Proceedings of the Eastern Asia Society for Transportation Studies, Vol.11,2017

Layout Criteria of an Access Mode's On and Off Facility at Railway Stations

Sigon KIM [a], Kwang-kyun LIM [b]

[a] *Seoul National University of Science and Technology, Seoul, 01811, Korea*
[b] *Songwon University, Gwangju, 61756, Korea*

[a] *E-mail: sigonkim@seoultech.ac.kr*
[b] *E-mail: ikay@songwon.ac.kr*

Abstract: We have developed layout criteria for an access mode's on-off facility in various access modes that approach railway stations. The facility layout criterion of various access modes is to propose a standard to minimize the travel distance to the on-off facility based on a main mode. The weight of the escalator was less than that of the flat distance in the calculation of equivalent distance of walking. As a measure of effectiveness, the user-based weighted average equivalent distance for each access mode was adopted. The proposed standard is applied to Gimpo airport, and the position of the on-off facilities of the access modes and suggestions for improvement are suggested.

Keywords: Access mode, On-off facility, Layout criteria, Weighted average distance

1. Background

The rapid increase in passenger traffic is causing traffic jams in most metropolitan areas. In the case of vehicles traveling between Seoul metropolitan area and Gyeonggi Province, passenger cars accounted for 60% of the total, and more than 80% of them are driving-alone. Traffic patterns cannot be solved without changing the pattern of such traffic patterns. From this perspective, it is recognized that the central and local governments should develop attractive policies increasing public transportation uses such as buses and urban railways. The increase of public transportation uses became a top priority for all local governments in mitigating traffics.

Nevertheless, the uses of passenger car are not reduced due to the convenience that can be connected to the door-to-door service, but public transportation is required to multiple transfer to get to a destination.

Several conventional treatments had been applied in the public transportation system such as bus-only-lane and rapid trains, commonly for reducing travel times. A convenient method of connecting transfer system is needed to reduce the transfer time of public transit.

The location between the adjacent bus stops and metro stations is too far away, so that it takes too much time for transfer between them. In addition, the fact that the walking distance is long becomes a block in transit use increases especially to the person with heavy baggage, elders, children and pregnant women. At this point, there has been an increase in the need to set the standard for the layout of transportation facilities for access to the railway stations.

The purpose of this study is to present the standard for determining layout by considering the number of users, the existence of stairs, escalators, and elevators along the transferring route. In addition, the proposed standard is applied to an existing railway station, and evaluation and improvement measures are suggested.

The data used for this study is from 2010 and the spatial range is set within a radius of 500m around the transfer center mentioned in the table below. A transfer center means a facility in which transfer support facilities such as convenience facilities, commercial facilities, cultural facilities, business facilities, accommodation facilities, and residential facilities necessary for socioeconomic activities are gathered together in one place.

Table 1. Types of Transfer Center by Transportation Modes

Aviation	International Airport, Domestic Airport
Railroad	Hi-speed, Conventional, Intercity, Urban
Marin and Buses	Ferry terminal, Express bus, Intercity bus, BRT terminal

This research has conducted as: first, the status and problems of the existing railway stations with multiple access modes were examined. Then the characteristics of transit passengers, and the influence of transfer are analyzed. Based on this, the standard for the layout of the railway station facilities is suggested. The service level was evaluated by applying the layout standard proposed in this study to the existing railway station. In addition, the measures needed to improve service level of the layout are presented.

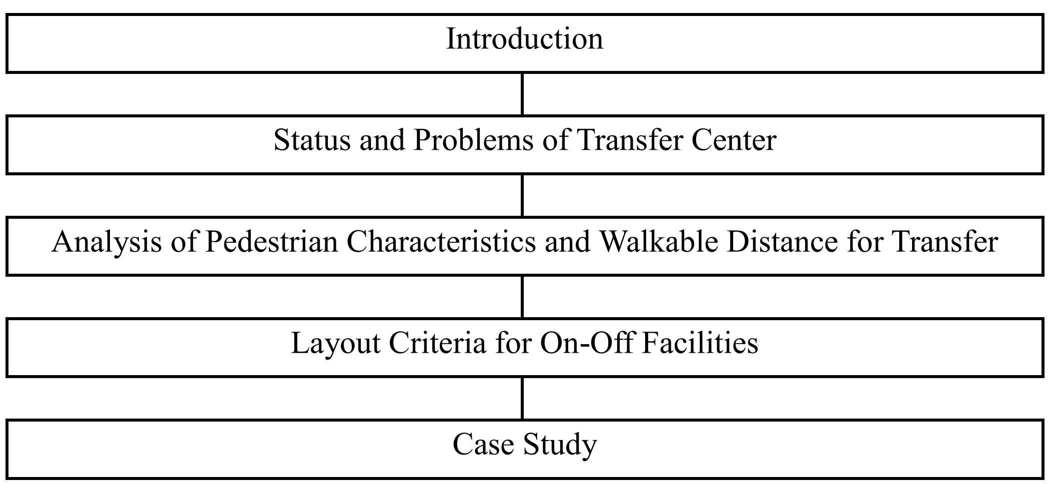

Figure 1. Research Procedure

2. Literature Reviews

The studies of layout criteria dealing with on- and off-facilities to support efficient transfer between transportation modes at railway stations are relatively rare. The way of moving among transfer facilities by travelers is defined as a transfer path, which is the whole stretch of the distance from an arrival point of one mode to the departure point of the connecting mode. Cha et al.(2009) studied the transfer path by considering into three typical segments as side walk, stairways, and indoor corridors to construct a transfer utility function representing overall satisfaction levels. A preference survey was conducted on each of these segments, resulting in relative resistance. The proposed function gives a good implication in estimating the relative resistance of transfer at a certain railway station. Joel Volinski & Oliver Page(2004) and William A. Taggart & Nadia Rubaii-Barrett(1992) reported the necessity of that transfer paths have to be minimized when constructing an intermodal transfer center or a transit transfer center without an specific guidance of transfer paths. Instead, Ron Kasprisin & Michael LaFond(1991) mentioned the walking distance is within 800~1000 feet to ensure travelers comfortable transfer between transport modes. Service Evaluation Indicators of Transfer Facilities in the High-speed Railway Stations were developed by Kim et al.(2008). There were three groups of indicators: the level of service (LOS) related to que and congesting at ticket booths and concourses, distance of transfer paths and the quality of information throughout the transfer paths. Such evaluations were however mainly focused on level of service during the facility operations, which means the layout of transfer facilities has to be considered from the initial phase of designing with a specific layout criterion.

3. Status and Problems of Transfer Center

3.1 Existing High-Speed Railway Station

Most of the existing transfer centers were developed around the high-speed railway stations. In this study, the distance and the number of passengers were analyzed from the platform of the high speed railway station to the points of access modes in Korea. Based on this, we evaluated the level of service according to the proposed layout standard.

Yongsan Station of high speed railway

Yongsan Station of high speed railway has 14 access modes. The distance and the number of passengers have been investigated by access mode at the Yongsan Station. The average walking distance of 14 access modes is 332 meters, specifically having the longest outside distance 308 meter by ‘Bus-only-lane (to seoul)’ mode. The percentages of persons using access modes with the total distance over 300 meters are relatively small except persons using their own cars and taxies. In contrast, the most dominant access modes of persons chosen (47%) have the distance within 200 meters. It implicates that the shorter the walking distance of access mode, the more persons likely to choose. The table and figure below show the distance and the number of person used by access mode.

Table 2. The Distance and the Number of Person Used by Access Mode at Yongsan Station

Access mode		No. of Person (%)	Distance(m)			
			Outside	Staircase	Hallway	Total
1	Metro Line 1 (northbound)	26.5	0	52	148	200
2	Metro Line 2 (southbound)	11.0	0	54	138	192
3	Middle Line (E. Incheon, Cheonan)	9.5	0	47	124	171
4	Shin-Yonsan Stat.	1.3	203	90	255	548
5	Janghang Line	2.5				
6	Bus-only-lane (to Norangjin)	1.4	233	66	211	510
7	Bus-only-lane (to Seoul)	0.4	308	66	211	585
8	Green bus 1	0.8	63	66	211	340
9	Green bus 2	0.4	106	66	211	383
10	Bus stop	0.2	166	57	155	378
11	Parking lot 1	4.1	0	42	212	254
12	Parking lot 2	6.2	0	42	367	409
13	Taxi	21.0	63	66	211	340
14	Walking	14.7				
	Total	100				

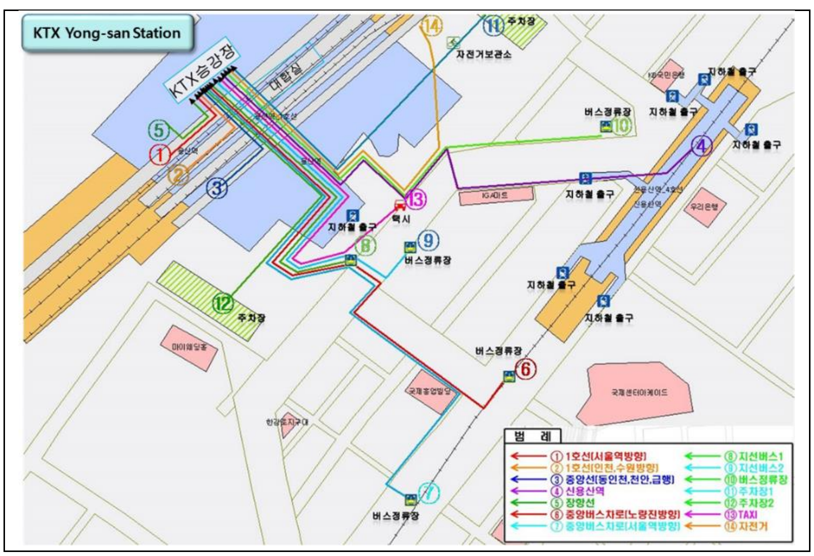

Figure 2. Locations of On-Off Facilities and Routes by Access Modes at Yongsan Station

Seoul Station of high speed railway

Seoul Station of high speed railway has 7 access modes. The distance and the number of passengers have been investigated by access mode at the Seoul Station. 53.7% of persons are accessed by Metro Line 1 & 4 with the longest distance around 400 meters. The table and figure below show the distance and the number of person used by access mode.

Table 3. The Distance and the Number of Person Used by Access Mode at Seoul Station

Access mode		No. of Person (%)	Distance(m)			
			Outside	Staircase	Hallway	Total
1	Metro Line 1	30.3	44	60	294	398
2	Metro Line 4	23.4	44	71	346	461
3	Intercity Bus	2.8	372	37	127	536
4	Blue and Green Bus	4.5	73	37	127	237
5	Taxi	18.1	91	37	127	255
6	Parking lot	9.1	154	34	262	450
	Walking	11.8				
	Total	100				

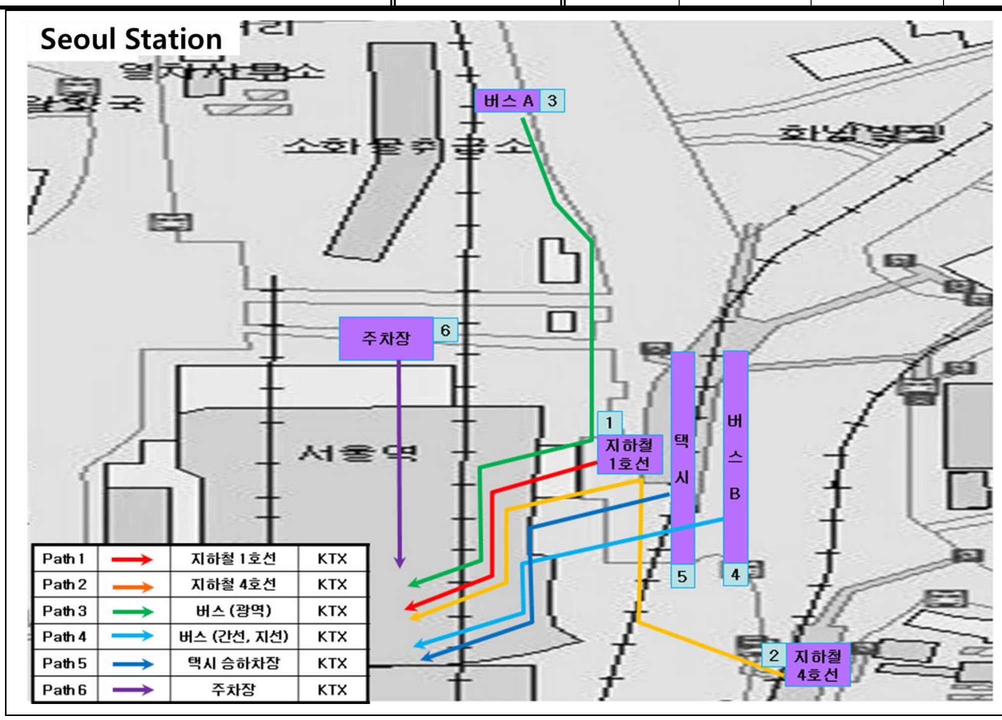

Figure 3. Locations of On-Off Facilities and Routes by Access Modes at Seoul Station

.

3.2 Assessment and Problems on the Layout of On-Off Facilities for High Speed Railway Stations

We assessed the level of access mode's on-off facilities for existing high-speed rail stations. The average travel time per person was calculated by considering the size of the facilities by access mode. The walking speed of the pedestrian is assumed as 1m/sec. The degree of convenience of stairs and escalators along the route is not considered.

As a result, it took about 8 minutes for Gwangmyeong Station, which was the worst place to get on and off, and 4 minutes for Daejeon Station as the best case.

Table 4. Estimation of Transfer Times by Railway Station

Railway Station	Transfer time(sec)/person	Railway Station	Transfer time(sec)/person
Yongsan	265	Daejeon	245
Seoul	389	Dongdaegu	368
Gwangmyeong	447	Busan	402
Cheonan·Asan	290		

Excessive Transferring Distance

There is a station where the transfer distance exceeds 500m, which is the available distance for the transfer. In the case of Yongsan Station on the high-speed railway, the distance from the metro Yongsan Station exceeds 600m. As a result, only 1.3% of the high-speed railway passengers arrived by metro. It tells the metro do not function as an access mode.

Conflicts between Transit Passengers and Transfer Support Facility Users

Railway stations are used by transit center users and transit support facility users. However, there is no consistency in design due to the difference in construction time between them. As a result, there is a case where the route of the transit passenger and the transit support facility user is overlapped.

4. Analysis of Pedestrian Characteristics and Walkable Distance for Transfer

4.1 Walkers by Walking Distance

Song and Park (2008) reported that people are unlikely to walk when the walking distance is longer than 500 meters. This is an 8-minute distance, given that the average walking speed is 60 m/min. Also it can be seen that above 50% of the walking distance is within the range of about 100m to 240m.

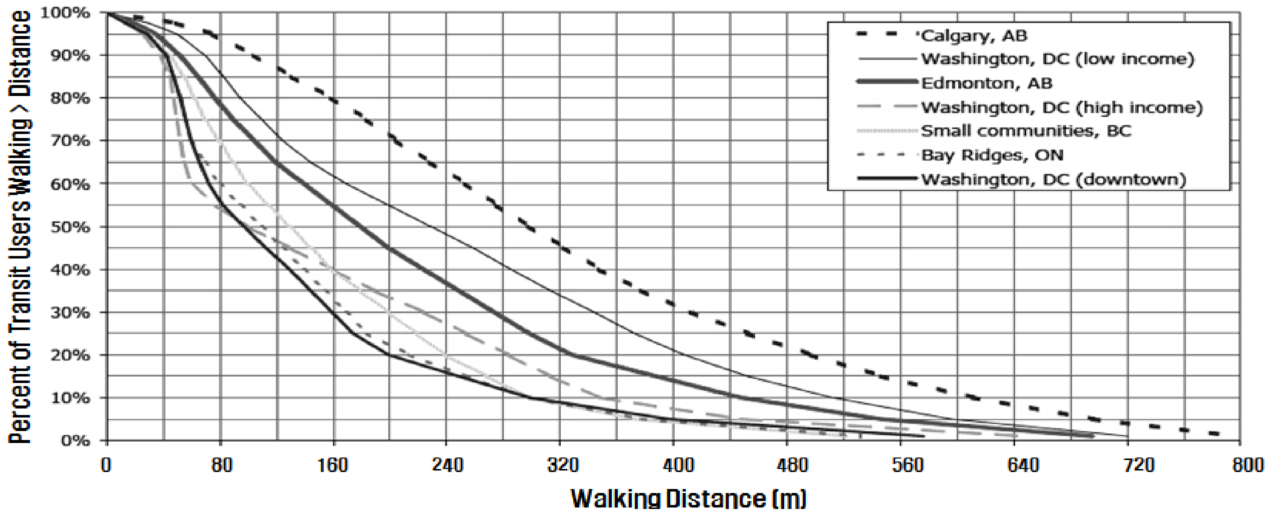

Figure 4. Probability of Walking by Distance

4.2 Establishing Walkable Distance for the Transfer in Railway Stations

The maximum distance for the transfer can be inferred based on the walking distance data of the walkers. If the maximum travel distance is over 500m, it tends to use the car rather than walking. The time is 8 to 10 minutes. That is, the maximum distance for transit at the railway station should not exceed 500 meters.

5. Layout Criteria for On-Off Facilities

5.1 Principals

The standard of layout for access to the railway station should have close access to many transportation facilities close to the railway station. In other words, it is necessary to deploy diverse access modes close each other that makes passengers convenient.

The most common mode of access depends on the geographical location of the railway station and the land use. In other words, the railway station within the metropolitan area will be a metro or bus due to the development of public transportation, and a passenger vehicle will be a priority located in a relatively rural area. For Incheon International Airport, bus station facilities should be given priority because limousines are the most used.

5.2 Identification of Layout Criteria for On-Off Facilities

The landing and take-off facilities of the railway station should be arranged in the order of the access mode with the number of passengers, making the transfer distance (flat equivalent distance) short. The minimum standard shall be such that the weighted average equivalent distance does not exceed 240m, the LOS D level. In addition, the maximum flat equivalent distance of each access mode cannot exceed a maximum of 500 meters. It is meaningless to install on and off facilities on a distance beyond the boundary of transfer.

A flat equivalent distance is the distance of between an access mode and a main mode to be transferred, considering the existence of moving walk, escalators, and elevators. The following equation is to estimate a flat equivalent distance.

Flat Equivalent Distance = Distance of walking hallway + (α×Distance of stairway) + (β×Distance of moving walk) + (γ×Distance of Escalators or/and Elevators)

The unit of distance is meters, and α, β, γ are the equivalent factors reflecting the hardness to walk on stairways, escalators and elevators relative to on hallways (α=2, β= 0.5, γ=0.5).

The weighted average equivalent distance is averaged by weighting the number of users by the flat equivalent distance of each access mode. The following equation shows how to calculate the weighted average equivalent distance.

$$\text{WAED (Weighted Average Equivalent Distance)} = \frac{\sum P_i \times Ph_i}{P}$$

where, P_i is the travel demand of direct access mode i to transfer to the railway station, Ph_i is the equivalent flat distance required to move from the alighting point of an direct access mode to the boarding point of railway.

The service level (LOS) of the on and off facility layout was set based on the weighted average equivalent distance. LOS C, which is the standard of design, was made within 3 minutes of transfer time. Based on this, a difference of 1 minute was provided for each increment/decrement of LOS. This is shown in the following table.

Table 5. LOS for On-Off Facilities by WAED

LOS	Transfer time	WAED
A	less than 1 min	less than 60m
B	1～2 min	60m～120m
C	2～3 min	120m～180m
D	3～4 min	180m～240m
E	4～5 min	240m～300m
F	over 5 min	over 300m

Note: assumed walking speed as 1.0m/sec

6. Case study

Gimpo Airport Station has various transportations such as aviation, railway, urban railway, buses, taxi, and passenger cars. There is a high demand for passengers who want to use aviation.

In addition, Metro Line 9, Sosa-Daegok Railway and Gimpo Light Railroad will be operated soon. Therefore, after evaluating the service level of accessing transportation facilities at Gimpo airport station, we suggest the improvements as.

6.1 LOS of Access Mode′s On-Off Facilities at Gimpo Airport

There are currently 6 access modes provided at Gimpo Airport Station: airport railway, urban railway, intercity bus, city bus, taxi and passenger car. The number of users and total flat equivalent distance for each access mode are shown in the following table.

Table 6. Estimation of Flat Equivalent Distance at Gimpo Station

Access mode	No. of person (P)	Distance(Ph)					P×Ph
		Outside	Stairway	Escalator	Inside	Total (m)	
Airport railway	2,298	-	-	43.3	344.3	388	840,953
Urban railway	2,184	-	-	34.8	80.1	115	212,940
Intercity bus	12,386	81.0	-	16.0	80.4	177	2,098,188
Local bus	10,725	14.6	-	16.0	80.4	111	1,190,475
Taxi	13,246	51.2	-	16.0	80.4	148	1,849,142
Auto(Parking lot)	10,720	139.9	-	16.0	80.4	236	2,447,376
Total	51,559	286.7	-	142.1	746.0	1,175	8,639,074

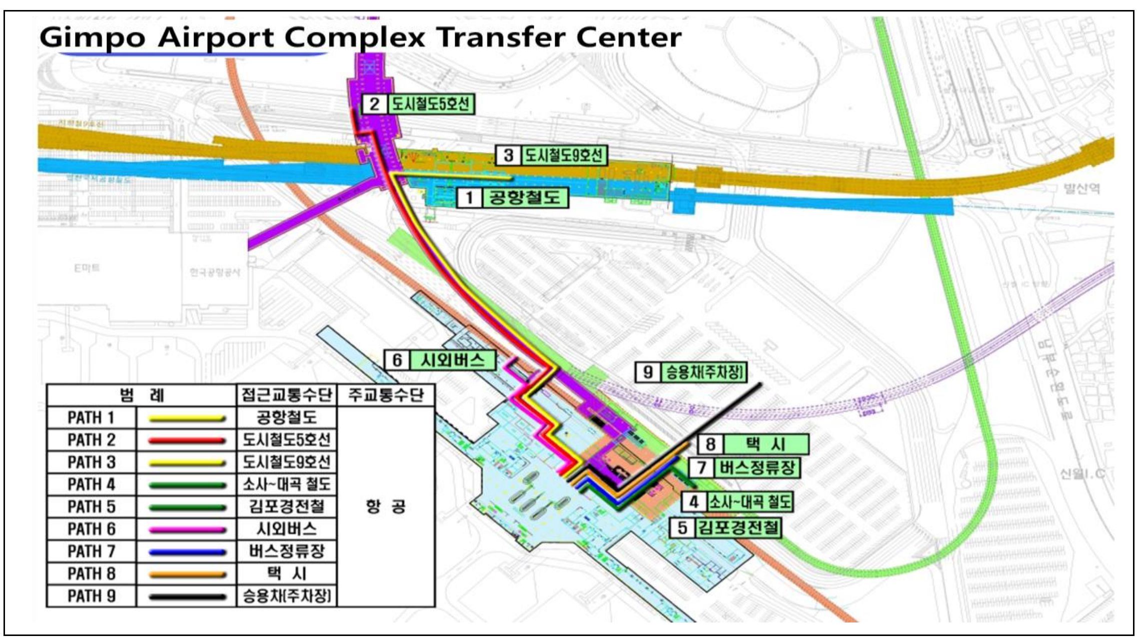

Figure 5. Routes by Access Mode at Gimpo Station

.

Based on this, the weighted average equivalent distance is 167.6m, corresponding to LOS "C".

$$\text{Weighted average equivalent distance} = \frac{\sum P_i \times Ph_i}{P}$$

$$= 8{,}639{,}074 \text{ person·m} / 51{,}559 \text{ person}$$

$$= 167.6\text{m}$$

6.2 Layout Issues of On-Off Facilities for Access Modes at Gimpo Airport

Excessive transfer distance to railway station

Railways (such as urban railways and airport railways), which have high access rates, require excessive transfer distance and transit time to get to airport, the main transportation at Gimpo station. Currently, airport railways and Metro lines 5 and 9 have a difficulty in using railways because of the long distance between the station and the airport as shown in following figure.

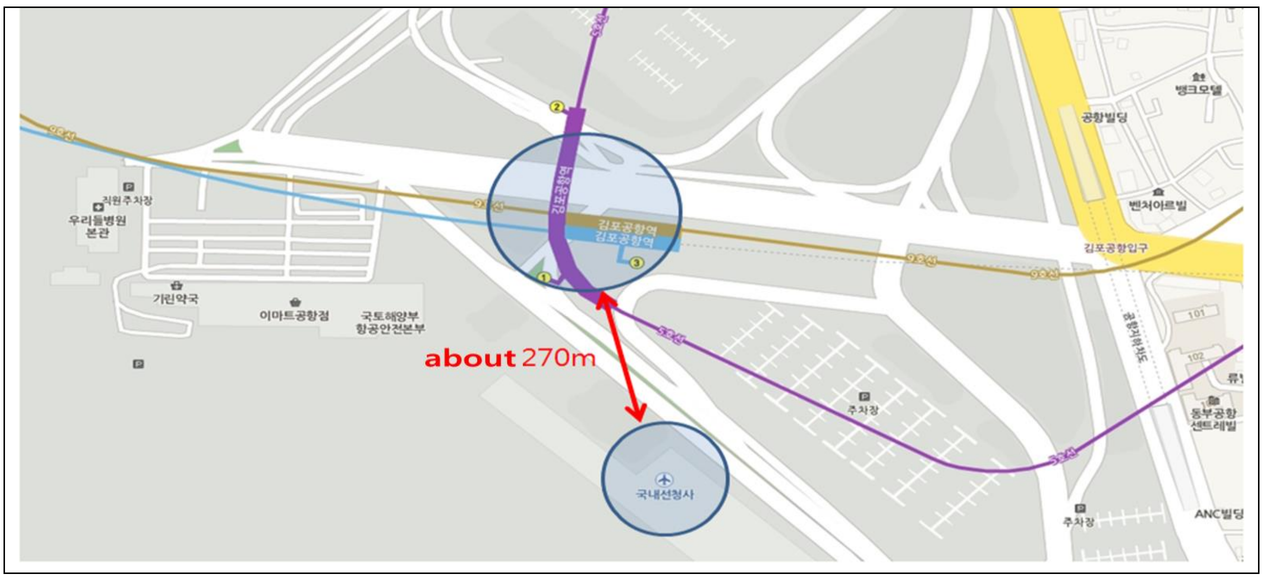

Figure 6. Current Layout between Railway Station and Airport

.

Ineffective walking paths

The first planned Metro Line 5, Gimpo Light Railway, and Sosa-Daegok stations were designed to be placed closer to the airport than the airport railway and Metro Line 9 stations. However, inconveniences may arise because a transit-walking facility capable of facilitating the convenience of the passengers is not properly arranged. Unnecessary detours or circulation arrangements may delay the transit time of the users, which may lead to a decrease in the use of public transportation by the airport users. In addition, pedestrian facilities such as staircases and escalators, which are currently in operation, have not been able to optimize the route of the user. As a result, passengers are ineffectively transferred to pedestrian facilities that do not consider the shortest distance. As a result, it is another factor to increase transfer time.

Conflicting routes between passengers arriving and departing at the airport

Gimpo Airport is the second largest airport in Korea, and there are many users of domestic flights, so it is inefficient because the route for transfer is complex not only inside the airport but also outside the airport. This congestion on the transfer route increases the friction between users with large and small baggage, which results in inconvenience of users and increases the transfer time.

6.3 Improvements

Relocation of an urban railway station

In order to arrange the stations of Gimpo Light Railway and Sosa-Daegok Railway as close as possible to the airport, the railway station was located in the basement close to the airport building. As a result, the route from the railway station to the airport was minimized. In addition, in order to reduce the friction between transit passengers moving between Sosa-Daegok and Gimpo Light Rail Transit, arriving and departing were located on different floors, which made it convenient the railway passengers.

Optimizing the layout of walk supporting facilities

The arrangement of the existing inefficient pedestrian facilities was efficiently arranged to optimize the movement route. The distance between the pedestrian facilities (stairs - stairs, stairs - escalator) for transit is minimized to enhance the user convenience. In order to shorten the transit distance, an additional pedestrian facility was installed where necessary. Gimpo Light Railway, Sosa-Daegok Railway Stations, and the elevators and escalators that directly connect each floor of the airport building were newly installed to shorten the transfer time.

The escalator, which directly connects the second floor of the airport building to the second basement floor of the metro station, allows the passengers to go directly to the check-in counter. In addition, the elevator that directly connects the second floor of the airport building to the second basement floor has increased the mobility of the elderly as well as the users with large luggage.

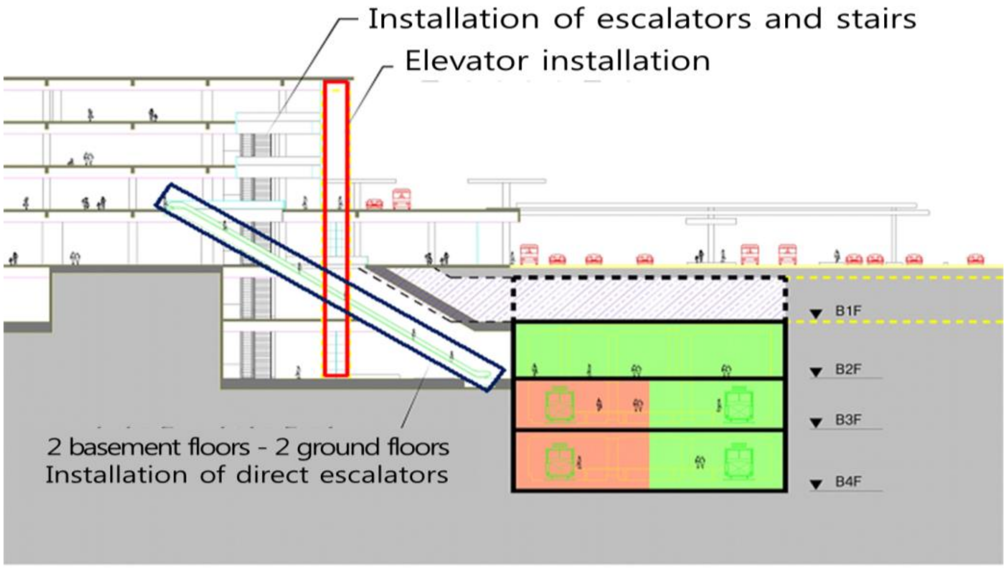

Figure 7. A Proposed Cross-section to Reduce Transfer Distance at Gimpo Airport

Separating walking routes by travel purpose at the airport

Airport users choose the transfer route according to their destination (departing passenger, arriving passenger, return passenger, etc.). By using these characteristics, we tried to minimize the conflict among the pedestrians by reflecting the movement route to the facility layout plan. Those who use the airport can distinguish between people visiting the airport (departure) and people arriving at the airport (arrival) to use the flight. The Gimpo Airport building is divided into arrival on the first floor and departure and check-in counters on the second floor. According to the characteristics of the choice of transfer route of airport users, the users were divided into two groups of mainly departure group (including freight) and arrival group (including welcome).

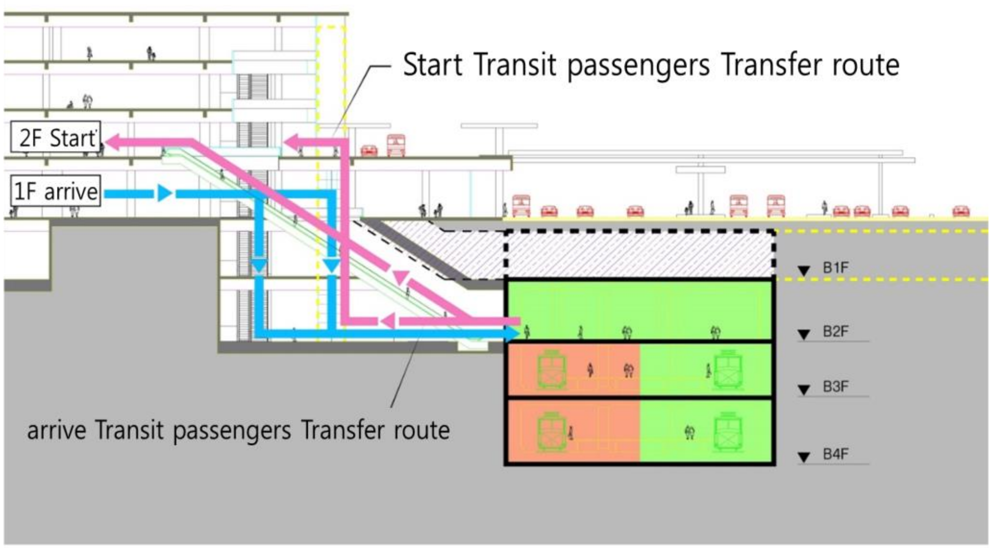

Figure 8. A proposed cross-section to separate departing and arriving passenger’s movement

6.4 Assessment of improvement effect

In the future, the access modes to Gimpo Airport Station will be nine with the addition of Metro Line 9, Daegok-Sosa, and Gimpo Light Railway. As mentioned above, congestion has been alleviated by improving the transit facilities and by separating the routes of the users who have different purposes at the place where the users gather for the interlayer movement. In addition, the relocation of the escalator on the moving route in the airport building improved the inconvenience of the passengers by reducing the transfer time. As a result, the weighted average equivalent distance was 84.9m, which was improved to LOS "B".

$$\text{Weighted Average Equivalent Distance} = \frac{\sum P_i \times Ph_i}{P}$$

= 4,378,830 person·meter / 51,559 person

= 84.9m

The number of users and total flat equivalent distance for each access mode are shown in the following table.

Table 7: Estimation of Flat Equivalent Distance and Demand by Access Mode at Gimpo Airport

Access mode	No. of person (P)	Distance (Ph)					P×Ph
		Outside	Stairway	Escalator	Inside	Total (m)	
Airport railway	1,540			43.3	344.3	388	530,222
Metor line 5	1,399			34.8	352.6	387	493,287
Metor line 9	1,438			43.3	351.4	395	505,313
Daegok-Sosa railway	9,946			10.5	50.5	61	502,273
Gimpo light railway	8,977			10.5	52.5	63	471,293
Intecity bus	8,865	51		10.5	52.5	114	465,413
Local bus	9,972	14.6		10.5	68.4	94	682,085
Taxi	4,845	51.2		10.5	74.5	136	360,953
Auto (Parking lot)	4,577	118		10.5	80.4	209	367,991
Total	51,559	235	0	184	1,427	1,846	4,378,830

7. Conclusions

The facility layout standard proposed in this study is based on the demand for improvement of 'lack of transfer system', which is one of the biggest inconveniences of public transportation use. In other words, it can be used to minimize transfer inconvenience by developing evaluation technology and design guideline for convenience facilities for transfer facilities. It is possible to improve accessibility and convenience of public transportation by inducing user-centered optimum design. As a result, it is possible to increase national competitiveness by decreasing traffic congestion cost and by increasing convenience of users, promoting the use of public transportation, and restricting the use of private cars.

REFERENCES

Song GiTae, Junsik Park, “Determination of Transfer Ratio According to Transfer Time Reflecting Passenger Attributes”, Journal of Korean Transportation Society, Vol 24, No 4, 2008, p 217-227.

John J Fruin, “Pedestrian Planning and Design”, 1971

Cha Dongdeuk, Jaehak Oh, Wanyong Park and Sonbok Park, “A model of a relative evaluation of the transfer distance between two modes”, Journal of Korean Transportation Society , Vol 27-1, 2009, p.35-42.

Joel Volinski & Oliver Page, “Developing Bus Transfer Facilities for Maximum Transit Agency and Community Benefit”, National Center for Transit Research, University of South Florida, Tampa, FL, USA.Northwest, Department of Civil Engineering, University of Washington, Seattle, Washington, 2004

Ron Kasprisin & Michael LaFond, “Major Activity Center PRT Circulator System Intermodal Transfer Station Design and Visual Impact Study”, Final Report TNW 91-13, Transportation, 1991

William A. Taggart & Nadia Rubaii-Barrett, “Funding and Operation of an Intermodal Transportation Facility at the Santa Teresa Border Crossing”, Final Report, Department of Government, Public Administration Program, New Mexico State University, Las Cruces, New Maxico, 1992

Kim Chelosoon, Sigon Kim and Junghwan Kim “The Development and Application of the Service Evaluation Indicators of Transfer Facilities in the High-speed Railway Stations”, Journal of Civil Engineering, Vol 28, No 4D, 2008, p 533-538.