypothesized that life fixity has a high correlation with social status and income level. One of the representative indicators of the social status and income level of individuals is the land price of the area where they live. Seoul, like many other major cities in the world, has rather clear geographical divisions of neighborhoods with varying social statuses, which are frequently represented by the different average land prices of the corresponding neighborhood. The study assessed the overall change in travel behavior during the MERS outbreak and revealed the differences in behavioral change according to the land price of the neighborhood and the MERS-affected area. The resulting analysis generated statistical inferences to generalize the findings at the Transportation Analysis Zone (TAZ) level. The study also derived some implications from the analysis results.

3. Data and Analysis Results

The analysis was focused on the MERS outbreak reported in South Korea on May 20, 2015, and on the fear that persisted until the end of June. The capital city of Seoul, the area of this study, is located at the center of the Korean peninsula and consists of 424 administrative units (*dongs*) with an area size of 605 km^2 and a population of 10 million peoplemillion. On average, a dong in Seoul has an area size of 1.42 km^2, a population size of 23,584 inhabitants, an employment size of approximately 12,000 workers, a population density of 16,609 inhabitants per km^2, and an employment density of 8470 workers per km^2. The city also has a highly dense network of roads and railways. Seoul has 278 subway stations with 331.9 km of railways, which can accommodate more than 5 million passengers (including net and transfer) every day as of 2014. Seoul is one of three large local governments of the SMA, which consist of the city of Seoul, the city of Inchon, and Gyeonggi province. The transit system is closely connected with subway and bus lines within the SMA region. When transferring to another mode of transport within the SMA, passengers pay only the additional costs that are calculated by subtraction of the precedent mode fee from the subsequent mode fee. The company that operates Smart Card mainly manages the transactions in Seoul, and the company that operates EB Card mainly manages the transactions in Gyeonggi and Inchon. Although two different companies are involved, the two cards have the same function. The current study obtained transit use data of Smart Card transactions; thus, the analysis was mostly on travel in Seoul (about 90% of the data obtained). It should be noted that TAZ, the basic unit of transportation data collection and analysis, is almost the same with the administrative unit (*dong*) in Seoul. This is because transportation analysis should be linked to population data that are available at the dong level in Seoul. Hence, the number of TAZs of Seoul is the same as the number of *dongs*.

3.1 Data

The study used three kinds of data: Smart Card transaction data of individual transit use, average land values of a TAZ, and locations of potential MERS hotspots in Seoul. First, smart card data of individual transit use were collected on May 20, 2015, when people first knew about MERS, and on June 10, 2015, when public fear was at an extremely high level. The data contained a log of the trips of each individual who uses Smart Card for transit from the first "get-on" until the last "get-off" event of a particular day. The information on each trip included an encrypted personal ID (which is valid only for the day), user type (adult, children, youth, senior, disabled, and national merit), transport mode used (village bus, local bus, mainline bus, outer bus, circular bus, and subway), a flag for transfer, bus line ID, service operator ID, vehicle ID, departure time, departure bus stop or subway station ID, arrival bus stop or subway station ID, the number of accompanying passengers, get-on fare, and get-off fare.

Second, data on land price per square meter averaged of each TAZ were obtained from the Ministry of Land, Infrastructure, and Transportation. Land price was used as a representative indicator of the various socioeconomic statuses or income levels averaged across individuals in each TAZ. Seoul has a clear socio-spatial segregation within its territory. The old downtown and new city center have areas of very high housing values and land prices; those who are well-off live in these areas. A recent analysis of big data on the Korean national health insurance conducted by a medical expert revealed that living location determines life standard and even life expectancy (Daily Hankook, 2015). Therefore, this study hypothesized that people living outside of these areas would have a higher level of life fixity and thus less sensitive to external demands for change in daily activities as their income is on average lower than the income of those living in those areas. Given the overall change in response to the threat of MERS, areas with high land prices would show a bigger change in travel behavior because of the low level of life fixity, whereas other areas with low land prices would show a smaller change because of the high level of life fixity. In addition to land price, the data of other characteristics were also collected at the TAZ level for statistical inference.

Finally, the study identified 31 potential MERS hotspots, which were TAZs with locations that people suspected as sites with a high risk for disease transmission. The potential hotspots included 5 big transport terminal complexes and rail stations, 3 grand stadiums, 4 big gathering places, 7 hospitals and clinics that the central government announced as the medical facilities (potentially) affected by the disease, and 12 other big general hospitals in Seoul. They were the major locations that people feared during the MERS outbreak because the disease was believed to be highly contagious, and those locations were regarded as high-risk places that should not be visited.

3.2 Analysis Results

3.2.1 Significant Influence of Fear on Travel Behavior

People in Seoul traveled much less following the MERS outbreak in 2015. Activity on May 20 was normal like any other day, whereas fear peaked on June 10 during which the number of trips was sharply decreased by 11.8%. This large reduction in public transit use in a short period of time could not be explained by any other reason except a pandemic situation. The number of people traveling was also reduced by 10.8%. The number of trips per person dropped from 2.80 to 2.77, and the number of tours was reduced from 1.95 to 1.91. Total travel cost per person was also reduced from USD 1.76 to 1.74, and total travel time was reduced from 62.63 to 60.40 min. The number of people who visited the TAZs with potential MERS hotspots was sharply decreased by 13.88%, whereas the number of people who visited the TAZs without potential MERS hotspots was decreased by only 8.80%. The situational change resulting from fear is illustrated in Table 1. The data revealed that tourists had an extreme response to fear, and subway use was affected much more compared with buses. People may suspect subway stations to have a higher risk for disease transmission because of the higher traffic of people at these places than at bus stops.

3.2.2 Role of Life Fixity

Table 2 shows the difference in travel behavior according to type of smart card user. Kids and senior users drastically reduced their use of public transport, whereas adults and youths only slightly reduced public transport use. A number of primary schools were closed for several days during the MERS outbreak because of fear of disease transmission, and parents were very much reluctant to send their children to school at this time. A large reduction in senior citizens traveling was also observed because the disease is known to be particularly deadly to them. Adults who had to work and youths who were strictly required to attend classes showed a smaller % change than others in trip frequency as they have higher life fixity. It is interesting to see that the school system is rather different between primary and secondary schools in terms of their rigidity in studying time during the MERS outbreak. Some primary school kids who normally travel by public transport were driven by their parents with private cars to schools. Nevertheless, a distinct difference still existed between the two school systems; most primary schools were closed during the pandemic period, but most secondary schools followed their usual academic calendar because of the tight schedule in studying for university entrance examinations.

Table 1. Decreases in Trip Frequency According to Transport Mode

	5/20	6/10	% Change
Village bus	1335262	1204578	-9.8
Local bus	2311655	2090676	-9.6
Mainline bus	2445268	2215638	-9.4
Outer bus	1134441	1014565	-10.6
Circular bus	4949	3096	-37.4
Subway	5819761	4983266	-14.4
Total	13051336	11511819	-11.8

Note: Village bus mainly connects people to the nearest subway station. Mainline bus is a long-range line in the city. Circular bus has a short line for connecting the main tourist spots in the city.

Table 2. Decreases in Trip Frequency According to User Type throughout the Day

	5/20	6/10	% Change
Adult	3827380	3464998	-9.47
Kid	63456	49768	-21.57
Youth	328349	299242	-8.86
Senior	358596	271407	-24.31
Disabled	83683	71412	-14.66
National merit	7688	6377	-17.05
Total	4669152	4163204	-10.8

Note: Kids are at primary school age, and youths are at secondary school age. People with senior, disabled, or national merit status can use the subway free of charge.

Another example of the role of life fixity was demonstrated during peak hours. The number of people who traveled during off-peak hours was decreased by 12.77%, whereas the number of people who traveled during peak hours (7 to 9 am) at least once on the day was decreased by only 7.22%. This finding strongly indicated that work and school responsibilities increase life fixity, leaving less room for changes in daily activities. Moreover, people tend to refrain from going out when there is no obligation to do so.

The role of life fixity was also demonstrated when comparing Table 3 with Table 1; the comparison revealed that reduction in the frequency of subway use was much smaller during peak hours than during the entire day. This indicated that people refrained from taking the subway as much as possible during the

Table 3. Decreases in Trip Frequency According to Transport Mode during Peak Hours

	5/20	6/10	% Change
Village bus	252872	235393	-6.9
Local bus	411366	387922	-5.7
Mainline bus	396444	375270	-5.3
Outer bus	212081	193594	-8.7
Circular bus	329	271	-17.6
Subway	1105042	1015247	-8.1
Total	2378134	2207697	-7.2

day, but they were not able to do so when they have to take the subway during peak hours, which are typically associated with work or school responsibilities.

3.2.3 Life Fixity and Potential MERS Hotspots

Life fixity, which was represented by land price, had an effect on the general change in travel behavior and particularly transit get-on frequency during peak hours, whereas potential MERS hotspots did not have a direct effect on trips during peak hours. Transit get-on frequency had a high correlation with residential area, which in turn was related to land price or life fixity. Since a land price value in Korean Won is a very large number, a natural logarithm transformation was used instead. On the other hand, destination had a more direct relationship with out-of-home activities, which might be near potential MERS hotspots. Fig. 1 shows that land price had a high correlation with reduction in transit get-on frequency during peak hours. The relationship between the location of potential MERS hotspots and reduction in transit get-off frequency is also shown in Fig. 2.

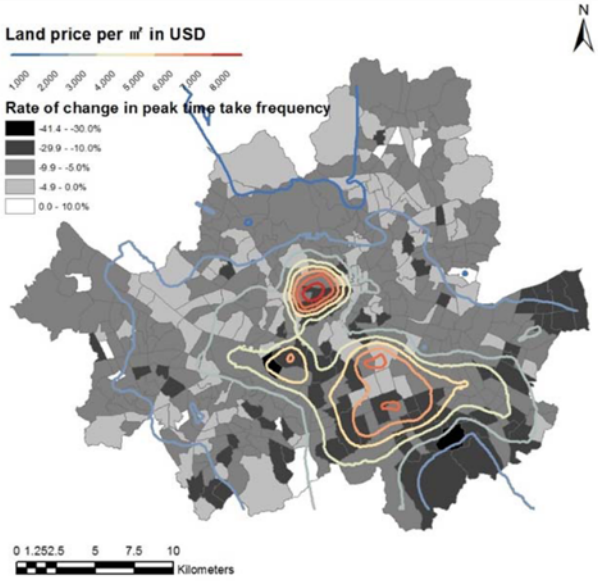

Fig. 1. Land Price Contour and Rate of Change in Transit Get-On Frequency during Peak Hours

A statistical test of the relationship between the variables is shown in Table 4 and 5. The Pearson correlation result in Table 4 shows that land price level significantly affected transit get-on

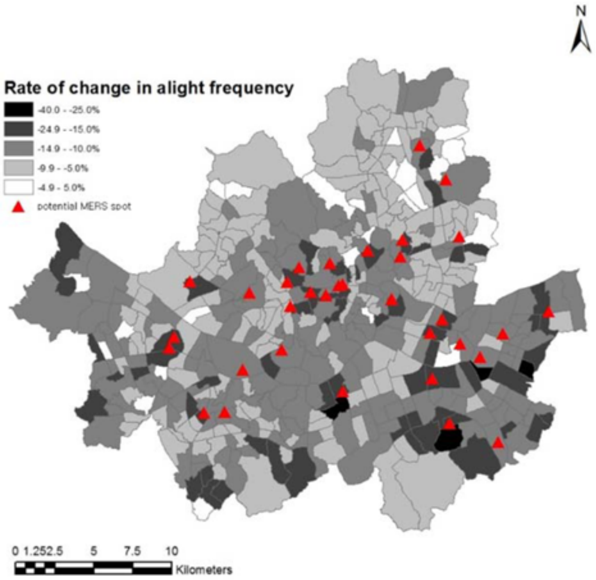

Fig. 2. Potential MERS Hotspots and Changes in Transit Get-Off Frequency (Alight)

Table 4. Pearson Correlation Coefficients between Average Land Values of a TAZ and Changes in Travel Behavior

Whole day					
Get-on	Get-off	Get-on (bus)	Get-on (subway)	Get-off (bus)	Get-off (subway)
-0.261**	-0.231**	-0.138**	-0.241**	-0.125*	-0.196**
Peak hour					
Get-on	Get-off	Get-on (bus)	Get-on (subway)	Get-off (bus)	Get-off (subway)
-0.254**	-0.041	-0.062	-0.433**	-0.026	0.062

Note: *, **, and *** indicate significance at the level of a = 0.1, 0.05, and 0.01, respectively.

Table 5. T-Test of the Differences in Travel Behavior between the TAZs with and without MERS Hotspots (31 TAZs vs. Other 393 TAZs)

Whole day												
	Get-on		Get-off		Get-on (bus)		Get-on (subway)		Get-off (bus)		Get-off (subway)	
TAZs with and without MERS hotspots	without	with	without	with	without	with	without	with	without	with	without	with
Av	-10.42	-15.09	-10.61	-14.91	-9.22	-12.54	-13.51	-17.55	-9.43	-12.87	-14.08	-17.21
p	0.000		0.000		0.000		0.001		0.000		0.006	
Peak hour												
	Get-on		Get-off		Get-on (bus)		Get-on (subway)		Get-off (bus)		Get-off (subway)	
TAZs with and without MERS hotspots	without	with	without	with	without	with	without	with	without	with	without	with
Av	-6.92	-7.12	-6.86	-8.98	-5.87	-5.27	-8.65	-9.67	-6.03	-8.46	-8.66	-12.01
p	0.799		0.180		0.528		0.342		0.152		0.075	

Note: Av indicates the average rate of change in trip frequency.

and get-off frequency throughout the day and particularly transit get-on frequency during peak hours. Higher land value was associated with a higher reduction in trip frequency. However, unlike whole day statistics, peak hour statistics had several variables that were not significant. This indicated that people traveling during peak hours were less sensitive to external demands for behavioral change, which weakened the influence of land value on behavioral change during the MERS outbreak. The results in Table 5 revealed several trends. First, the reduction in trip frequency was bigger in TAZs with MERS hotspots than in those without MERS hotspots for all variables. Second, the overall reduction was much smaller during peak hours than throughout the day. Finally, the difference in reduction between the areas with and without potential MERS hotspots was much smaller during peak hours compared with the entire day. The results strongly suggested that although the potential MERS hotspots influenced behavioral changes throughout the day, they did not have a direct influence on behavioral change in people with high life fixity during peak hours.

3.2.4 Factors that Significantly Influence Behavioral Change

The statistical significance of our observations was further assessed using a set of regression analyses to identify the factors that significantly contribute to the change in travel behavior during MERS outbreak. Changes in travel behavior can be explained by changes in trip frequency. For changes in trip frequency, we considered three factors: change in total trip frequency, change in bus trip frequency, and change in subway trip frequency.

These factors were regressed by a set of TAZ characteristics, including land price, whether the TAZ had potentially problematic hotspots, the number of companies, the number of individuals over 65 years old, the number of primary school children, the number of accommodation businesses, the number of day care centers, the number of restaurant businesses, the number of health care institutions, and whether the TAZ had fresh food markets. Prior to regression analyses, we examined the overall correlation between these explanatory variables and changes in trip frequency, as shown in Table 6 and 7. Most explanatory variables were significantly associated with all three variables of trip frequency change. Land price, potential MERS hotspots, and other public gathering places had significant effects on the reduction in trip frequency with the exception of marketplaces. However, age-related explanatory variables showed a different pattern. The number of senior citizens in a TAZ only demonstrated a significant correlation with bus trip reduction; this may be because they normally rely on buses more than other modes of transport. On the other hand, the number of primary school children in relation to changes in trip frequency seemed to be unaffected by MERS outbreak. This may be because a neighborhood with a higher number of kids normally has a higher number of young married couples who typically have a lower income. These neighborhoods often have low land prices, and land prices demonstrated high negative correlations with the trip frequency variables.

Each of three variables of trip frequency change was used in a regression equation to identify influencing explanatory variables. Given a statistical significance of $a = 0.05$, the identified influencing variables of all three equations were land price, potentially problematic hotspots, and the number of restaurant businesses, as shown in Table 8. The number of companies and the number of individuals over 65 were also found to influence changes in subway trip and bus trip, respectively. These changes may indicate that people who work at business centers in Seoul rely on the subway system for commuting, whereas senior citizens frequently use the bus network to travel short distances. When the values of these explanatory variables increased, trip frequency decreased. One exception was the number of accommodation businesses that inversely affected the increase in bus trips.

With regard to spatial autocorrelation issues, we performed diagnostic tests for spatial dependence in a total trip model, as shown in Table 9. Moran's I estimation for measuring spatial

Table 6. Pairwise Pearson Correlation Coefficients between TAZ Characteristics and Changes in Trip Frequency

Changes TAZ / Characteristics	v1	v3	v4	v5	v6	v7	v8	v9
Change in total trips	0.008**	-0.554**	0.020	0.071	-0.421**	0.110*	-0.620**	-0.402**
Change in bus trips	-0.070	-0.421**	-0.160**	-0.058	-0.333**	-0.033	-0.507**	-0.276**
Change in subway trips	0.036**	-0.508**	0.084	0.107*	-0.381**	0.145**	-0.555**	-0.380**

Note: v1 = natural logarithm of land price (KRW); v3 = the number of companies; v4 = the number of individuals over 65; v5 = the number of primary school children; v6 = the number of accommodation businesses; v7 = the number of day care centers; v8 = the number of restaurant businesses; v9 = the number of health care institutions.

Table 7. T-Test of the Differences in Trip Frequency before and after MERS Outbreak in Relation to the Effect of MERS Hotspots and Markets

Case		n	Total					Bus					Subway				
			mean	s.t.d.	*t*	d.f.	sig.	mean	s.t.d.	*t*	d.f.	sig.	mean	s.t.d.	*t*	d.f.	sig.
v2	No	394	5331.9	6190.19	-3.92	30.47	0.00	2333.72	2074.28	-4.11	30.14	0.00	2999.03	5924.14	-3.145	30.68	0.00
	Yes	30	14072.67	12065				5438.23	4100.58				8634.43	9677.34			
v10	No	257	5535.1	6636.11	-1.38	422	0.17	2484.64	2317.37	-0.73	422	0.47	3050.84	5236.8	-1.39	422	0.17
	Yes	167	6589.4	9094.89				2659.16	2538.13				3931.66	7875.01			

Note: s.t.d. is standard deviation; v2 = whether the TAZ had potentially problematic hotspots; v10 = whether the TAZ had markets.

Table 8. Regressions of the Changes in Total Trip Frequency, Bus Trip Frequency, and Subway Trip Frequency

	Change in total trip frequency				Change in bus trip frequency				Change in subway trip frequency			
	β	s.e.	*t*	sig.	β	s.e.	*t*	sig.	β	s.e.	*t*	sig.
v0	6724.60	1782.14	3.77	0.00	1723.33	604.40	2.85	0.00	5001.20	1598.76	3.13	0.00
v1	-734.81	217.47	-3.38	0.00	-192.65	73.75	-2.61	0.01	-542.08	195.09	-2.78	0.01
v2	4451.85	1122.59	3.97	0.00	2149.55	380.72	5.65	0.00	2301.91	1007.08	2.29	0.02
v3	0.86	0.28	3.01	0.00	0.10	0.10	1.02	0.31	0.76	0.26	2.96	0.00
v4	-0.32	0.49	-0.64	0.52	0.51	0.17	3.06	0.00	-0.83	0.44	-1.87	0.06
v5	-0.08	0.60	-0.13	0.90	-0.05	0.20	-0.22	0.82	-0.03	0.54	-0.06	0.95
v6	-8.87	10.23	-0.87	0.39	-7.62	3.47	-2.20	0.03	-1.24	9.17	-0.14	0.89
v7	-47.97	50.19	-0.96	0.34	-3.76	17.02	-0.22	0.83	-44.00	45.02	-0.98	0.33
v8	10.27	1.67	6.16	0.00	3.63	0.57	6.43	0.00	6.64	1.50	4.44	0.00
v9	21.38	8.17	2.62	0.01	2.15	2.77	0.78	0.44	19.22	7.33	2.62	0.01
v10	-320.24	616.15	-0.52	0.60	-149.83	208.96	-0.72	0.47	-169.60	552.75	-0.31	0.76
	$R^2 = 0.467$				$R^2 = 0.371$				$R^2 = 0.381$			

Note: s.e. is standard error; v0 = constant; v1 = natural logarithm of land price (KRW); v2 = whether the TAZ had potentially problematic hotspots; v3 = the number of companies; v4 = the number of individuals over 65; v5 = the number of primary school children; v6 = the number of accommodation businesses; v7 = the number of day care centers; v8 = the number of restaurant businesses; v9 = the number of health care institutions; v10 = whether the TAZ had markets.

Table 9. Diagnostics for Spatial Dependence Using Queen's Contiguity-Based Spatial Weight Matrix

Tests for total trip	MI/DF	t	sig.
Moran's I (error)	0.02	1.06	0.29
LM_{LAG}	1.00	1.31	0.25
Robust LM_{LAG}	1.00	0.66	0.42
LM_{ERROR}	1.00	0.66	0.42
Robust LM_{ERROR}	1.00	0.01	0.91
Portmanteau test (LM_{SARMA})	2.00	1.32	0.52

Note: MI = Moran's I score; DF = 10 (the number of independent variables); $LM_{SARMA} = LM_{EROOR}$ + Robust LM_{LAG}.

Table 10. A Test of Regression Model

Regression diagnostics	Total trip	Bus trip	Subway trip
Multicollinearity condition number	23.793948		
Test for normality of errors (Jarque-Bera)	527.2373	310.3352	870.384
Diagnostics for heteroscedasticity (Breusch-Pagan test)	256.3838	104.1665	363.3333

autocorrelation in regression models (Anselin, 1995) showed an estimated score (0.02) that indicated no suspected spatial autocorrelation of the residuals. A set of additional tests for spatial dependence were further conducted. Five statistics were selected for testing spatial dependence using Geoda program. This straightforward testing approach used Lagrange Multiplier (LM) tests based on the residuals of the OLS regression model (Lee and Park, 2013; Anselin, 2010). A simple LM test for a missing spatially lagged dependent variable and error dependence and a robust LM were performed, which were required to develop a Spatial Autocorrelation Regression (SAR) model. All the LM tests were insignificant, implying there were no benefits to further develop an SAR model in this study.

Table 10 provides additional information on the regression model, indicating that this model had no suspected multicollinearity problem, and all the exploratory variables following the homoscedasticity from the results of normal distribution of error term (Jarque-Bera test) and diagnostics for heteroscedasticity in error terms (Breusch-Pagan test). Indeed, the test results confirmed that there were no spatial spillover effects (spatial dependence) in the data sets.

Overall, it can be said that life fixity and pandemic-specific characteristics of the TAZs affected travel behavior. The identified influential variables represented life fixity (land price and the number of restaurant businesses) and pandemic-specific characteristics (whether the TAZ had potentially problematic hotspots, the number of businesses, and the number of individuals over 65). People often enjoy eating out. However, eating out is not a daily responsibility and thus easily affected by external factors. It was not economic factors but MERS that influenced the eating-out behavior of people. The use of the subway system, the main transport mode for commuting to business places, was reduced during MERS outbreak. The use of busses, the main transport mode of senior citizens, was also reduced during MERS outbreak.

4. Conclusions

The study aimed to examine the role of life fixity to initiate the discussion on why and how socioeconomic characteristics affect travel behavior differently in our daily lives. To this end, we analyzed the smart card data of transit use in Seoul before and after the MERS outbreak in South Korea. In addition, the differences in travel behavior among different geographical areas and groups of people were investigated. We proposed an activity-centered concept of life fixity. The concept of life fixity was not explicitly defined here; however, it would help understand the different degrees of behavioral changes in response to external influences.

The study identified several key findings. First, fear had a significant influence on travel behavior. Second, life fixity, the degree of which was represented by land prices, was relevant when determining the extent of behavioral change. Third, life fixity and potential MERS hotspots were affected in different manners. Life fixity affected the overall reduction in trip frequency and particularly transit get-on frequency. People living in neighborhoods with higher land prices were found to reduce transit use more than others do. However, the potential MERS hotspots did not have a significant influence on behavioral change during peak hours even though they had a general effect on travel frequency throughout the day. Finally, regression analysis statistically demonstrated the influence of land price, MERS hotspots, and some other geographical variables on the change in travel behavior. In addition, regression analysis identified the influential variables that caused the reduction in trip frequency during MERS outbreak, which included land price, whether the TAZ had potentially problematic hotspots, the number of businesses, the number of individuals over 65, and the number of restaurant businesses. These variables reflected either the effect of life fixity or pandemic-specific characteristics of the TAZs.

Further research needs and objectives were identified. First, transit user type, transport mode, and travel time of the day should have a close relationship when explaining the changes in travel behavior during MERS outbreak. A set of cross-correlation studies and additional spatial analyses using GIS would be required. Second, a rigorous measure of life fixity needs to be developed. This concept has a strong social implication and is an interdisciplinary theme in topics of transportation science, geography, urban planning, sociology, and psychology. A defined measure would provide a better understanding of the different behavioral changes in response to external influences. Third, spatial resolution can be an issue. If any suspicious MERS hotspot is relatively small within a TAZ, the influence of MERS on trip reduction will be small, and the influence will be the other way around if the MERS hotspot is relatively large. Therefore, a buffer boundary around the MERS hotspot, instead of a TAZ boundary, should be investigated. Finally, there should be some regularity in the pattern of change in travel behavior itself. The mathematical functional relationships representing the behavioral changes over time could be formed by different socioeconomic groups and geographical areas.

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