

OPINIONS OF INTERMODAL TRANSFER FUNCTIONS OF URBAN RAILWAY SYSTEMS: A CASE STUDY OF DELHI METRO

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ABSTRACT

Actual ridership of urban railway systems recently developed especially in the developing world tends to be lower than forecast. While low ridership is caused by several factors, this research focuses on intermodal transfer functions at railway stations, identifying current problems and vital issues of intermodal transfer functions at railway stations. Taking the Delhi Metro System as a case study, this paper presents the result of a Questionnaire Survey, which was conducted to identify satisfaction levels of Metro users and non-Metro users in terms of intermodal transfer facilities and services along with their improvement needs. Metro stations were classified into four groups based on the characteristics of each station. A representative station was selected from each group and the Survey was conducted around this station.

Improvement needs that were revealed in the Survey imply several significant measures for strengthening the intermodal mobility of the Metro. Those include not only physical improvement of railway stations such as a barrier-free system but also improvement of intermodal facilities including user-friendliness of transport facilities (e.g., pedestrian walks, parking lots), enhancement of the convenience level for transferring activities by improving physical conditions (e.g., shorter walking distance for transfer), and provision of safe and comfortable waiting space for transferring passengers. Furthermore, over half of the Metro users residing in suburban areas desire the improvement of feeder bus services in terms of service accessibility, frequency, and operational punctuality. These proved to be the vital points to strengthen the intermodal functions of the overall public transport network in Delhi.

Keywords: Railway, Transfer Function, Intermodality, Opinion Survey, Delhi Metro

1. INTRODUCTION

In response to the growing motorization in urban areas of the developing world, government has undertaken several large-scale transportation infrastructure projects, including limited access expressways, road-widening, flyover construction and Intelligent Transportation Systems projects, as well as an extensive rapid transit system project, the Mass Rapid Transport System (MRTS). While the construction of a high-speed, high-capacity public transportation system is commendable, rail forecasts in general have been significantly optimistic compared to reality (Thakuria, 2009). Actual ridership is usually lower than forecast, and actual costs are higher (Shoup, 2006). In the case of the MRTS in Delhi or Delhi Metro, while some reviews regarding its congestion mitigation and air quality improvement potential have been positive (Murty et al., 2006; DMRC, 2007), others have criticized its low ridership levels and so on (Mohan, 2006; Advani and Tiwari, 2005).

While low ridership is caused by several factors, this research focuses on intermodal transfer functions at railway stations. Thus, the main objective of this research is to identify current problems and vital issues of intermodal transfer functions at railway stations in the urban railway systems recently developed especially in the developing world, and to formulate improvement measures for the intermodal transfer functions to facilitate more passenger use of the railway systems (JICA, 2009).

As a case study, the current situation of the Delhi Metro stations was investigated, and this paper presents the result of a Questionnaire Survey, which was conducted to identify actual usage of passengers of the Delhi Metro and potential demands on facilities and services to improve transfer activities. Based on this case study, improvement measures for the intermodal transfer function in Delhi Metro were examined, especially taking into account strengthening of integration with feeder systems including pedestrians.

Delhi Metropolitan Area, with a population of 12.9 million (Census of India, 2001), has developed a public transportation network system with bus, Metro, taxi, and paratransit systems. In particular, bus is the prime mode, sharing approximately 30-35% of the total demand (Tiwari, 2002).

The Delhi Metro System, which consists of both with underground structure in CBD and elevated structure in suburban areas, has been well developed and rapidly expanded to widen the service areas. The Delhi Metro System, which is operated by Delhi Metro Rail Corporation (DMRC) and has three lines with a combined route length of 65 km and 59 stations (DMRC, 2009), does/will play a prime role in the overall public transport network under the condition that chronically heavy traffic congestions always take place on roads. Also, the Metro System is expected to contribute to mitigate the ambient air pollution.

The first 65 km section completed was opened for commercial operation in November 2006. It was reported that about 800,000 passengers were using the system every day as of March 2009 though the ridership is still lower than the original forecast. At present, in order to meet the increasing demand, the second phase of the Project has been implemented to construct 83 km more. The second phase is scheduled to be completed by 2011, thereby resulting in six lines with a total length of 148 km.

2. QUESTIONNAIRE SURVEY

The Questionnaire Survey on Delhi Metro and Intermodal Transfer Facilities aims at understanding current usage of the Metro and clarifying what aspects Metro users are satisfied with and dissatisfied with, especially focusing on the intermodal transfer function of each Metro station access/egress. Metro stations should be located and designed to promote the shift to the Metro from other transportation modes and to maximize Metro users' utility level. More concretely, this survey was conducted to identify:

1. Usage of the Delhi Metro of residents and employees within the Metro service corridors; and
2. Satisfaction levels of Metro users and non-metro users in terms of intermodal transfer facilities and services along with their improvement needs.

2.1 Station Categories

Metro stations were classified into four groups based on the characteristics of each station according to the following points: 1) location (suburban area or central business district (CBD)), 2) existence of a station plaza, 3) service levels of feeder bus, 4) existence of a parking area, and 5) surrounding development that is often done by DMRC along with the Metro construction. A representative station has been selected from each group and the Questionnaire Survey has been conducted around this station as the main target. Following are the representative stations from four groups.

1. Shahdara Station (Group 1):
Location: (Suburban Area), Station Plaza: (Yes), Car Parking: (Yes), Surrounding Development by DMRC: (Yes)
2. Janakpuri West Station (Group 2):
Location: (Suburban Area), Station Plaza: (No), Car Parking: (Yes); Surrounding Development by DMRC: (No)
3. Uttam Nagar West Station (Group 3):
Location: (Suburban Area), Station Plaza: (No), Car Parking: (No), Surrounding Development by DMRC: (No)
4. Rajiv Chowk Station (Group 4):
Location: (Central Business District), Station Plaza: (No), Car Parking: (No), Surrounding Development by DMRC: (No)

2.2 Survey Method

There are two types of respondents for the Questionnaire Survey: residents around the stations in the suburban area, and employees of establishments in CBD. A total of 500

samples are randomly selected for the four stations, that is, 125 samples for each type of the station. As explained below, samples were selected in consideration of the conditions of their residential or work places in terms of physical distance from the stations, availability of feeder bus services, and convenience of their transportation modes, so on.

Residents Living around Stations in Suburban Area:

For sampling of residents living around the stations, they should be evenly divided into those living within 1 km of the station where walk is considered as the main access mode to the station, and those living in the range of 1km – 3km from the station where the probability of using other transport modes is higher. Surveyors visited each sampled household, explained the purpose and contents of the questionnaire survey, asked each household member (of age 18 or over, and to make a trip to CBD direction more than once a week) to fill in the questionnaire, and came back to the same household later to collect the questionnaires. The survey asked questions about the most frequent Metro trip for each respondent among several purposes (to work, to school, shopping, or for other private purpose). For those who do not use the Metro, the survey asked questions about the most frequent trip to the city center for each respondent among several purposes (to work, to school, shopping, or for other private purpose).

Employees of Establishments around Stations in CBD:

For sampling of establishments around stations, they should be evenly divided into those located within 300m of the station and those located further than 300m from the station. Surveyors visited each sampled establishment, explained the purpose and contents of the questionnaire survey, asked each employee to fill in the questionnaire, and came back to the same establishment later to collect the questionnaires. The survey asked questions about the most frequent work-based Metro trip. For those who do not use the Metro, the survey asked questions about the most frequent work-based trip around the city center.

2.3 Characteristics of Respondents

The questionnaire survey for residents and employees around the representative stations was conducted through home-visit face-to-face interviews. Individual attributes as well as household attributes were surveyed from the Metro users and non-Metro users who make trips to/around the CBD. General characteristics of the questionnaire respondents were first analyzed by user type (i.e., Metro users and non-Metro users).

Over 80% of the respondents of both Metro users and non-Metro users are workers (Figure 1a). Workers of Metro users consist of a variety of classes from employers/managers to part-time/day workers. In addition, relatively more students are observed in the Metro users. Although car-owning households are less than half, a larger share of car-owning households is observed in Metro users' households (Figure 1b). Meanwhile, motorcycle-owning households take about 70% with a higher motorcycle-owning ratio in Metro users' households (Figure 1c).

As for average monthly household income (Figure 1d), the shares of households of middle-income classes are larger in Metro users. This may be due to the fact that lower-income people cannot afford to take the Metro while higher-income people prefer to use private travel modes such as cars.

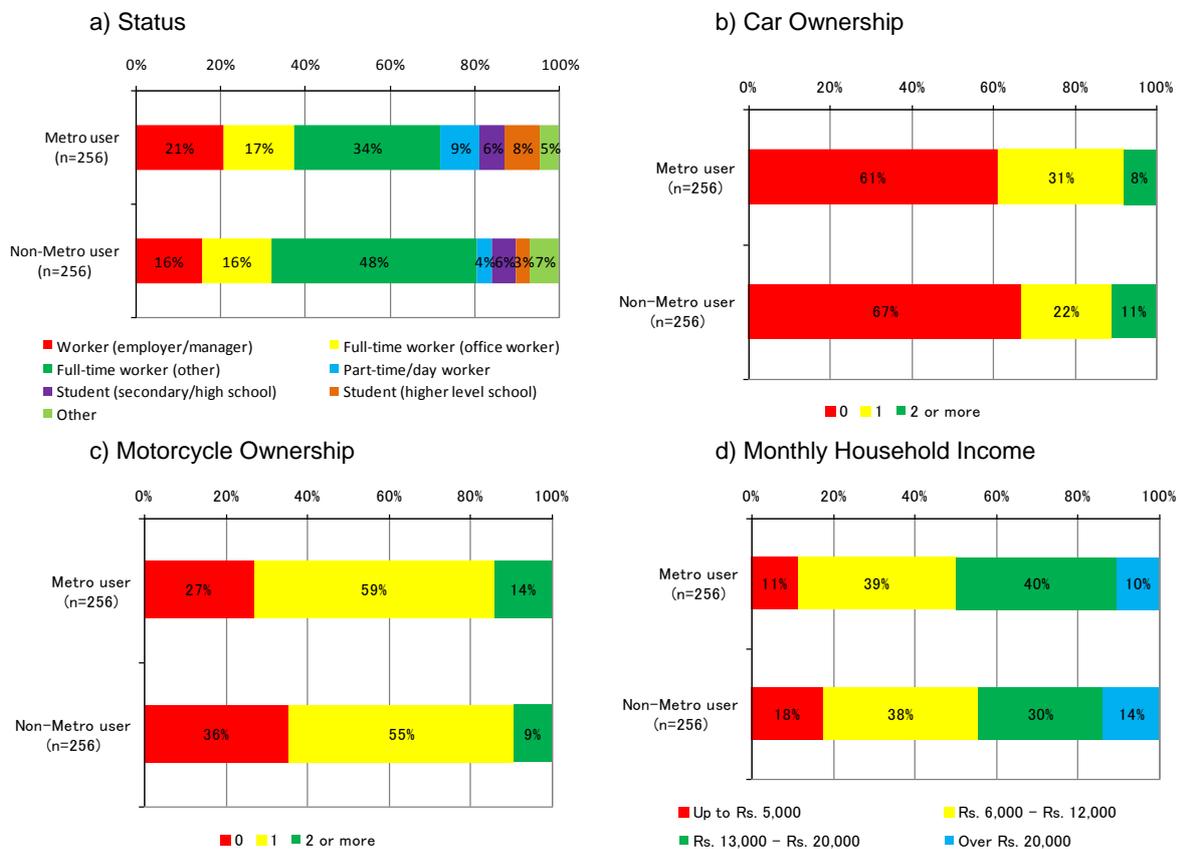


Figure 1 - Characteristics of Metro users and non-Metro users

3. ANALYSIS OF GENERAL IMPROVEMENT NEEDS

3.1 Improvement Needs for Metro Users

Metro users' access mode to the stations was analyzed by distance from the station (Figure 2a). Among suburban residents, while larger shares of access modes other than walk (i.e., private vehicles and buses) are observed in Metro users living over 1 km from the station, walk still takes around 50%. As described earlier, this may be because a considerable number of Metro users have no other option than to walk to the station under the current conditions.

Furthermore, which facilities/services Metro users are dissatisfied with was asked (Figure 2b). Though the result varies by station, dissatisfactions with bus facilities/services take the largest share in the suburban stations. Those who use conventional bus operated by Delhi Transport Corporation (DTC) or DMRC feeder bus as an access mode to the station take less than 20%; however, dissatisfactions with bus facilities/services take much larger share.

It implies that, since bus services are not available to some Metro users at present, they have to take other access modes such as walk.

With respect to bus facilities/services, station facilities, and taxi/auto tricycle rickshaw (hereinafter called 'auto rickshaw')/cycle rickshaw (hereinafter called 'rickshaw') facilities with which Metro users are most dissatisfied, their improvement needs were aggregated. Major improvement needs in terms of bus facilities/services are new feeder bus routes, more frequent bus services (including DTC buses), and punctual bus services (Figure 3a). Thus, requests regarding improvement of bus services take the majority. For station facilities (Figure 3b), additional escalators/elevators, additional waiting facilities such as benches, and additional services to reduce the queues for ticket purchase and security check are needed. As for taxi/auto rickshaw/rickshaw facilities (Figure 3c), requests for more rickshaw space take the largest share. It may imply that the respondents request for improvement of traffic congestion caused by rickshaws waiting at the roadside due to the lack of a station square.

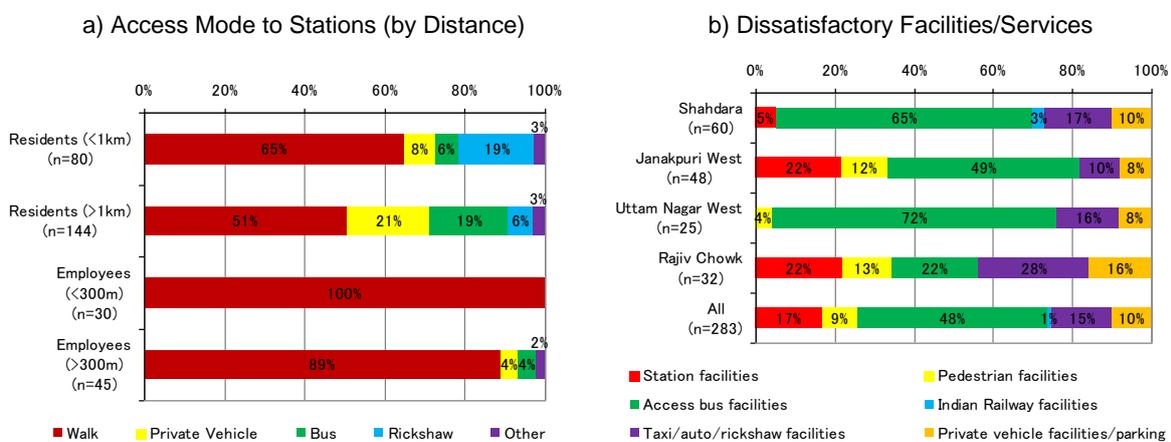


Figure 2 - Result of analysis for Metro users

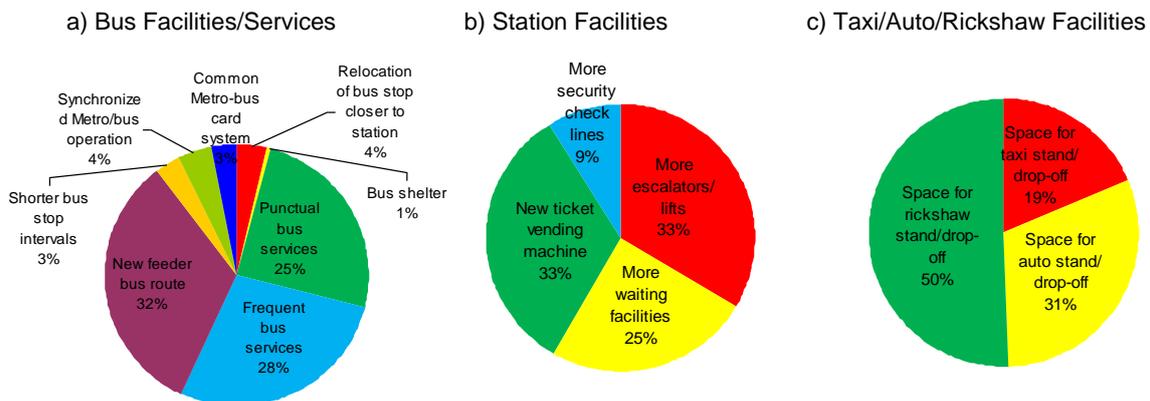


Figure 3 - Metro users' improvement needs

3.2 Improvement Needs for Non-Metro Users

Around 60% of suburban non-Metro users take bus to go to CBD (Figure 4a). As for CBD employees, while about 40% of them take bus, shares of motorcycles, auto rickshaws, and rickshaws are relatively larger.

For trips to/around CBD made by non-Metro users, nearly half of suburban residents admit that their destinations are accessible by Metro, whether they live within 1 km of the station or not (Figure 4b). It may be natural that those who live within 1 km of the station have a larger share of having tried Metro before. As for CBD employees, they have a higher probability that their destinations are accessible by Metro because their workplace is relatively closer to the station. As a whole, there are not so many cases in which Metro cannot be used for trips to/around CBD (e.g., the destinations are physically inaccessible from Metro stations).

Regarding which facilities/services non-Metro users are particularly dissatisfied with (Figure 4c), dissatisfactions with bus facilities/services take the largest share. This implies that current non-Metro users also have a great potential of using Metro if DTC buses or DMRC feeder buses become more easily available for access to the stations. For non-Metro users, dissatisfactions with private vehicle facilities/parking take the second largest share, followed by those with station facilities. It may be because, at present, there are many private vehicle users to go to CBD. Therefore, it can be inferred that improvement of private vehicle facilities/parking is extremely important to encourage non-Metro users to shift to Metro.

With respect to bus facilities/services, station facilities, and private vehicle facilities/ parking with which non-Metro users are most dissatisfied, their improvement needs were aggregated. For improvement needs in terms of bus facilities/services (Figure 5a), a similar trend is observed as in the case of Metro users. That is, requests regarding improvement of bus services take the majority. While other requests include construction of bus shelters (equipped with waiting facilities and information boards), requests that are related to enhancement of intermodal transfer functions between bus and Metro take only a small share. As for station facilities (Figure 5b), the result is nearly the same as that of Metro users. That is, additional escalators/elevators, additional waiting facilities such as benches, and additional services to reduce the queues for ticket purchase and security check are needed. For private vehicle facilities/parking (Figure 5c), requests that are related to expansion of car and motorcycle park & ride facilities, in which congestion is currently severe, take the majority. Parking restriction against non-Metro users is also requested by non-Metro users themselves. Thus, alleviation of congestion at parking facilities is an important issue. Current non-Metro users also have a great potential of shifting to Metro if this problem has been solved. There is also a significant share of requesting pick-up/drop-off space for private vehicles as one of the functions of station plazas.

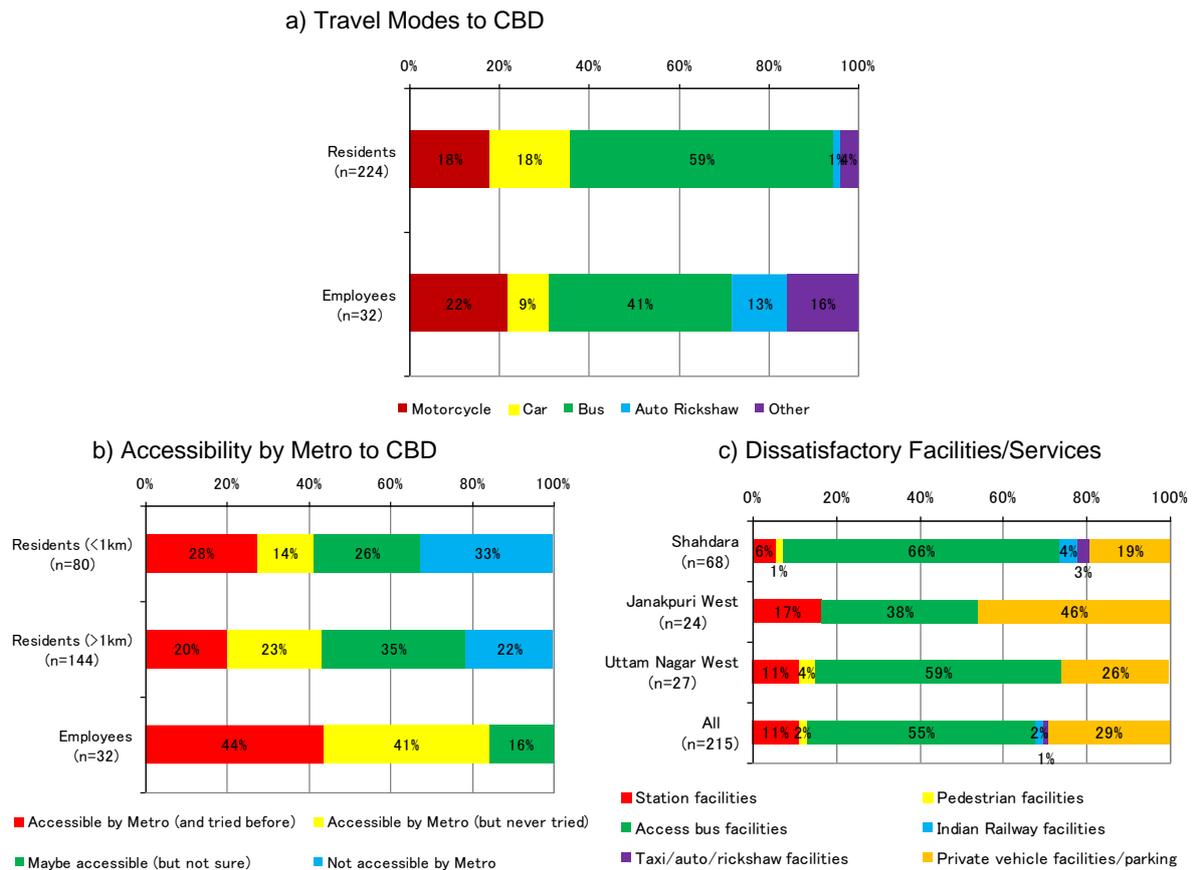


Figure 4 - Result of analysis for non-Metro users

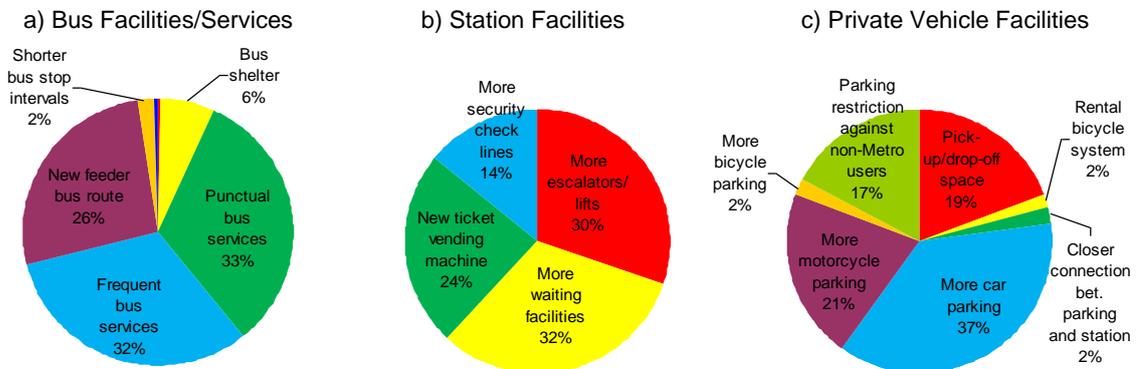


Figure 5 - Non-Metro users' improvement needs

3.3 Issues on Intermodal Transfer Functions

Based on the site survey and the analysis of the above-mentioned questionnaire survey, issues and measures on intermodal transfer functions of stations of Delhi Metro are identified and sorted by relevant facility/service type as follows.

Station Facilities

1. Though escalators and elevators have been installed in all the Delhi Metro stations, there are further requests for more escalators and elevators. It may be because escalators or elevators are not available in certain exits/directions or because escalators and elevators are often not installed to connect with station plazas or roads outside the station. It may be one of the resistant factors in using Metro.
2. Congestion occurs for ticket purchase and security check before the ticket gate, and the queues become especially long at major stations in CBD as well as in the suburbs during peak hours. This congestion is one of the resistant factors in taking Metro. Thus, additional security check lines and new automatic ticket vending machines are important issues to solve the current congestion problem.
3. In the stations, due to the security reasons, there are few waiting facilities such as benches even on the platforms. Although these waiting facilities need to be added for enhancement of convenience for users, how to maintain the security of the public while at the same time making people comfortable enough to want to ride the Metro is an important trade-off which should be discussed in a greater depth.

Pedestrian Facilities

1. Since Delhi Metro was often constructed by making use of the space over or beside the existing roads, space for a station plaza was hardly available at many stations. Consequently, distances to access transport modes tend to be long, and thus it is important to secure comfort in walking between the access modes and the station. The fundamental solution is to provide dedicated and secured pedestrian pavements, and other options should also be considered such as roofed pedestrian walks (including green shelters) and moving walkways.
2. In cases where pedestrian passages are not well provided to connect the station and the road, some Metro users are obliged to cross the road to take access transport modes. While pedestrian crossings are often provided, traffic signals and pedestrian overpasses are not provided and it is difficult to cross the road in most cases. Thus, safe pedestrian crossing facilities are necessary.

Bus Facilities/Services

1. Improvement in bus services as an access mode to Metro stations is requested by most respondents whether they currently use bus or not. Major improvement needs are new feeder bus routes, more frequent bus services (including DTC buses), and punctual bus services.
2. Current Metro users make use of not only DMRC feeder buses but also conventional DTC buses as an access mode to Metro stations. Since improvement of bus transport to Metro stations is often requested by Metro users who currently take other

access modes as well as by non-Metro users, not only DMRC feeder buses but also DTC buses should be targeted for improvement of the entire bus services to enhance the intermodal transfer functions of urban railway systems.

3. While DMRC feeder buses pick up and drop off passengers close to Metro stations, DTC bus stops tend to be located a little far from the stations. In future, it is necessary to improve the convenience of access bus users through relocation of bus stops closer to the stations, construction of bus shelters (including waiting facilities and information boards), and so on by reviewing the layouts of space around Metro stations or by securing the space for station plazas.
4. Overall, access bus service levels around Metro stations are currently not very high. Therefore, shorter bus stop intervals (i.e., shorter than the current standard of 1 km intervals) need to be considered to reduce the reluctance to use Metro.
5. In terms of the system issues, improvements should include synchronized Metro-bus operation, common Metro-bus card system (with a discount for transfers), and so on in order to enhance the connectivity between Metro and bus.

Taxi/Auto Rickshaw/Rickshaw Facilities

1. Space for a taxi or auto rickshaw stand is provided in station plazas of only limited number of stations such as transfer stations to Indian Railways. Such space is not available at other stations. Even if space for a station plaza is available, it is not well planned to cope with the access traffic and consequently taxis and auto rickshaws are often one of the causes of traffic congestion. Thus, it is necessary to study how to provide the space for a taxi or auto rickshaw stand.
2. Rickshaws are more frequently used around suburban stations. However, if there is no space for a station plaza, rickshaws occupy space beside the access road, creating traffic congestion. It is important to secure the pick-up/drop-off space for rickshaws for smoother traffic flow of other access transport.

Private Vehicle Facilities

1. As car and motorcycle parking areas around many Metro stations are heavily congested, expansion of parking facilities is requested not only by Metro users but also by non-Metro users. Increase in parking capacity is an important issue, and parking buildings are being planned at some stations. If parking space becomes more easily available, it is hoped that a significant number of non-Metro users who currently use private vehicles all the way to the destinations will shift to Metro.
2. On the other hand, it should be noted that expansion of parking space may have the unintended effect of disrupting operations of buses which will now have a more difficult time negotiating the increased traffic to reach the Metro station. Therefore,

separation of flows of public transport from those of private vehicles should be considered. In addition, securing safe passage for pedestrians should be deliberately planned as well.

3. As one of the measures to alleviate congestion at car and motorcycle parks, there are many requests for parking restriction against non-Metro users. At present, holders of a Metro Smart Card have free access to bicycle parks. A similar checking system should also be applied to car and motorcycle parks as well.
4. As one of the measures to enhance the intermodal transfer functions of Metro, there are many requests for providing pick-up/drop-off space for cars and motorcycles. In addition, as for passage between parking facilities and stations, comfort and safety should be considered.
5. Ratio of motorcycle-owning households is relatively high, and it is assumed that motorcycle users easily shift to cars or bicycles depending on the situation. Therefore, current situation of usage of park & ride as well as the situation around stations needs to be studied in detail. Shifting to bicycles is preferable to shifting to cars from a viewpoint of efficient use of the limited space around stations. Thus, it is necessary to study expansion of bicycle parking space and potential for diffusing rental bicycle systems as measures to improve the intermodal transfer functions.

4. IMPLICATIONS OF IMPROVEMENT NEEDS AT REPRESENTATIVE STATIONS

4.1 Comparison by Representative Stations

Metro users' access mode to each representative station varies in each station of which conditions are different in terms of availability of station plazas, feeder buses, DTC buses, car parks, and so on (Figure 6a). However, walk takes at least 50% at all the stations. At Rajiv Chowk Station, in particular, walk takes the overwhelming majority. In the suburbs, access by bus or rickshaw takes relatively larger shares at Shahdara Station, which has a variety of access transport modes as well as a station plaza. On the other hand, access by walking takes nearly 80% at Uttam Nagar West Station, where few access modes are available.

In terms of Metro users' satisfaction level of intermodal transfer functions at the station (Figure 6b), more than half of them are dissatisfied with some intermodal transfer functions of their suburban station except for Rajiv Chowk Station in CBD. The share of dissatisfaction is the largest at Uttam Nagar West Station, in which few access modes are available.

About reasons why non-Metro users do not use Metro (Figure 6c), there are a considerable number of respondents who stated that the total cost including the Metro fare is higher than that of the current travel mode at each representative station. While current Metro users were not asked about the cost in this research, according to another questionnaire survey that was conducted earlier targeting about 5,000 Metro users (Rites et al., 2008), 23% requested for a reduction in the Metro fare and thus the cost issue deserves some more

attention. On the other hand, considerable shares of non-Metro users also pointed out dissatisfactions with intermodal transfer functions such as inconvenience of transfers and insufficient access transport means. Those shares are especially large at Uttam Nagar West Station, which has a problem in accessibility to the station. On the other hand, as for Rajiv Chowk Station, which is located in CBD, there are a significant number of employees who answered discomfort of Metro as a reason for not using Metro. This may be partly because the Metro is crowded particularly in CBD.

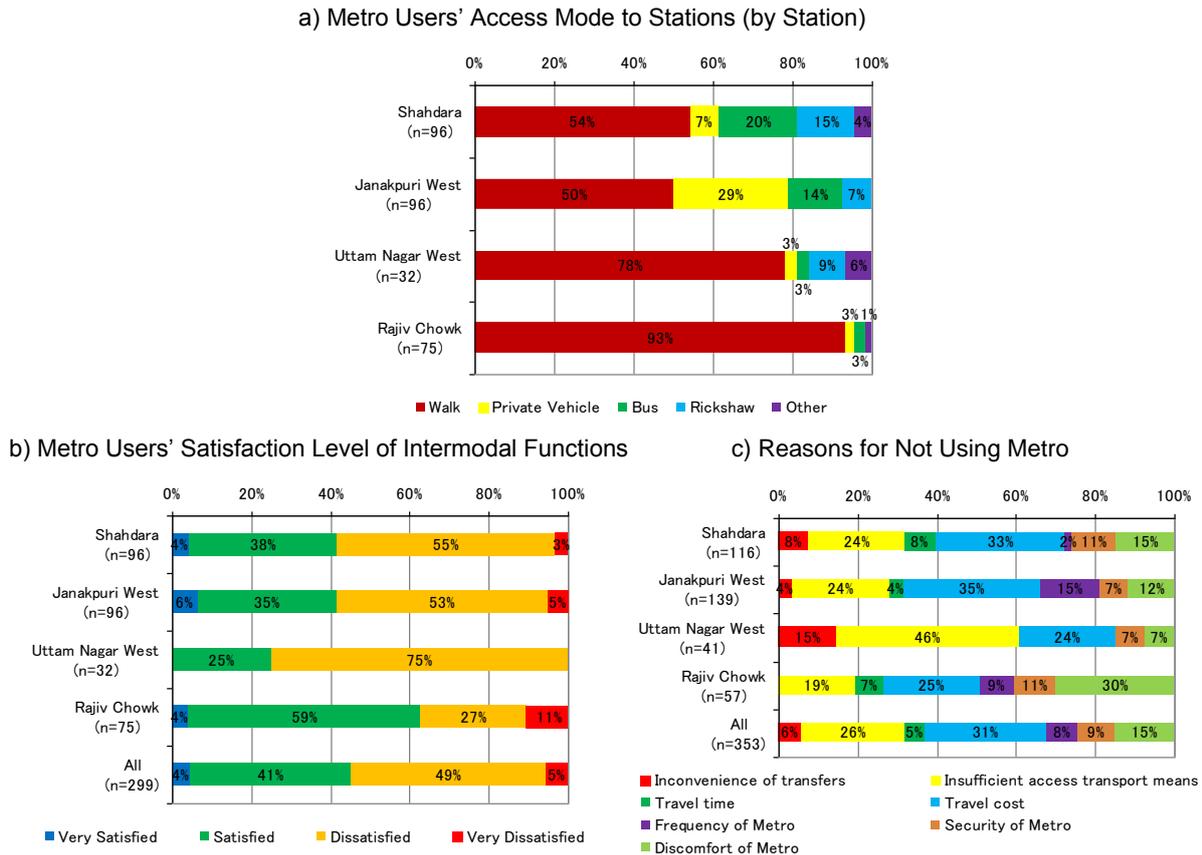


Figure 6 - Comparison by representative stations

4.2 Issues of Each Representative Station

Shahdara Station

Supplemental questionnaire surveys were conducted at Shahdara Station, which is a representative station of Group 1 with a station plaza and connections with various transfer modes. Improvement needs of intermodal transfer functions were asked of Metro users transferring to/from Indian Railways and other access transport modes (i.e., DTC bus and park & ride) at the station.

In terms of station facilities (Figure 7a), there are particularly many requests for additional services to reduce the queues for ticket purchase and security check. Since Shahdara is a transfer station with various transport modes, a heavy concentration of passengers can be imagined.

With respect to improvement of pedestrian facilities (Figure 7b), there are many requests for installation of roofs (including green shelters) or moving walkways for pedestrian passages to be used for transfers, partly because walking distance between the station and the access modes tends to be long at Shahdara Station. In addition, there are many requests for safe pedestrian crossing facilities or dedicated pedestrian pavements, as the roads around the station are often congested with vehicles and there are no traffic signals or pedestrian overpasses. Over half of requests of pedestrian facilities made by Metro users transferring to/from DTC bus are especially concentrated on such pedestrian crossing facilities.

Major improvement needs in terms of Indian Railway facilities/services are related to improvement of the railway service itself such as more frequent and punctual railway services (Figure 7c). In addition, there are many requests that are related to enhancement of intermodal transfer functions between Indian Railways and Metro, including shortcuts to transfer to/from Indian Railways through a dedicated passage, synchronized Metro-railway operation, and so on.

Major improvement needs in terms of bus facilities/services are related to improvement of bus services such as new feeder bus routes, more frequent bus services, and punctual bus services, and they take more than half of the total improvement needs (Figure 7d). However, the share is relatively smaller since Shahdara Station is currently served by relatively many bus routes. Meanwhile, requests that are related to further enhancement of the convenience are more remarkable including shorter bus stop intervals, construction of bus shelters, synchronized Metro-bus operation, and introduction of a common Metro-bus card system.

While the major request made by Metro users transferring to/from motorcycle park & ride is expansion of motorcycle parks, there are also significant shares of requests for expansion of car parks and bicycle parks (Figure 7e). This implies that motorcycle park & ride users may switch to car or bicycle for access to the station depending on the situation. In addition, there is also a significant share of requesting pick-up/drop-off space for private vehicles as one of the functions of station plazas. Other requests include introduction of a rental bicycle system.

The major request made by Metro users transferring to/from car park & ride is expansion of car parks only (Figure 7f). In addition, parking restriction against non-Metro users is also requested by many car park & ride users. Thus, alleviation of congestion at parking facilities is an important issue. Other requests include closer connection between parking facilities and the station as well as more pick-up/drop-off space for cars.

While those who transfer to/from auto rickshaws/rickshaws were not specifically interviewed, it was often requested by Metro users to provide more space for waiting and drop-off/pick-up. Such space is desired beside the station rather than on the trunk road.

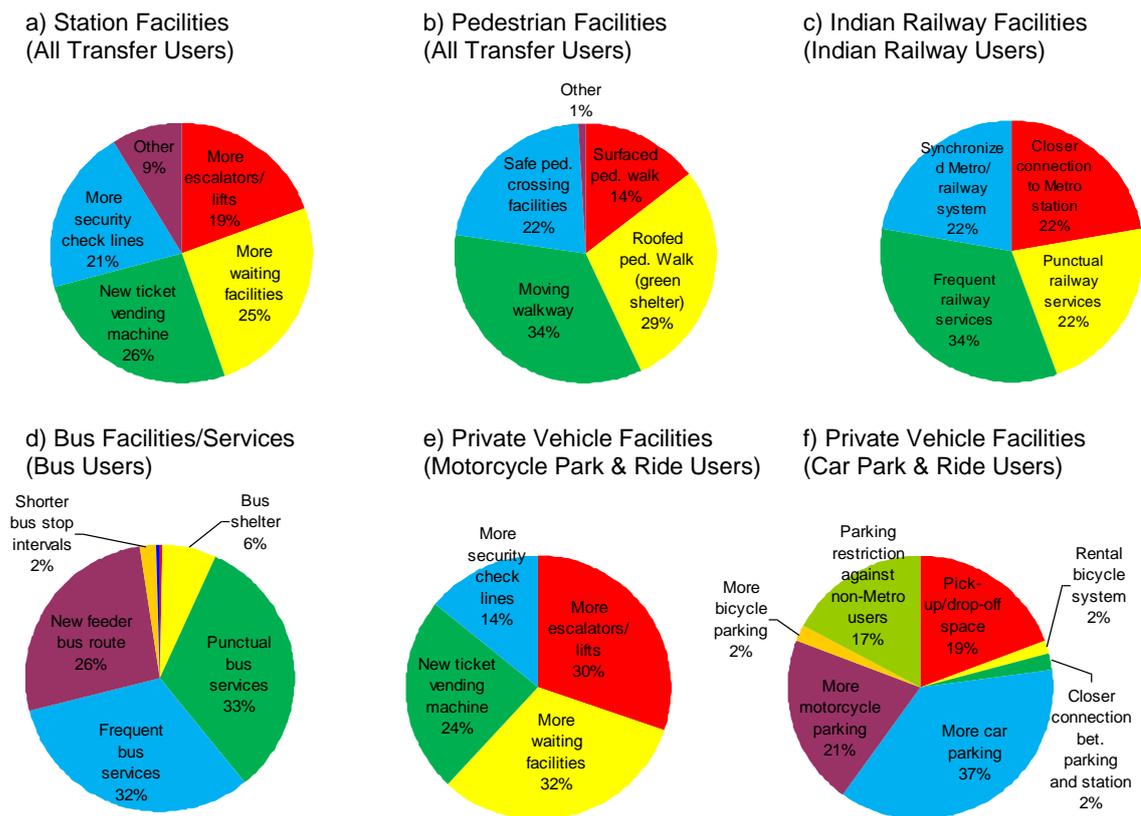


Figure 7 - Improvement needs of Metro users transferring to other modes

Janakpuri West Station

Janakpuri West Station, which is a representative station of Group 2, is a medium-scale station with feeder bus services as well as parking facilities. However, the station has no station plaza, and hence it is considered that facilities/services of each access transport mode need to be improved.

The majority of requests made by Metro users are related to bus facilities/services such as new feeder bus routes, increase in service frequency, and improvement in punctuality. On the other hand, improvement needs about private vehicle facilities/parking are relatively large especially among non-Metro users. In fact, it is larger than the share of bus facilities/services. As for access mode shares of Metro users, private vehicle take about 30% which is larger than the other stations. Major requests for improvement include expansion of the car and motorcycle parks, provision of pick-up/drop-off space, parking restriction against non-Metro users, and so on.

The share of those who are dissatisfied with station and pedestrian facilities is greater than that of other stations, and there are requests for additional security check lines, automatic ticket vending machines, and waiting facilities such as benches. Furthermore, while the station has an elevated structure over the trunk road, there is no passage available through the station. Thus, there are also requests for pedestrian facilities.

Uttam Nagar West Station

Uttam Nagar West Station, which is a representative station of Group 3, has no station plaza. Feeder bus services and parking facilities are also non-existent; thus, 80% of Metro users access the station by walking and the remaining are likely to use rickshaws. Available services and facilities for access transport are thus limited. Therefore, the share of Metro users who are dissatisfied with intermodal transfer functions is the largest of the four representative stations. About reasons why non-Metro users do not use Metro, while the major reasons is that the total cost including the Metro fare is higher than that of the current travel mode at the other three stations, what the non-Metro users pointed out most regarding Uttam Nagar West Station is dissatisfaction with intermodal transfer functions such as inconvenience of transfers and insufficient access transport means.

Since at present there are no DTC bus or feeder bus services for Uttam Nagar West Station, the share of complaints about bus facilities/services is overwhelmingly large among both Metro users and non-Metro users. Although it may imply that new (feeder) bus services are requested as an access mode to the station, the roads are currently not wide enough for buses to pass through the urban areas around the station.

Furthermore, Metro users request more pick-up/drop-off space of rickshaws that are virtually the only access transport mode available. In addition, from both Metro users and non-Metro users, there are improvement needs about private vehicle facilities/parking including provision of car and motorcycle parks as well as pick-up/ drop-off space in front of the station.

Rajiv Chowk Station

Although Rajiv Chowk Station, which is a representative station in CBD, has no station plaza, the Metro users' level of satisfaction in terms of intermodal transfer functions is relatively higher compared to the suburban representative stations. The number of passengers who use this station is very large, and walk is the dominant access mode with a 90% share. Meanwhile, there are a variety of access modes, and the questionnaire survey revealed complaints about those facilities/services. Thus, intermodal transfer functions need to be enhanced.

Taxis and auto rickshaws are often used as an access mode to Rajiv Chowk Station. Thus, there are relatively more complaints about taxis and auto rickshaws compared to the suburban stations. In fact, improvement needs for taxis and auto rickshaws take the largest share among Metro users, including providing taxi bays, securing space for pick-up/drop-off, and so on.

The share of complaints about bus facilities/services is relatively small as compared to the suburban stations. In addition to the basic improvement needs for new feeder bus routes, more frequent bus services, and punctual bus services, accessibility between the station and the bus terminals located outside the ring road is an issue which is also related to pedestrian facilities.

About station facilities, since many passengers concentrate at this station, there are relatively more requests for additional security check and ticket vending facilities and equipments to reduce the queue of passengers compared to the other stations. Furthermore, as the

platforms and trains are always crowded with passengers, alleviation of this congestion is also requested.

5. SUMMARY

In this paper, actual usage of passengers of the urban railway systems was identified and potential demands on facilities and services to improve transfer activities was analyzed through a Questionnaire Survey taking the Delhi Metro System as a case study. Improvement needs that were revealed in the paper imply several significant measures for strengthening the intermodal mobility of the Metro system in terms of relatively short-term perspectives.

For physical improvement of railway stations, a barrier-free system needs to be introduced for ensuring smooth movement of passengers or handicapped people in particular. Their vertical movements should be supported by elevators and/or escalators in order to make their transfer from one transport mode to another as easy as possible.

In terms of improvement of intermodal facilities, since the railway is a network utility, the intermodal transfer system at railway stations should be improved to ensure the convenience of transfer from one public transport mode to another with less impedance on passengers. The following measures deserve to be implemented for this purpose:

1. To improve the user-friendliness of the transport facilities, by providing pedestrian walks, car parking lots and other transport services;
2. To upgrade the convenience level for transferring activities, by improving physical conditions such as shortening the walking distance for transferring from the metro to another mode and provision of Information on timetables and operational conditions; and
3. To prepare the safe and comfortable waiting space for transferring passengers.

Furthermore, according to the result of the Questionnaire Survey, more than half of the Metro users residing in suburban areas desire the improvement of feeder bus services in terms of: 1) accessibility to bus service; 2) frequency of the services; and 3) punctuality of the operation. This is the most vital point to strengthen the intermodal system of the overall public transport network.

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