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A Study on Passenger Level Change Mode Choice in a Public Transport Transfer System -Gwangmyeong station case-

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Abstract: Public transportation has become more important as natural resources are exhausted and environmental pollution increases. However, there are many factors that interrupt the use of public transportation, including cost, in-out vehicle time, level of service and transfer. To encourage the use of public transportation, local governments have reduced public transport transfer fares, thereby eliminating a major obstacle. However, key issues beyond cost and transfer have a large effect on passenger usage of public transportation. This study estimates the effects of passenger choices at change facilities. This study collected data at Gwangmyeong station in South Korea. The effect on passenger-level change facilities choice consists of change facility user time, route moving time and overlap facilities (path-size). The result shows that the escalator was preferred for increasing route moving time and path-size. The escalator is the most efficient means for passengers to move a long distance through a large transfer system.

Key Words : *Public transportation, Level change, Mode choice, Path-size, Gwangmyeong station*

1. INTRODUCTION

Public transportation, which could decrease social costs, is a very important issue. It has become more important as natural resources are exhausted and environmental pollution increases.

There are many factors that reduce public transportation use, including cost, in-out vehicle time, level of service and transfer. In the case of cost, local governments, including the city government of Seoul, enforced a reduction of public transport transfer fares, thereby minimizing resistance to public transportation due to cost.

According to Seoul Metro (Survey on passenger using metro, 2002), although importance of transfer was highly ranked (21.9%), the level of satisfaction of transfer factor was ranked the lowest (51.9%). Therefore, transfer is a key issue that has a large effect on passengers using the public transportation system. In South Korea, almost all public transport transfer structures were constructed stereoscopically; therefore, level change facilities which overcome the vertical dimension are a very important factor while designing public transportation transfer structures. This study analyzes the effect of passenger choice level change facilities at Gwangmyeong station in South Korea.

This study defined public transportation transfer as not only between public transport, but also walking-public transportation and motor vehicles-public transportation, and level change facilities are facilities that could overcome vertical dimensions; for example, stairs, escalators, ramps and elevators.

2. THE PREVIOUS STUDIES OF PASSENGER ROUTE CHOICE

C. Y. Cheung and William H. K. Lam (1998) analyzed the behavior of pedestrians in choosing between escalators and stairways in the Hong Kong Mass Transit Railway stations during peak hours using a binary logit model. It was found that pedestrians are more sensitive to the relative delays when using the vertical pedestrian facilities in the descending direction than in the ascending direction.

S.P. Hoogendoorn and P.H.L Bovy (2004) compared walking to other modes of transport. A characteristic feature of pedestrian route choice is that routes are continuous trajectories in time and space since a pedestrian chooses a route from an infinite set of alternatives; dedicated theories and models describing pedestrian route choice are required. This study put forward a new theory of pedestrian behavior under uncertainty based on the concept of utility maximization. The main behavioral assumption is that pedestrians optimize some predicted pedestrian-specific utility function, representing a trade-off between the utility gained from performing activities at a specific location, and the predicted cost of walking subject to the physical limitations of the pedestrians and the kinematics of the pedestrian. The uncertainty reflects the randomness of the experienced traffic conditions. Based on this normative theory, route choice, activity area choice, and activity scheduling are simultaneously optimized using dynamic programming for different traffic conditions and uncertainty levels.

Winnie Daamen *et al.* reported passenger route choice concerning level change in railway station. In this research, route choice data were collected in two Dutch train stations by following passengers from their origin to their destinations through the facilities. These data were used to estimate extended route choice models. The focus in this contribution is on the influence of changes of level in walking routes on passenger route choice behavior. It appears that the different ways of bridging level change (ramps, stairs, escalators) each have a significant and different impact on the attractiveness of a route to the traveler.

Table 1 The previous studies of passenger route choice

Researcher	**Type of choice model**
Cheung & Lam	Binomial logit
Hoogendoorn & Bovy	Utility maximization in continuous space
Winnie Damman *et al.*	Multinomial logit

3. MODEL DEVELOPMENT

A path-size logit model includes overlap routes. In this study, physical overlap expresses length (Ramming. 2002). It is calculated as follows:

$$PS_r = \ln(\sum_{a \in r} \frac{l_a}{L_r} \frac{1}{N_a}) \qquad (1)$$

where PS_r means the overlap factor for route r; a is the index for an element of the infrastructure(each level change facility at route r on transfer system); r is the route index; l_a is the length of element a (physical distance each level change facility), which is a link of route r and L_r is the length of route r (physical distance at route r on transfer system); and N_a is the number of alternatives in the choice set of which element a is a part.

This study focuses on the influence of different types of level change facilities on passenger route choice. The utility function to be estimated consists of moving times on different types of level facilities and the overlap factor:

$$U_r = \alpha T_r^{es} + \beta T_r^{st} + \gamma T_r^{ev} + \delta T_r + \zeta PS_r + \varepsilon_r \qquad (2)$$

where U_r : level change mode choice of route r

T_r^{es} : moving time at escalators on route r

T_r^{st} : moving time at stairs on route r

T_r^{ev} : moving time at elevators on route r

T_r : entire moving time on route r

PS_r : path size on route r

$\alpha \cdots,$: parameters to be estimated in the utility function

The moving time at each facility on route r meant moving time using each facility. Although this study included waiting for using facilities, there is no waiting time except elevator, because that study area was very wide and it had a lot of level change facilities. And entire moving time was walking or moving time on route r except shopping, ticketing and resting time.

4. DATA COLLECTION AND CHARACTERSITCS

This study focuses on analysis of facilities choice to level change using RP data. Although, RP data have weaknesses, the purpose of this study is to analyze status of pedestrian transfer; thus, RP data analysis is needed.

The pedestrian transfer data were collected at Gwangmyeong station in South Korea, because Gwangmyeong station is a mass transfer where passengers may transfer among the Korea Train Express (KTX), subways, buses and motors.

Gwangmyeong station was nearly showing the pedestrian congestion and waiting time, because that it was very wide station for number of passengers.

Data collection techniques were mixed with video observation and investigators following pedestrians. The observations were taken during 3 days in October 2008. Two hundred and forty total samples were available. Video observation had been performed this follows;(1) 12 cameras ware set at first floor on station, (2) 12 cameras ware set at basement floor on station, (3) whole cameras were recorded pedestrians at same time, (4) data collected watching 16 video. The observation scope is limited to the gate at first floor and ticket gate at basement floor because the pedestrian route choice on the basement floor.

The characteristics of the observation data were gender, luggage, direction, moving time on facilities, and moving time on route. In terms of gender, 158 (68%) were males and 45 (20%) were pedestrians with luggage.

Table 2 Gender and with luggage or not

<table>
<tr><td rowspan="2">Gender</td><td>Male</td><td>158</td><td>66%</td><td rowspan="2">With luggage</td><td>Yes</td><td>45</td><td>19%</td></tr>
<tr><td>female</td><td>82</td><td>34%</td><td>No</td><td>195</td><td>81%</td></tr>
<tr><td colspan="2">Total</td><td colspan="6">240</td></tr>
</table>

The purpose of this study is to analyze level change facilities choice overcoming vertical dimension; thus, collecting data was separated into up and downward directions. *Upward* means from the platform; on the contrary, *downward* means to the platform. There were 197 (82%) downward pedestrians.

Table 3 Directional pedestrian

Direction	**Observation**
Upward	43 (18%)
Downward	197 (82%)
Total	240

One hundred and sixty nine pedestrians used escalators, 40 used stairs, and 31 used elevators, so escalators were the most chosen facility. The average usage time of each of these facilities was 23.6 s for escalators, 19.3 s for the stairs, and 39.7 s for the elevators, and the average moving time of route *r* was 165.4 s.
The moving time of route *r* was defined as the moving time to transfer, except for the rest time, such as ticketing and shopping.

Table 4 Average moving time of facilities and route *r*

Facilities	Sample	Average moving time of facilities (seconds)	Average moving time of route *r* (seconds)
Escalators	169 (70%)	23.6	168.1
Stairs	40 (17%)	19.3	123.2
Elevators	31 (13%)	39.7	199.6
Total	240	24.7	164.5

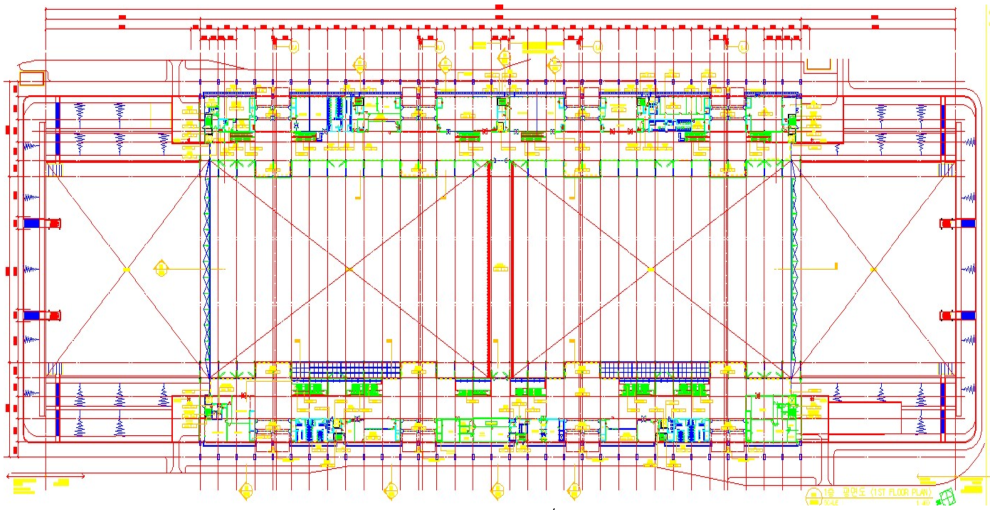

Figure 1 A construction drawing of 1st floor at Gwamyeong station

Gwangmyeong station had 12 stairs, 12 escalatos and 7 elevators on first floor.

5. ANALYSIS RESULT

This study analyzed the effect on pedestrian level change facilities choice in route choice using a multi nomial logit model and LIMDEP 8.0, which is econometric software used as analysis tool.

The developed Model 1 consists of moving time of route r, moving time of each facility and overlap factor (path-size). In the analysis result, estimation parameters of facilities were escalator -0.675, stair -1.326, elevator -0.953, route r 0.064 and overlap factor (PS) -0.300.

Table 5 shows the increased probability for selecting the escalator as the moving time of route r increases because passive pedestrians who were older, handicapped and with luggage preferred the escalator. Over the same route, the probability of selecting an escalator increases as the required number of level changes increases, but the parameter of PS were not significant.

Table 5 The result of Model 1

			Downward		Upward	
	parameter	t-value	parameter	t-value	parameter	t-value
Escalators	-0.675	-1.605	-0.619	-1.154	-0.745	-1.099
Stairs	-1.326	-2.720	-1.284	-2.071	-1.368	-1.735
Elevators	-0.923	-3.292	-0.919	-2.579	-0.905	-1.991
Moving time of route r	0.064	3.123	0.066	2.615	0.062	1.715
Overlap factor (PS)	-0.300	-0.816	-0.419	-0.930	-0.060	-0.094
ρ^2	0.280		0.295		0.253	

In Model 1, as escalator moving time increases 10%, the probability of selecting the escalator goes down by 3.78%, and as its moving time doubles, the probability decreases by 35.15%. In addition, the probability of selecting stairs increases by 0.07 (7%), and the probability of selecting elevators increases by 0.08 (8%). As the escalator moving time increases, the pedestrian choice of elevators increases a little.

Also, as the stairs moving time increases by 10%, the probability of selecting escalators decreases 9.61%, and as its moving time doubles, the probability of selecting escalators probability decreases by 67.46%. Further, the probability of selecting escalators increases by 0.1 (10%), and the probability of selecting elevators increases by 0.07 (7%). Stair pedestrians are more sensitive than the elevator, because stairs require more physical activity.

Table 6 Directional penalties of Model 1

	downward	upward
Escalators	0.917	1.104
Stairs	0.968	1.031
Elevators	0.996	0.980
Moving time of route r	1.023	0.961
Overlap factor (PS)	1.397	0.201

Table 6 shows direction penalties of Model 1. The result shows that the upward direction was more sensitive than downward. This is because upward activity requires more physical effort than downward activity.

Model 2 was developed, except for the overlap factor (PS), which was not significant. Because a high correlation exists between moving time of route r and PS, the result of Model 2 is similar to that of Model 1.

In Model 2, as escalator moving time increases by 10%, the probability of selecting escalators decreases by 4.02% and as its moving time doubles, probability decreases by 35.89%. Further, the probability of selecting stairs increases by 0.07 (7%), and the probability of selecting elevators s by 0.09 (9%). As escalator moving time, increases the transferred pedestrian choice of elevators increases by 2%.

Table 7 The result of Model 2

			Downward		Upward	
	Parameter	t-value	parameter	t-value	parameter	t-value
Escalators	-0.698	-1.688	-0.655	-1.252	-0.750	-1.110
Stairs	-1.330	-2.764	-1.293	-2.127	-1.368	-1.740
Elevators	-0.875	-3.241	-0.855	-2.499	-0.895	-1.991
Moving time of route r	0.008	4.687	0.008	4.273	0.006	2.383
ρ^2	0.279		0.293		0.253	

In addition, as the stairs moving time increases by 10%, the probability of selecting stair decreases by 9.70%, and as its moving time doubles, the probability of selecting stair decreases by 67.73%. Further, the probability of selecting escalators increases 0.09 (9%), and

the probability of selecting elevators increases 0.07 (7%). Stair pedestrians are more sensitive than those on the elevator because that stairs need more physical activity.
Furthermore, as the elevator moving time increases by 10%, the probability of selecting elevators decreases by 6.52%, and as its moving time increases doubles, the probability decreases by 52.65%. Additionally, the probability of selecting escalators increases by 0.10 (10%), and the probability of selecting stairs increases by 0.06 (6%).

Also, the directional penalties of Model 2 appeared similar to those of Model 1, so that, the result shows that the upward direction was more sensitive than the downward direction.

Table 8 Directional penalties of Model 2

	downward	upward
Escalators	0.938	1.073
Stairs	0.972	1.029
Elevators	0.976	1.022
Moving time of route r	1.078	0.848

Table 9 The result of Model 3

			Downward		Upward	
	parameter	t-value	parameter	t-value	parameter	t-value
Escalators	-0.480	-1.064	-0.425	-0.732	-0.546	-0.766
Stairs	-1.230	-2.321	-1.190	-1.748	-1.267	-1.503
Elevators	-0.952	-3.141	-0.954	-2.454	-0.923	-1.910
Overlap factor (PS)	-1.087	-3.797	-0.233	-3.475	-0.804	-1.637
ρ^2	0.260		0.274		0.235	

Although, PS was estimated to be insignificant on Model 1, this study focuses on overlap physical facilities. Therefore, Model 3 was developed, except moving time for route r was not considered. In the analysis result, the estimation parameters of facilities were escalator -0.480, stair -1.230, elevator -0.952 and overlap factor (PS) -1.087. The result means that pedestrians prefer the escalator as the rate of level change facilities increase on their route, because the moving distance on level change facilities increases as the vertical dimension increases.

In Model 3, as the escalator moving time increases by 10%, the probability of selecting escalators decreases by 2.51%, and as its moving time doubles, the probability decreases by 4.41%. In addition, the probability of selecting stairs increases by 0.06 (7%), and the probability of selecting elevators increases by 0.06 (6%).

Moreover, as the stairs moving time increases by 10%, the probability of selecting escalators decreases by 9.70%, and as its moving time doubles, the probability decreases by 64.69%. Further, the probability of selecting escalators increases by 0.10 (10%), and the probability of selecting elevators increases by 0.06 (6%). Stair pedestrians are more sensitive than elevator pedestrians because the stairs require more physical activity.

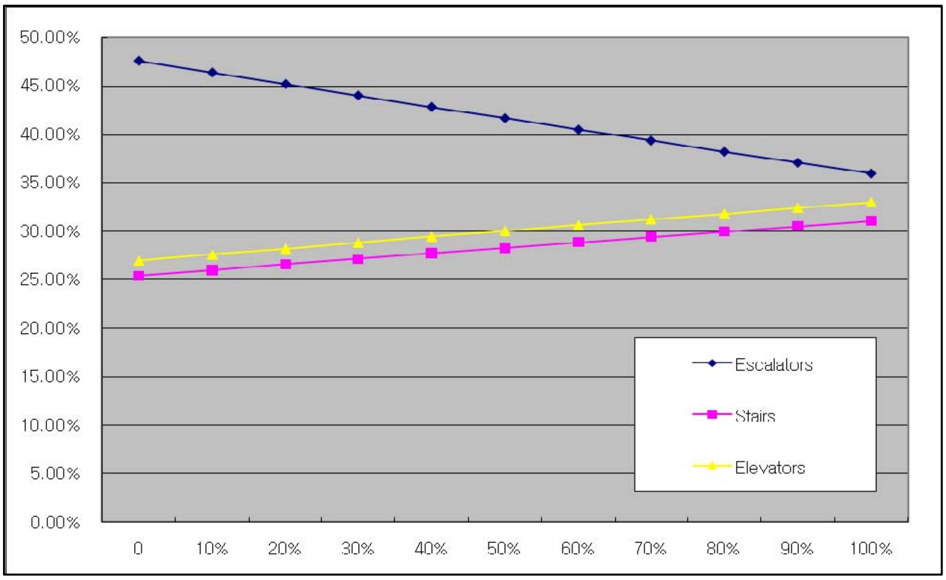

Figure 2 Changing probability on increasing escalators moving time

Additionally, as the elevator moving time increases by 10%, the probability of selecting elevators decreases by 6.76%, and as its moving time doubles, the probability decreases by 53.60%. Finally, the probability of selecting escalators increases by 0.09 (9%), and the probability of selecting stairs increases by 0.05 (5%).

Figure 2, 3, 4 showed changing probability on increasing each facilities moving time using estimated coefficient of Model 3.

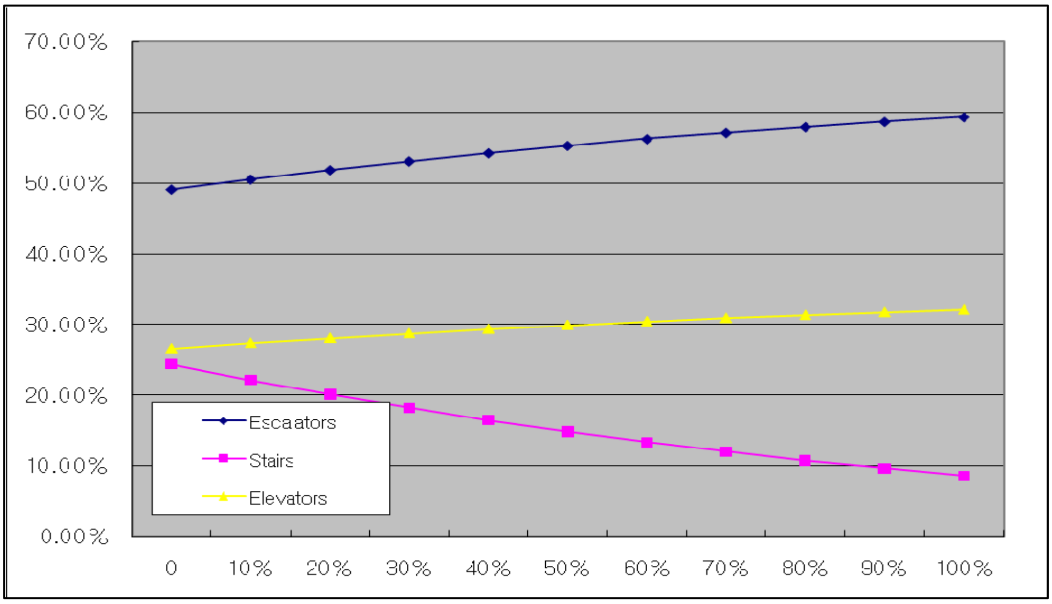

Figure 3 Changing probability on increasing stairs moving time

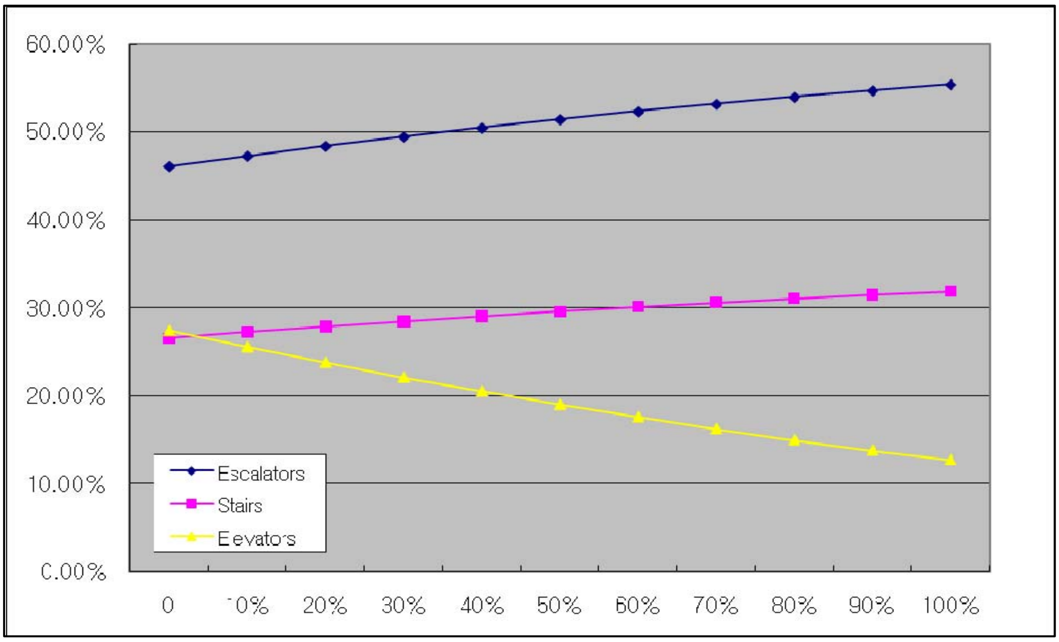

Figure 4 Changing probability on increasing elevators moving time

In addition, the directional penalties of Model 3 appear to be similar to those of Models 1 and 2; and, the upward direction was more sensitive than the downward direction.

Table 10 Directional penalties of Model 3

	downward	upward
Escalators	0.887	1.139
Stairs	0.967	1.030
Elevators	1.002	0.969
Overlap factor (PS)	1.135	0.740

6. CONCLUSION AND RECOMMENDATIONS

This study analyzes the effects on level change facilities choice considering overlap facilities on route at this point in time when the importance of public transportation is expanding.

In South Korea, almost all public transportation transfer structure were constructed stereoscopically; therefore, level change facilities that overcome the vertical dimension are a very important factor while designing a public transportation transfer structure. This study analyzes effect on passenger choice level change facilities at Gwangmyeong station in South Korea.

This study developed three models. Model 1 consists of the moving time of route r, the moving time of each facility and the overlap factor (path-size); Model 2 was the same except for PS; and Model 3 was the same as Model 1 except for the moving time of route r. All models were estimated similarly, and showed that pedestrians chose escalators as moving time route increased and rate of level change facilities on route increased.

The direction penalty upward was more sensitive than that going downward, and stairs were also sensitive, because moving upward and stairs required more physical activity.

The result indicated pedestrians prefer escalators when there is an increased moving time in route at a mass transfer structure or at an increasing rate of level change facilities in larger vertical dimension structure. Further, pedestrians prefer elevators a little as the escalator moving time increases because of confusion or delay.
This study analyzed Gwangmyeon station in South Korea; this station is a mass transfer structure and not confusing; therefore, research on the effects of the size of structure and level of service are needed. This future research can allow for facility construction with a high level of service. This study used a multi nomial logit model to analyze level facility choice, but various methods that could analyze impossible observation factors were needed.

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