International Transport Forum

Seamless Public Transport for All

Proceedings of a Joint Seminar held in Paris, France on 6 March 2012

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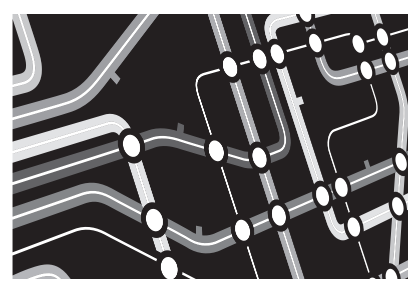
Seamless Public Transport for All



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INTERNATIONAL TRANSPORT FORUM

The International Transport Forum at the OECD is an intergovernmental organisation with 54 member countries. It acts as a strategic think tank with the objective of helping shape the transport policy agenda on a global level and ensuring that it contributes to economic growth, environmental protection, social inclusion and the preservation of human life and well-being. The International Transport Forum organises an annual summit of Ministers along with leading representatives from industry civil society and academia.

The International Transport Forum was created under Declaration issued by the Council of Ministers of the ECMT (European Conference of Ministers of Transport) at its Ministerial Session in May 2006. Under the legal authority of the Protocol of the ECMT, signed in Brussels on 17 October 1953, and legal instruments of the OECD.

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The International Transport Forum's Research Centre gathers statistics and conducts co-operative research programmes addressing all modes of transport. It findings are widely disseminated and support policymaking in Member countries as well as contributing to the annual summit.

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FOREWORD

The Joint International Transport Forum (ITF) / Korea Transport Institute (KOTI) Seminar on Seamless Public Transport took place in the OECD Conference Centre, in Paris on 6 March 2012. The theme of the Joint Seminar, Seamless Public Transport for All, was decided in order to contribute to the theme of the 2012 ITF Summit, Seamless Transport. The Joint Seminar consisted of three sessions as:

- Session 1: Seamless public transport strategy for national perspectives
- Session 2: Better network design for seamless public transport operation
- Session 3: New technology to facilitate seamless transport operation.

Two presentations were made in each session, one from Korea and the other from Europe, together with panel discussions. The presentation slides are available on the ITF website (www.internationaltransportforum.org).

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1 INTRODUCTION

1.1 Seamless public transport strategy for national perspectives

The first session of theseminar discussed strategic public transport policies from national perspectives. Dr. Sang-Min Lee (KOTI) showed the extent to which the use of public transport in Korea can be compared, unfavourably, to using private cars – particularly for trips between cities. He pointed out that public transport is expensive in this country, and travel takes longer than by car owing to poor linkage between inter-regional and intra-regional public transport. This in turn results in fewer public transport demands, while the amount of subsidies to public transport operators increases. However, Mr. Lee insisted that public transport could be faster and more convenient and competitive by integration in the five areas of networks, physical facility design, fares, institutions and information. The Korean government is planning to promote this integration policy following nationwide studies.

Mr. Francis Cheung (Dutch Ministry of Infrastructure and the Environment) explained how an electronic fare collection system, *OV-chipkaart*, was introduced throughout the Netherlands. This smart fare collection system requires that all travellers swipe their cards when they get on, or disembark from, any type of public transport. He presented a cost benefit estimation of this system, showing a strong net benefit arising particularly from time savings in obtaining tickets as well as the elimination of fraud. Other advantages were provided by the ability of the system to collect travel information, including how many people use public transport between certain origin-and-destination pairs at particular times of the day. This data had been quite expensive to collect in the past. The new ticketing system can also differentiate pricing according to user type. Mr. Cheung mentioned that a close partnership between public transport authorities and operators was one of the keys to implementation of the new scheme.

1.2 Better network design for seamless public transport operation

The second session covered how public transport can be better connected by improvements in the network design. Dr. Youngjong Kwon (KOTI) estimated that there had been a seventy percent reduction in demand for inter-city buses between 1990 and 2010. He presented the survey results which showed the reasons that people find public transport not as attractive to use as private cars. It appears that the main reason for voyagers not using public transport is the poor accessibility to bus terminals and main railway stations. Dr. Kwon then referred to specific cases where connections between transport modes are disrupted, and showed the economic benefits that can be gained through using the hub-and-spoke design principle in the public transport network. One typical example is an Expressway Transfer Centre in the rest areas of motorways, where inter-city bus passengers can transfer onto buses to their final destinations. This helps passengers to avoid going into city centres in order to transfer and thus saves a substantial amount of time. He also suggested some design improvements in transit hub stations which would help improve transfer services.

Mr. Gustav Nielsen (Norway) pointed out that ‘simplicity’ and ‘ease of use’ is the key to promoting public transport. People will not use public transport if it is too complicated. Even new users should be able to quickly understand how to get to their destination using the public transport. He also stressed the network effect which he believes could be exploited more, but that the public transport has not thus far capitalised. He suggested some cities with good public transport services in Europe and North America make the most of the network by providing frequent service in main corridors, and removing barriers in transfer between modes. Some technical issues of optimal frequency, distance between stops, and speeds are explained in detail. This can be practically [particularly?] important and useful for the efficient operation of the public transport system. Mr. Nielsen emphasised that, in order to promote sustainability, public transport systems need to be well connected with walking and cycling. Finally, he stressed the importance of integration between transport plans and land-use plans.

1.3 New technology to facilitate seamless transport operation

The third session focused on how new information and communications technology can contribute to the seamless operation of public transport. Dr. Jungsil Lim, from KOTI, spoke of the technologies that have been applied in the course of the reform of public transport in Seoul since 2004. She continued by outlining the concept of Mobile Transit for All, which integrates travel information as well as fare collection nationwide through smart phone technology. This covers all inter- and intra-regional transport modes, including bikes, buses, metros, railways, regional buses and flights. If implemented, this could provide huge benefit to users, but the concept requires further study.

Mr. Hudson, of Transport for London (TfL), explained how London's smart card, the *Oyster Card*, has contributed to an increase in gate throughput in stations as well as a reduction in fraud. In London, the business case for introducing the Oyster Card was driven by the prohibitive cost of expanding conventional gate capacity in overcrowded station concourses due to the high land prices in central London. Mr Hudson then outlined TfL's new transit model, using contactless bank credit and debit cards on all modes. These cards have the advantage of processing all data in the back-office rather than at the ticket gate terminal, thus allowing for more streamlined data processing. With this capacity travellers can enjoy the lowest fares, and can also be given refunds more easily when problems with services arise. All sorts of marketing opportunities are also opened up, making discounts and other incentives available. The biggest benefit of all is that these cards will become universal payment systems, acceptable to any system, where the banks agree to underwrite a minimum level of fraudulent use for travel, as they do for retailers accepting conventional bank cards.

1.4 Main discussions

To summarise the benefits of electronic ticketing with smart cards for public transport: firstly, it has reduced waiting times to buy paper tickets, and has shortened boarding times on buses. For operators, it has helped to reduce passenger fraud and vandalism, while increasing revenues; this, in turn, has reduced the need for government subsidies. Above all, the electronic cards enable operators to provide optimal services according to anticipated travel demand, which can be estimated based on previous ticketing data. Distance-based fares can also be charged by means of smart cards, charging less to those who travel short distances and more to long-distance travellers.

However, ticketing technology needs to be totally reliable; otherwise operators and users will lose confidence and fear losing their money. Transition to smart cards can also be facilitated by means of simple fare structures, as can be found in Singapore and Hong Kong. The main inconvenience of the current smart card system used in London and Amsterdam is that it applies the maximum charges to travellers who have failed to swipe their cards on the check-through pads, either from the users' mistake or operators' error. This leads to unnecessary administrative costs for reimbursement.

Electronic ticketing may evolve in the future to be integrated into bank cards and smart phones. Users will not require separate smart cards for public transport, and will not be charged before use. They will pay credit card or smart phone bills which will include ticketing costs. This account-based system is more convenient for travellers, mainly because they will not need to worry about the lowest fares and the remaining credits: they will simply turn up and use the public transport. Most of all, it may enable travellers to pay all sorts of public transport fares in any city and country. For operators, it can eliminate concerns about security, including hacking issues. This can be transferred from smart card operators to banks.

Network design is a fundamental aspect that needs to be carefully considered in making public transport seamless, particularly because public transport exhibits network economies. This means that costs per unit of service decline as loads increase. A careful network design can help to increase demand and allow better seamless service. For example, when adding one more bus to a particular link, the frequency of service rises for all passengers using the route, while waiting and transfer times decline. Similarly, adding stops reduces walking times, and using bigger buses saves on operating costs per passenger. It seems that network benefits are not being fully exploited, due to a lack of focus on cost-effectiveness during the network design stage.

There are two kinds of approach for linking one place to another in a public transport network: hub-and-spoke, and point-to-point. In the hub-and-spoke approach, passengers take subsidiary modes to reach a hub or terminal with frequent and fast trunk line services, and then use subsidiary modes once again to arrive at the final destination. In the case of the point-to-point approach, passengers can travel directly – from a point of origin to a point of destination – without transfer.

In general, passengers may be better off if they can travel without transfer, based on the point-to-point approach, but services may be less frequent unless there is enough demand. On the other hand, the hub-and-spoke approach can share trunk lines and provide frequent services between hubs. However, this is not always economically viable, because it implies higher investment as well as operation costs, and it cannot respond flexibly to changing demand. Further in-depth studies are needed to examine which approach is comparatively beneficial under various conditions.

Public transport terminals need to be carefully designed and operated. Evidence from surveys carried out in Korea shows that the major impediments to the use of high-speed trains (called KTX) are: poor access to stations; and inconvenient transfers from trains to local transport modes. Better access to and from terminals, as well as convenient transfer design and operation between modes, can boost passenger use.

The accessibility of public transport terminals can be enhanced by developing the environment and services for all transport modes: walking, cycling, local buses and rental or private cars. In particular, bike- and car-sharing programmes can significantly improve access to public transport terminals. Integrating public transport terminal development with land-use plans can also contribute to improved accessibility. Agglomerations of economic and social activities such as working, shopping, eating, and leisure near terminals can considerably reduce the necessities of travel by private cars. Good practice access and transfer design and operation can be found in some Swiss cities, including Zurich, where routes and timetables of trains and buses are coordinated with each other to provide convenient transfer services.

The importance of institutional coordination cannot be overstressed when it comes to the seamless operation of public transport. The keys to success for smart card operation and network design rely on co-operation between stakeholders, and this can only be guaranteed through good institutional coordination.

To introduce a smart card scheme, public transport operators should agree on a fare collection system. In many cases, it has been shown to be beneficial to both passengers and operators to introduce such a scheme, but operators can be ambivalent about it, at least in the initial stages. They may not wish to share revenue data with other operators or with governments. They may worry about loss of revenue due to mechanical errors in an electronic revenue-sharing system. Smart card operation, in itself, cannot guarantee more customers.

Experience in the Netherlands, Korea and the United Kingdom, shows that a coordination role for government is extremely important when introducing a smart card or e-ticketing system. Initially, governments must convince the major operators (which account for a substantial market share) to participate in the new fare system. A strong political will, or leadership, can be important at this stage, and some government subsidies for installation of the new payment scheme, as well as for the purchase of smart cards, are essential in the course of the initial coordination.

In later stages, a tendering system can be a good instrument to facilitate the introduction of the new payment scheme. It can oblige operators to share relevant data on public goods. Furthermore, standardisation of smart cards is crucial to guarantee interoperability between different modes and operators. Then it can be applied over wider regions, possibly at national level. In this way, possibly all transport modes, including bus, metro, train and plane, may be used continuously nationwide, without separate ticketing for each mode.

Improved network design and operation can also be implemented by coordination routes and timetables between modes and operators. It is not yet common for operators to help each other voluntarily to provide better service and increase revenues. But the role of coordination will become vital for the realisation of seamless public transport. This role may be under government responsibility, or may be handed over to new, or existing, public authorities and organisations.

PART I: SEAMLESS PUBLIC TRANSPORT STRATEGY FOR NATIONAL PERSPECTIVES

2. ONE NATION, ONE SEAMLESS PUBLIC TRANSPORT SYSTEM

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Public transport reform is essential in order to encompass an entire nation into one transport city under a unified transport system; thereby helping to realize transport welfare, build an environment-friendly green transport network, and improve national competitiveness. In this context, this paper examines ways to ensure an integrated, nationwide, public transport system, focusing on critical requirements such as a public transport linkage transfer system, fare integration, integrated information service, and integrative management and operations.

2.1 Necessity for Building an Integrated Nationwide Public Transport System (One Nation, One Transport City)

Need for Public Transport Integration

Under the present public transport system, operations of various traffic modes are planned and implemented independently of each other. This lack of adequate intermodal linkage is causing inconvenience to the users. In addition, public transport's decreasing competitiveness against private passenger cars is adding to the inefficiency of the social transport network. Under these conditions, it is essential to improve the status of connections between public transport modes. Maximisation of the linkage would help minimise demand for high-cost investments in individual facilities such as urban railways, light rail and provincial airports. It would also contribute to revitalising the regional economies, by increasing the mobility toward destinations through improved accessibility to public transport.

It is therefore necessary to optimise the social transport system, thereby reducing social costs and improving the transport welfare of users in a way that is consistent with the global agenda of green and sustainable growth. Specifically, this task will involve efforts to build a single nationwide transport system (One Nation, One Seamless Transport Network) that can handle all the affairs related to public transport such as routes, transfers, information service and administration. These endeavors will represent a public transport reform based on a new transport paradigm calling for the pursuit of sustainable, environment-friendly and human-centric goals.

The Current Status of Public Transport and the Factors Responsible for Its Weakening Competitiveness

Intercity public transport has various problems, such as the lack of intermodal linkage and transfer discount service, insufficient information service, and differences between supply and demand. These problems are weakening public transport's competitiveness against private passenger cars, causing inconvenience in usage, and deterioration in path efficiency. This paper examines the current status of public transport by analysing social costs caused by such external diseconomies, as well as the inequitable supply of public transport services.

1. Weakening competitiveness in time and cost

Intercity public transport is losing its competitiveness against private passenger cars in terms of cost and effectiveness. Table 1 shows this by citing, as an example, a three-member family travelling from Ilsan to Cheongju, North Chungcheong Province. If the family uses public transport, the trip will take 190 minutes and cost 38 700 KRW (3 x 12 900 KRW per person). In contrast, travel by private car would take 127 minutes and cost 11 433 KRW. This example shows that public transport is less competitive than the private car, which costs less and ensures door-to-door service.

2. Limitations in user convenience due to difference in payment schemes

Public transport also has a problem in terms of payment convenience. The family cited above would have to use three, to four, modes while moving from Ilsan to Cheongju by public transport. In addition, they would need to have various means of payment, such as transport cards, cash, as well credit cards. The family would also suffer the inconvenience of having to pay travel fares each time they transfer from one mode to another, without receiving transfer discounts.

Currently, the integrated fare system, which allows for the use of one card for all means of public transport as well as transfer discounts, is being implemented in Seoul and other metropolitan areas, and within cities. Yet, in the case of intercity public transport, the fare payment scheme differs from mode to mode, causing users the inconvenience of paying separately for each mode. In addition, the users are not offered transfer discounts; and there are no fare formulas (that could expand the scope of user choice) either.

3. Reduced path efficiency and inadequate public transport connections

Public transport users also experience inconveniences related to inefficiency, most typically the lengthening of paths. This phenomenon is related to the lack of transport nodes and intermodal transfer systems, which cause unnecessary increases in travel distance as well as extra costs.

Let's take, as an example, a resident of Bundang seeking to make a trip to Cheongyang in South Chungcheong Province, Gyeongju, or Busan, by using public transport. The resident would first have to move to the express bus terminal, the airport or the KTX station in Seoul. This means the lengthening of the travel path and time, as well as associated increases in costs. Such inconveniences would encourage travellers to opt for the private passenger car. They also offset the advantages of route minimisation and cost reduction the traveller can get when using KTX or air transport. For instance, a Bundang resident seeking to travel to Busan by air would entail up to six modes. The air travel would thus take 4 hours and 20 minutes – longer than 4 hours needed if travelling via KTX (see Table 1.).

Table 2.1. **Competitiveness comparison between private passenger cars and public transport category**

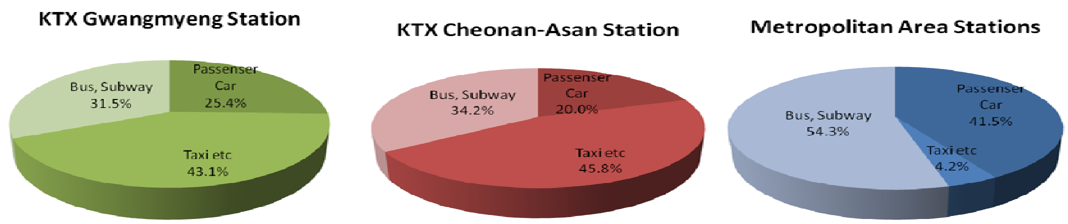
Category	Example 1 (Ilsan-Cheongju)			Example 2 (Bundang-Cheongyang)			Other Example 1 (Bundang- Gyeonju)			Other Example 2 (Bundang-Busan)			
	Bus	**Car**	**Bus/ Car**	**Bus**	**Car**	**Bus/ Car**	**BUS**	**KTX**	**Car**	**BUS**	**KTX**	**Airplane**	**Car**
Travel distance (km/trip)	167.5	175.8	0.95	170.9	119	1.44	334	355.8	333.89	396.2	432	432	378.76
Travel time (minute/trip)	190	127	1.5	207	120	1.73	294	251	225	294	238	238	257
Travel cost (KRW/person)	12 900	11 433	1.13	16 700	10 267	1.63	22 350	46 190	68 507	34 600	54 600	68 980	83 157
Traffic generation (㎡/person)	2.3	3.83	0.6	2.39	3.83	0.62	2.45	2.17	3.83	2.45	1.98	2.1	3.83
Carbon emission ($kgCO^2$/trip)	20.07	27.35	0.73	20.85	27.65	0.75	41.81	11.96	70.7	48.1	19.26	57.34	80.1

Note:

1. Car (Private vehicle) travel cost: fuel cost (based on the fuel efficiency of 12.4km/l, gasoline price of 1 975 KRW/l as of 24 November 2011) + tolls.
2. The average number of passengers inside an intercity bus: 9.98/vehicle (bus running between metropolitan areas).
3. The average number of passengers inside a bus operating within metropolitan areas: 12.33/vehicle (bus running within metropolitan areas).
4. The average number of passengers inside a bus operating within the Seoul metropolitan area.
5. Road space occupied by a private passenger car (based on parking space for ordinary cars as specified in Article 3-1 of the Parking Lot Act's enforcement decree).
6. Road space occupied by a bus (conversion coefficient in relation to private passenger cars).
7. Gas emissions are based on figures provided by TAGO.
8. Traffic generation index, travel distance, road space occupied by a person (i is mode of travel).

There is yet another problem concerning the usage of public transport from major nodes (KTX stations, airports, etc.) to final destinations. A survey found that taxis and private passenger cars accounted for 26.8% and 25.4% of the intermodal transfers at Gwangmyeong Station, respectively. The two modes occupied a share of over 52%, indicating the relative inconvenience of using public transport at the station. Taxis and private cars were also found to be major means of connections for passengers arriving at Cheonan Asan Station, by registering 35% and 20%, respectively.

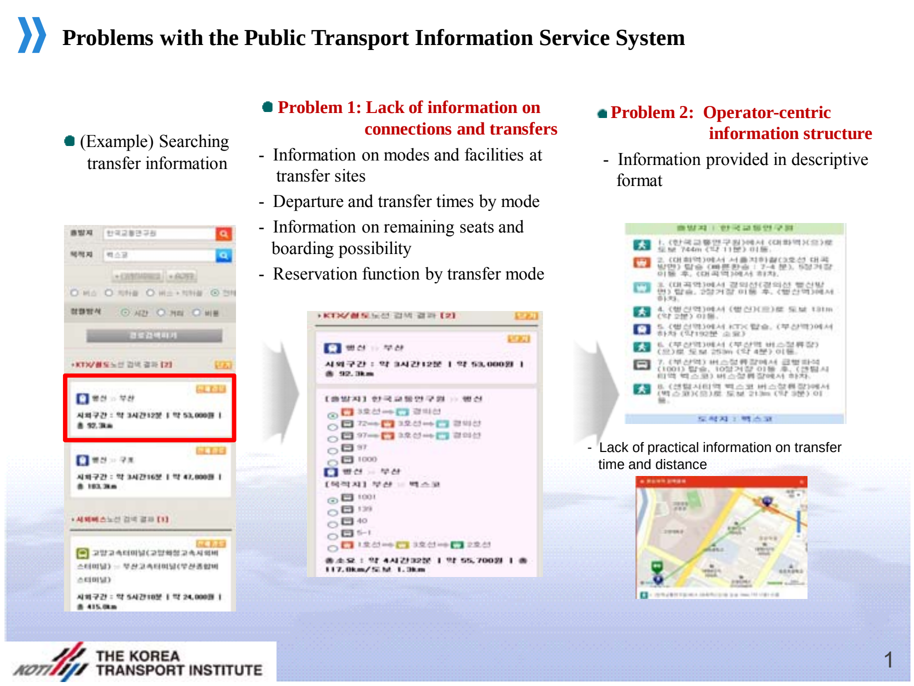
Figure 2.1. **Modal shares of transfers at KTX stations**



4. Insufficient Information Service and Restrictions on User Choice

Provision of advance information on public transport can be a key factor affecting the user choice of modes. As for travel within the Seoul metropolitan area, it is possible to obtain Internet- or mobile-based public transport information in advance. It is not easy to gain such information for intercity trips. At present, the Ministry of Land, Transport and Maritime Affairs is operating nationwide integrated transport information systems called TAGO and Garatagi. However, the systems do not provide sufficient information on real-time intercity traffic and transfer connections. Besides, the operator-oriented service structure and the difficulty of getting information on public transport operations and estimated travel time are further restricting the scope of user choice. Provision of such a limited scope of public transport information is making it difficult to expect operation reliability and predict travel time, thus causing people to give up travel plans or to be dependent on private cars.

Figure 2.2. **Problems with the public transport information service system**

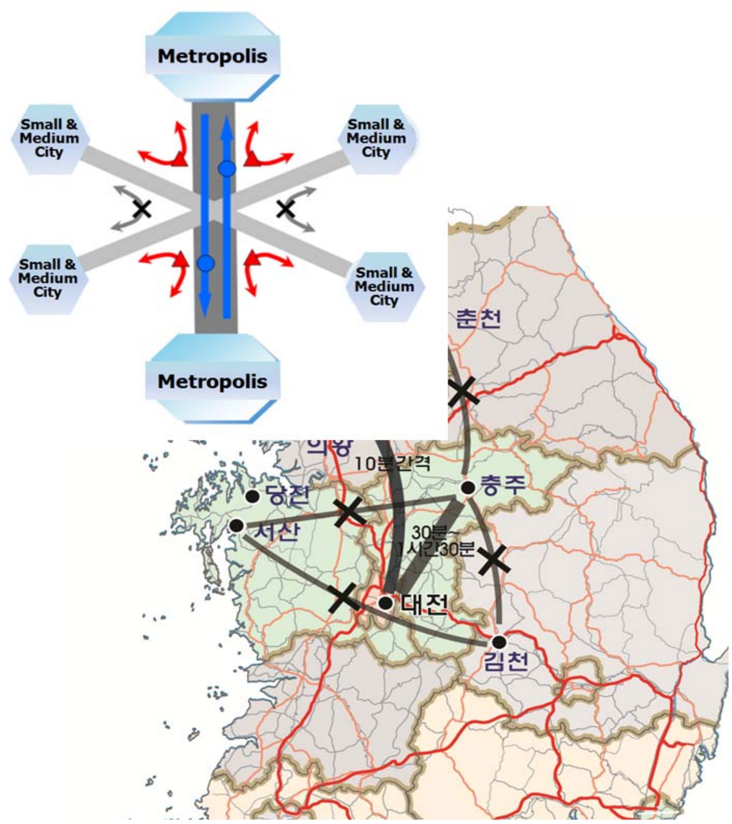


5. Regional Imbalance in Public Transport Facilities and Inequity in Mobility Rights

Having transport nodes in the nearest and convenient locations and using the shortest paths via the nodes are the essential elements in terms of securing transport rights. These are also factors that can contribute greatly to promoting urban growth and revitalizing regional economies. However, the accessibility of public transport to major terminals, rail stations and airports remains at low levels, compared to the number of users, in some regions. Besides, there is a problem of inequity among regions regarding the unbalanced placement of public transport hub facilities. This inequity in accessibility is causing inconvenience in mobility.

Movement between metropolises can be made conveniently because there are sufficient levels of routes and operating vehicles, compared to demand. However, the routes and vehicles are in short supply for travel between metropolises and medium/small cities. This inequity makes it necessary to restructure the routes and reexamine the supply levels. In the case of travel from Seoul to major metropolises (Busan, Daegu, Daejeon, etc.), the headway is usually 10 to 15 minutes. The vehicles run nonstop from Seoul to the destinations, thus ensuring short travel time. In contrast, the headway is from 30 minutes to as long as one and a half hours for travel between metropolises and medium/small cities. This may be partly explained by differences in demand levels. Yet, there is certainly a need to make adjustments in terms of efficiency in supply, transport rights, and operational efficiency.

Figure 2.3. **Status of accessibility between cities when using intercity buses**



2.2 Directions and goals of nationwide public transport integration

Directions for Integration

Nationwide public transport integration should be pursued in a way that is consistent with the paradigm calling for the establishment of an environment-friendly national transport system designed to minimize its unfavourable impacts related to climate change and socioeconomic external diseconomies. Increasing user demand for public transport through realization of the integrated system would be a most effective option for minimizing external diseconomies such as traffic congestion, carbon emissions, high costs, environmental contamination and noise.

Second, the integration should be aimed at ensuring universal mobility and accessibility as well as mobility convenience for people with mobility handicaps as part of efforts to promote public welfare, particularly in relation to the population aging phenomenon. It should also aim for guaranteeing basic transport rights for people in low-income brackets, residents in remote fishing and rural communities, and those living in areas with excessively low supply of public transport.

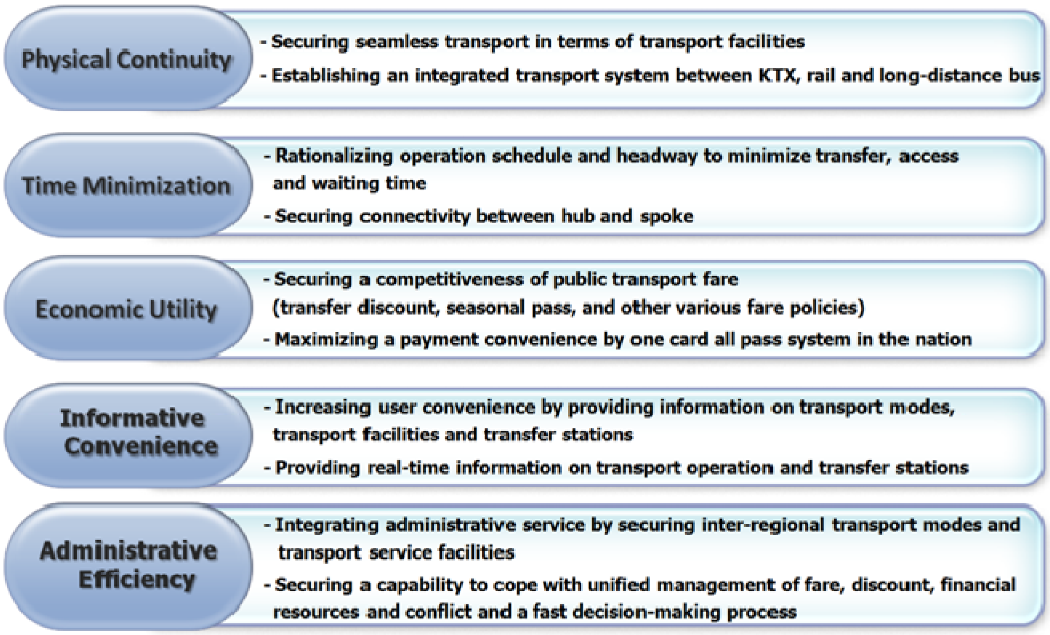
Third, the integration should be made in a way that can ensure balanced regional development through improvement of public transport connection systems and facility expansion as well as effective SOC investments, thereby making it possible to secure transport systems providing access to regional hubs and business cities and respond elastically to related developments. Improvement of public transport connection systems should generate the effect of substituting investments in regional access facilities such as roads and railways, thus saving national budget.

Fourth, efforts should be made to increase the competitiveness of public transport in terms of costs and time by ensuring a shift in policy emphasis from individual modes to organic integration of public transport. Various means of public transport need to be developed to cope with growing demand for high-performance, high-speed transport modes amid improving levels of per capita income. Attention should also be paid to building an integrated linkage system to minimize time and costs of users as well as preparing measures to increase user convenience.

Fifth, the social benefits resulting from the supply of public transport should be analyzed to ensure optimization of the social system through equitable supply of public transport among regions and classes. It is also necessary to prove the necessity for equitable supply of public transport by regions and prospective beneficiaries.

Sixth, proper policy measures should be taken to promote the development of public transport-related technologies concerning information integration, linkage and transfers, and fare integration. This would also help create jobs in public transport-related areas, thereby contributing to ensuring the virtuous cycle of government policies accelerating technological development and employment creation.

Figure 2.4. **Principles for promoting public transport integration**



Implementation goals

The following principles have been set to pursue public transport integration in accordance with the above-mentioned directions:

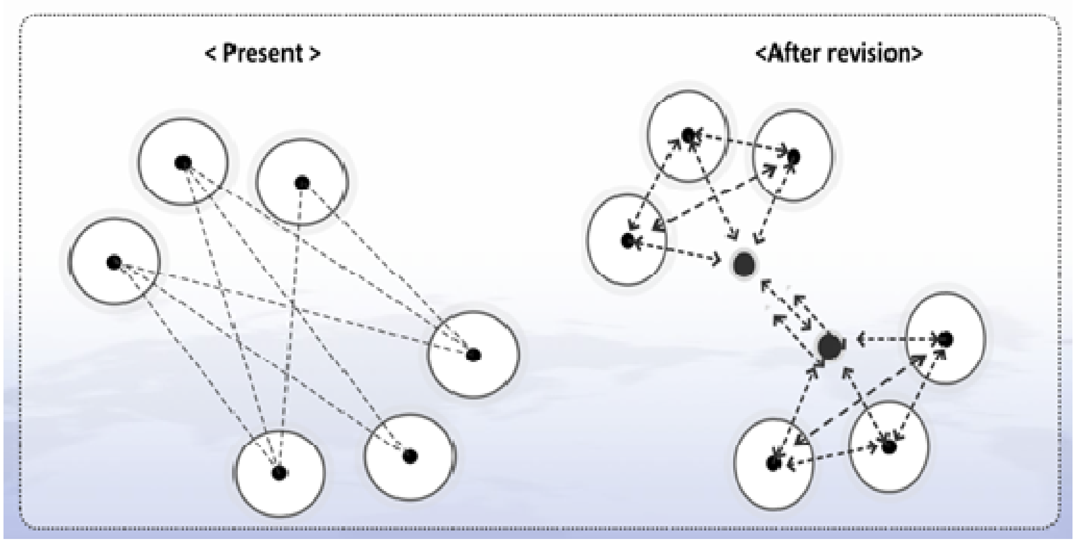
1. Building an intermodal public transport transfer system under a scheme to encompass the entire nation into a half-day living sphere, and realising transport welfare.
2. Implementing a user-oriented integrative fare system.
3. Building an intelligent public transport information service system.
4. Ensuring efficiency through integrated operation and management of public transport.

2.3 Implementation directions and tasks by sector

Network integration: reorganising the nationwide public transport routes

The nationwide public transport routes need to be redesigned in such a way as to ensure shortest travel paths by considering regional accessibility on the basis of user demand analysis, as well as surveys to determine whether public transport services are overlapping or in short supply. These efforts should involve conducting analyses of intramodal and intermodal transfer networks as well as changes in user demand. On the basis of these analyses, before-and-after comparisons of routes should be conducted by region in terms of equity and efficiency of supply. For this work, a relevant database must be prepared along with its utilisation plans.

Figure 2.5. **Nationwide public transportation routes revision**



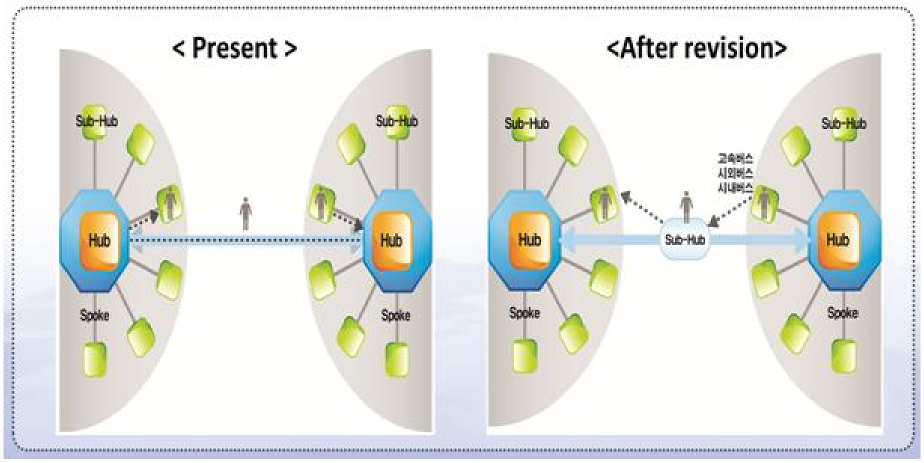
2.4 Physical integration: expansion of public transport facilities and their integrated operation

The goal of achieving expansion of public transport facilities and their integrated operation involves the tasks of improving the problem of the hub and spoke system, expanding related facilities, and introducing various modes of transport. Specific projects would be directed toward building a seamless public transport system by developing transit hubs and sub-hubs in areas with big demand for intermodal transfers, intensively improving trunk roads (expressways and national highways) as corridors for public transport, and introducing a diversity of new means of public transport.

Focus should be placed on building hub (sub-hub) and spoke systems at locations with large demand for transfers such as express bus terminals, KTX and metropolitan rail stations (public transport hubs), urban rail stations and expressway rest areas. Under this system, users would move from hub to hub, and then to desired spokes via sub-hubs, instead of going directly from hubs to spokes. This system needs to be promoted as an option for significantly reducing travel time and cost through improvement of efficiency in terms of path and travel time.

Building a public transport linkage system through route redesigning will inevitably involve the question of ensuring transfers between modes serving the trunk and feeder routes. It is therefore necessary to establish a seamless transfer system that can minimise the transfer distance and time through improvement of transfer facilities. Improvement should also be made as to intermodal scheduling, transfer discounts and transfer information service. Projects to connect various transfer modes are underway at major KTX stations. Yet, there is a need to explore more diverse measures aimed at building the linkage system.

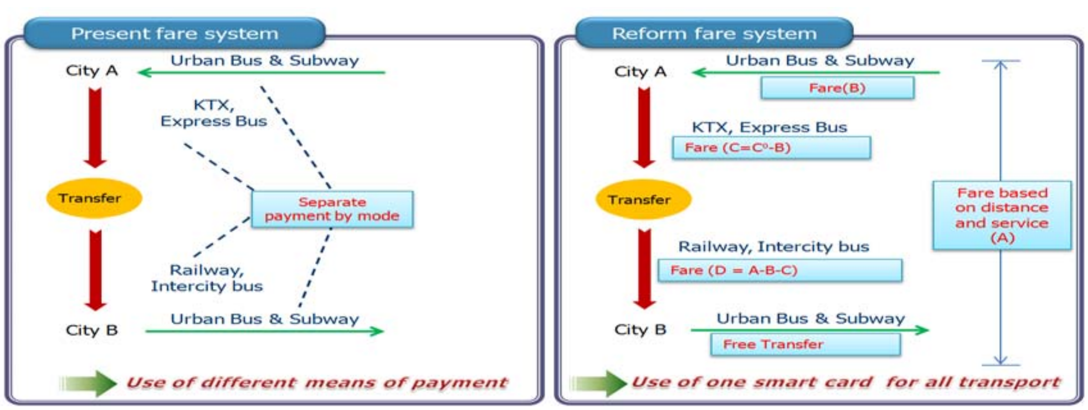
Figure 2.6. **Nationwide integrated public transport facilities**



2.5 Fare integration: integrated fare system for public transport

As mentioned above, there is a need to reform the fare system to remove the inconveniences caused by different payment schemes and the lack of transfer discount service, thereby improving public transport's competitiveness in terms of time and cost. The current public transport fares are managed separately by KORAIL, Korea Expressway Corp., transport operation bureaus of metropolitan governments and other local governments, and based on a supplier-centric system. This needs to be changed into a user-centric integrative mechanism. The core principle regarding fare integration is to prepare a scheme to use one card for all transport modes across the nation (One Card All Pass). Introduction of the One Card All Pass scheme requires the integration of various fare systems and the establishment of a settlement system to distribute revenues to operators. There is also a need to introduce various fare formulas to meet a diversity of user requests. Implementation of the integrated fare system nationwide would lead to improved competitiveness of public transport, consequently inducing private car users to turn to public transport, saving social costs caused by external diseconomies, revitalising the public transport industry, invigorating regional economies and ultimately the national economy.

Figure 2.7. **Effects of nationwide public transport integration**
(intercity + urban, metropolitan)



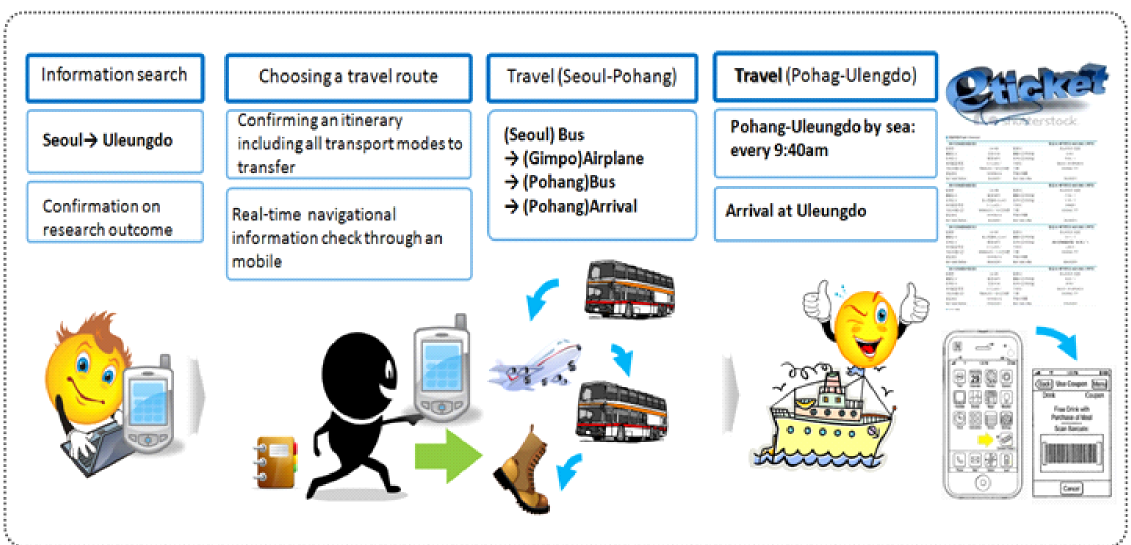
2.6 Information integration: building an integrated public transport information system

It is essential to make up for the weaknesses of the present nationwide integrated public transport information service system by devising a new-concept scheme. This task requires the building of a mobile-based system that provides user-centric information. Departing from the current method of providing just supplier-centric information by routes, the new scheme would offer various additional information to help users select optimal paths. As shown in Figure 2.6, the new system should be designed in a way that can provide various information such as time and transfers needed for the entire trip.

Building such a system would require implementation of the following tasks: establishment of an integrated centre to provide real-time information on public transport operations throughout the nation; development of information contents on mobile-based public transport information users; obtaining of mobile-based information through mobile-based transport smart cards; and, development of a system that can link decision making and fare payment.

Such a restructuring of the public transport information service system would make it possible to cope with individual lifestyle changes through provision of a customised information service based on smart IT technology, create various business services, and contribute to building a national green transport system. In addition, it could generate ripple effects, such as technological development related to the smart IT-based public transport information system, ensuring world-class competitiveness of software contents, enhancing the competitiveness of domestic products and services related to integrated information systems, production induction and employment creation, and developing new growth engines for other industrial sectors, such as broadcasting communication, telematics and automobiles.

Figure 2.8. **Example of post-reform information service**

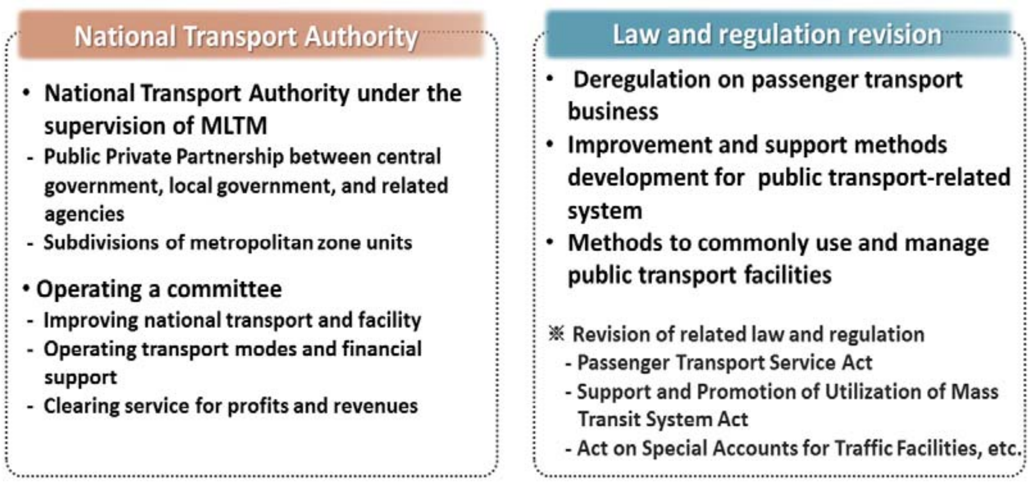


2.7 Institutional integration: launching an integrated public transport operation agency

At present, public transport operations are being carried out with the participation of various players: related public corporations, KORAIL, regional subway corporations, regional bus operators, local governments, intercity bus operators, metropolitan transport bureaus, etc. Integration of these entities is essential for implementing the nationwide public transport restructuring and integration project. Placed under the direct control of the central government, the unified body would consist of central government agencies and local governments, bus cooperatives, rail operating organisations, experts and consumer groups. It would manage bus operations and traffic facilities, adjust business zones for taxis, and control the question of cost settlement.

Public transport is, to a considerable extent, a public service. Thus, government organisations of various levels are providing subsidies to support public transport. The integrated body would need to take over the subsidy business, being in charge of the supply of financial resources and their distribution. It would have to ensure optimisation of subsidy issuance by preventing double subsidy payments, subsequently contributing to drawing investments in the restructuring project.

Figure 2.9. **Integrated administration and operation methods for a nationwide public transport**

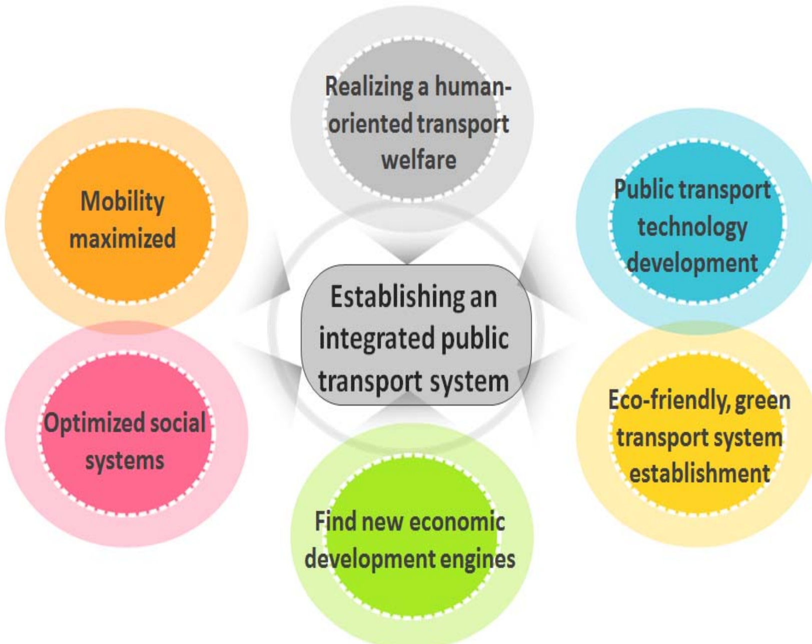


2.8 Expected effects of nationwide public transport integration

Nationwide public transport integration is urgently needed as a policy measure to achieve the following objectives: building an environment-friendly national transport system; providing transport means to guarantee universal mobility and accessibility in terms of social welfare and increasing mobility convenience; promoting balanced regional development and the efficiency of SOC facility investment through improvement of public transport connection systems and expansion of related facilities; securing the competitiveness of public transport in time and cost through a shift in planning emphasis from individual modes to an organic integrative system; promoting optimisation of social systems through supply of public transport services in such a way as to ensure equity among regions and social classes; developing technologies related to transfers, information service, revenue settlement and facilities; and creating employment through the project to build a public transport linkage system.

Building a nationwide integrated public transport system would lead to realisation of human-centric transport welfare and environment-friendly green transport. Secondly, it could promote optimisation of social systems and improve national competitiveness through maximisation of mobility efficiency. Lastly, by helping to establish an advanced public transport system, it could contribute to exploring related markets, developing relevant technologies, creating jobs and finding new engines of growth for the national economy.

Figure 2.10. **Expected Impacts of Integration**



3. SMART PUBLIC TRANSPORT TICKETING ACROSS THE NATION: DUTCH EXPERIENCE

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[The views expressed in this paper are those of the author, and do not necessarily represent the views or opinions of the Ministry of Infrastructure and the Environment (the Netherlands), Rijkswaterstaat or the Centre for Transport and Navigation.]

3.1 Introduction

The smart card is an electronic pass of credit-card size with an electronic chip (microprocessor) that will enable passengers to have easy access to the public transport system and to pay for the journey. The smart card, when compared with ordinary paper or magnetic tickets, offers extra security from fraud, higher data storage capacity, and greater capability to undertake multi-tasking (e.g. to calculate fares, update trip records, control validity and prepare accounts for billing). Card readers will register the beginning and the end of the journey. The electronic terminals will automatically make an accurate and detailed record of the time of travel, fares paid, by what mode and on which route. As such, the smart card system would provide convenience and ease of use for the passengers, reducing the threshold of complexity in using the public transport system. Passengers will not have to calculate the fares to be paid and will always have sufficient money in hand. For the operator, the easy payment and ticketing system makes the use of public transport more attractive, and has the potential to generate additional revenue. A successful implementation strategy will also facilitate the design of new marketing strategies and the introduction of loyalty schemes to entice new users. For the planners, the same technology could offer stakeholders the possibility to extend the payment system so as to be used as an electronic purse. In Hong Kong and Singapore, smart card technology has demonstrated its potential to be used for other transport functions, such as parking, or for the purchase of consumer products e.g. at McDonalds and 7-Eleven.

In the Netherlands, the transport policy is to provide public transport as an attractive alternative to the private car, and over time to increase its modal share in total travel demands wherever possible. The transport and traffic policy, as stated in the policy document *Nota Mobiliteit: Towards reliable and predictable accessibility 2004-2020,* is to provide a quality service at a reasonable price so that passengers can travel in comfort with convenience and ease in using all forms of public transport. Since the introduction of the strip ticket system (*strippenkaart*) in 1980, until its official withdrawal in November 2011, travellers had enjoyed the advantages offered by a fully integrated fare and ticketing system in urban and regional transport. The strip ticket could be used in bus, tram and metro as well as small sections of Netherlands Railways (NS) for individual or group travel.

The strip ticket system also had inherent weaknesses. For the passenger, it was necessary to know in advance how many zones the journey would traverse from origin to destination (station/stop) so that the number of strips would be correctly cancelled. Validity of the ticket depended on the number of strips cancelled, so the passenger had to ensure that the journey would complete within the allowed time limit.

For the transport authorities, officials had only a record of where tickets were sold and by what type of resale outlet. There was, however, an absence of information regarding where the tickets had been used, with what mode, when and how. Sketchy and partial user information was collected, infrequently, at local level for marketing purposes and the data was not shared unless by prior agreement. To provide management information for efficient operational planning and for the design of effective marketing strategies, large-scale questionnaire surveys (620 000+ questionnaires per survey) and a complicated programme of passenger-counts had to be undertaken at regular intervals. The research needed for the production of information in order to apportion revenues from ticket sales – and calculation of passenger-kilometre travelled by fare-paying passengers – was costly and time-consuming. While this elaborate process was necessary to ensure stakeholder acceptance, the lengthy process was considered prohibitive for the purpose of market liberalisation.

In 1992, the Brokx Commission cited the absence of a vigorous and robust management information system as a technical barrier to structural reforms of the Dutch public transport system. There was a growing call for greater fares differentiation as well as a cost-effective marketing strategy to cater for the changing mobility needs of the passengers. A consensus gradually emerged among the stakeholders that intensified and concerted efforts had to be made to take advantage of recent technical advancements in automatic fare collection (AFC) and ticketing technology. The primary policy objectives were: to obtain comprehensive performance data, and to provide accurate records of ridership in a management information system, so that transport planners and operators could serve the passengers in their region more efficiently and at low cost. The driving force was to enhance public transport patronage by providing seamless travel and one-step shopping. This corresponded well with the other policy goals of the Dutch government to liberalise the public transport market, to introduce competitive tendering of the network, and to give planning authorities greater freedom to decide their fares policy. There was urgency to acquire reliable and up-to-date ridership data at company and route levels. For authorities that wished to introduce fares differentiation or to refine their fare structure, the ticketing system in use had to be modernised and up-graded.

3.2 The strip ticket system

The forerunner of the nationwide implementation of the Public Transport Smart Card (*OV-Chipkaart*) was a paper ticketing system. The strip ticket (*strippenkaart*) and the star season tickets (*ster-abonnement*) system was introduced in 1980, replacing a diffused system of local fares and tickets with different prices and conditions for travel. The strip ticket system was unique: it enabled the users to enjoy the benefits associated with fully integrated fares and ticketing for the whole country. The travelling public could use the same strip ticket to pay for trips when travelling alone or in a group together on bus, tram and metro anywhere in the country. The same strip ticket could also be used on some sections of the railway lines around the big cities. The strip ticket was designed to be used in conjunction with a "honey-cone" zonal fare structure. There were 2 200 fare zones and each zone had a diagonal distance of 4-4.5 kilometres. The traveller was required to cancel the paper ticket by apparatus located in the vehicle, or by the station entrances and platforms, at the beginning of the journey. Fares payment was by counting the number of zones plus one basic strip. A journey not crossing the boundary was equal to 2 strips (the basic fares) with validity for travel within 60 minutes on local and regional services. Return trips could be made within the time allowance. When the strip ticket was cancelled in a particular way, it could be used as a day ticket for unlimited travel. Interchange between modes and between services operated by different companies was possible. Fare and ticket control was undertaken by the bus driver and by roving controllers working in teams in different operating areas.

Different ticket types were available. Ordinary passengers used a 15-strip or 45-strip ticket, both printed in blue. Elderly people with a 65-Plus Pass and children aged 4-11 were entitled to travel with reduced fares using a red 15-strip ticket. Children under 4 years of age were free. Season tickets in the form of a pass were divided into weekly, monthly and annual. The annual season was roughly equivalent to the price of 10 monthly season tickets. Strip tickets could be purchased at stations and from kiosks, post office, department stores, supermarkets, corner shops and tobacconists. There were 4 500 strip ticket sale points. Season tickets were available from Customers' Service Centres, main bus stations and at post offices. A separate photo card was issued to season ticket holders as an identity card. Annual season tickets and monthly passes could be booked and purchased via the internet website of the operating company. For incidental passengers, a choice of 2, 3 and 5 strip tickets could be purchased from the bus or tram drivers at a much higher unit cost per strip. On boarding the bus, passengers had to show their pass or strip ticket to the driver. On trams, metros and light rail transit, passengers with valid travel document had direct access to the vehicle. Swiping was not required.

3.3 Context of the smart card project

In the 1990s, the political scene in the Netherlands was in flux. At a time when the quest for a modern ticketing system was in progress, major organisational changes and administrative reforms were put into action. The policy goals were to reduce public expenditure, delegate administrative authority to the lower tiers of government, and give market forces a larger role. The Dutch government introduced decentralisation and took measures to liberalise the public transport market. During this period 19 Public Transport Authorities (PTAs) were created. Under the new legislation on passenger transport (*Wet Personenvervoer 2000*), PTAs have control over their own fare scale and structure. Studies of the literature as well as critical review of best practices in the public transport industry had indicated that smart card technology could improve the financial performance and operational efficiency of the operators. The technical possibilities offered, as well as the extensive range of detailed information provided, could facilitate the planners to reform the services and support network tendering in an open market as part of the liberalisation process. For example, an electronic ticketing system facilitates the collection and processing of data and, therefore, improves freshness, precision and reliability of management information. Such information would be particularly useful for route planning, the preparation of performance contracts or designing innovative schemes to provide seamless travel.

In operational terms, smart card ticketing can deter fraudulent travel and increase the sense of safety and personal security in the travel environment. Integrated electronic ticketing technology, together with gates, would enable the installation of a closed regime on the rail and metro stations. In Dutch society, molestations in the form of threatening behaviour and physical assault on passengers or operating staff by rogue passengers are regarded as priority areas for action. Internal studies have indicated that fraudulent travel is closely related to an increase in the incidence of mob behaviour, and is a major factor that adversely affects travel safety in public spaces. Research by NS has concluded that some 60% of abuse by passengers against the railway personnel could be attributed to travellers not in possession of a ticket or correct fares. The introduction of a smart card system in a closed station regime had been put forward as an effective measure to enhance public safety.

An important novelty for the Netherlands is that the smart card project initiative is a commercial venture by major operators who had chosen to work together to achieve common goals. The PTAs and the operators had undertaken a number of studies to investigate the technical feasibility as well as the financial viability of a national public transport smart card. On 20 November 1998, all the major operators (including NS) signed a declaration of intent to work together to develop and implement such a system across the whole country. The Ministry was supportive and set up a task force to facilitate their efforts. The front office would be the individual operators and the back office functions would be in the hand of Trans Link Systems (TLS), which is a joint venture consortium set up by NS together with the municipal operating companies in Amsterdam (GVB), Rotterdam (RET) and The Hague (HTM), as well as the regional operator Connexxion. Together, these companies accounted for some 80% of all users of the public transport market. TLS is responsible for card issuing, system administration and back-office monetary settlement of the revenues generated from the smart card operation in the public transport market. (Connexxion has since left the consortium.)

The Ministry’s prime responsibilities were to ensure that the smart card system would fulfil the basic requirements laid down by the Dutch Parliament, and to finalise the date when the strip ticket would be formally withdrawn from service as legitimate payment and a valid ticket for travel. To secure confidence from the travelling public and to ensure public acceptance, nine conditions were laid down by the Minister on 29 November 2007. These conditions were endorsed in the Action Plan for Public Transport Smart Card (29 February 2008) and subsequently approved by Parliament. They were essential and regarded as pre-requisites that must be met in full before the use of smart card ticketing became exclusive:

- Card use is demonstrated to be fully operational and stable.
- Ticket distribution in the region is on course as agreed.
- Proven and shown to be flexible in the transition for all passengers.
- Student smart cards are readily available to all holders of a Public Transport Student Pass
- Season tickets are embedded into the smart card.
- Companions to handicapped passengers and people eligible for free travel will be issued with appropriate travel document.
- Security and safety must be in order.
- Fares for the average passenger in the service area must be revenue neutral in the first year of operation.

To enable market liberalisation, the Dutch Parliament agreed at the onset of discussions that individual operators would be able to determine their own fares level and structure, on the condition that the same ticket or pass could be used anywhere, on any public transport mode, in the whole country. In short, while the standard format smart card with common logo may have a different outward appearance or design detail, the card technology has to be compatible (interoperability) and retain the feature of being a national card and ticketing system. To stimulate a competitive market, different manufactures can offer their wares provided that their specifications and functionality meet the basic requirements. At present, the East-West Consortium has the main share of the market. Another smart card supplier, ProData (based in Belgium), provides for The Hague Tram Company (HTM) in the Haagland region.

3.4 Learning from practical experience and by experimentation

Efforts to introduce a magnetic ticket in the 1990s, and trials using smart card technology (e.g. *Zeeland Card,* in Zeeland province, and Tripperpas, in the municipality of Groningen) between 2001-2003, represented a continuous process, with recurrent efforts to introduce a more robust ticketing system to facilitate operational planning. With the benefit of knowledge gained in smart card projects at home and abroad, the stakeholders planned to introduce the smart card step-by-step. The strategy was to create a pool of knowledge for sharing, provide sufficient time for operators to learn from practical experience, and to allow passengers to get acquainted with the new system. Therefore, the implementation path adopted was that the rolling-out programme in different regions would be in phases, and the system under trials would be monitored and evaluated with respect to technical proficiency and passenger acceptance. The understanding was that the learning curve should enable a smoother transition from a paper-based ticketing system to an integrated, electronic one.

In parallel with the change in the ticketing technology, it was also decided to try out a dual-regime in urban regions and some rural areas; with zonal fares based on the strip ticket, and distance-related fares if the passenger chose to use the smart card. The new planning philosophy is that a distance-related fare structure would be fairer, and less prohibitive, for passengers who travel short distances, particularly those journeys that just cross the zonal boundary. To ensure fairness and to secure public acceptance, it was stipulated by the Minister that, in the first year of introduction, the average fare per passenger journey within the administrative area would be (roughly) similar under both systems, and that the overall fare receipts obtained in balance would be neutral. In the early days, there were lingering doubts and suspicion whether the principle of neutrality was duly applied in practice. The Commission Kist was set up, and their report (sent to Parliament in March 2010) found no evidence to suggest that the neutrality principle was not overtly observed in the selected areas studied.

Learning by doing has been the motto. All the stakeholders were encouraged to co-ordinate their efforts, to share the experiences gained and to disseminate lessons learnt. Experience in the Rotterdam and (later) Amsterdam region could help operators elsewhere to avoid similar teething problems as the new ticketing system was gradually introduced in the remaining areas. To educate the public, and to promote public acceptance, regular consultation meetings were organised with national consumer councils and regional transport user associations. To gauge the reactions from the travelling public and to determine the level of user satisfactions, research studies were undertaken at different times in the implementation phase. Special attention was given to the elderly, people with mobility difficulty and physically-impaired users (including the blind and people in wheel-chairs) in order to identify their specific requirements and to determine how their needs could be catered for. The results of the monitoring reports and the findings from research were regularly presented to the management teams and to parliamentary committees.

3.5 The rolling out programme and field trials

On the basis of competitive tendering, the consortium East-West (made up of Thales, Accenture and Vialis – in partnership with MTRC and Octopus Card Ltd. of Hong Kong) won the contract, in 2003, to supply, install and maintain the Dutch smart card system. The primary aim of the project was to make travel by public transport services, provided by partner organisations within the consortium, simpler, easier to understand, convenient to use and safer. The smart card itself is of credit-card size, with a built-in memory chip and wireless. The read/write functions are encrypted with keys (algorithms) known only to the vendors. The card system is based on Philips (currently NXP Semiconductors) Mifare contactless card technology. For data protection, all personal details and trip transaction data are kept separate and are subject to the Dutch Personal Data Protection Act. Without the prior permission of the cardholder, the information cannot be made available for purposes other than what was originally intended and agreed.

The GO decision to proceed with the implementation programme was taken in the Dutch Parliament on June 2006, when it was decided that the responsibility of migrating from paper to electronic ticketing would be the responsibility of the PTA. The municipality authority of Rotterdam and the municipal operating company Rotterdam Electric Tram company (RET) were pioneers in their decision to migrate to a smart card-based ticketing system at the earliest opportunity. Following successful testing, the first introduction was in the Rotterdam region, with a rollout in the metro system in November 2005. The phased introduction was then extended, in 2006, to the NS main railway line between Rotterdam and the Hook of Holland, and on the bus lines operated by the regional operator Connexxion in Hoeksche Waard and Voorne Putten. In early 2007, the smart card was introduced to the metro system in Amsterdam. In January 2009, sufficient proven field experiences and adequate assurance enabled RET to have smart card ticketing to be used exclusively in the metro network. This meant the strip ticket would no longer be accepted by Rotterdam metro. From 11 February 2010 onwards, this exclusivity becomes universal for all bus/tram/metro in the whole of the Rotterdam region (SRR).

Following some delays, similar progress was made in the Amsterdam region. Exclusive smart card use was introduced in the metro network by Amsterdam Municipal Transport Company (GVB) on 27 August 2009. This practice was extended comprehensively to all bus/tram/metro in the Amsterdam region (ROA) from 3 June 2011 onwards. Two further, major, milestones were: the application of the smart card technology on NS discount pass (*Voordeelurenkaart*) in December 2009 (with 1.4 million holders, accounting for 90% of NS rail customers); and the introduction of the new Public Transport Student Pass (*OV-Studentenkaart,* with 650 000 holders) in March 2010. On 3 November 2011, the nationwide implementation of the Public Transport Smart Card was confirmed when strip tickets were formally withdrawn from use.

3.6. Features of the Dutch smart card

3.6.1 Three types of smart cards

Anonymous: The card is not registered to a single user, hence it is transferable. It can be readily purchased over the counter of Service Centres, or from ticket vending machines at stations with cash or PIN (a form of electronic money transfer offered by Dutch banks). However, if the card is lost or stolen, the balance amount on the card is not refundable. The card has a one-off charge of EUR 7.50 and is valid for 5 years. The holder can load it with cash or with a PIN-pass, use it as an e-purse and pay for train travels, but down-loading season tickets is not possible on this card.

Personalised: This card is suitable for frequent, or regular, users. It is personalised with a passport photograph on the card face. Having known name and address details will enable the pass holder to claim refund when the card is lost or stolen. The remaining balance on the card will be reimbursed after administrative charges are deducted. The one-time purchase cost is also EUR 7.50. The holder can use it as an e-purse, or with a travel product (e.g. season ticket or a train ticket). To benefit from the age-related discounts offered by the operator one needs a personalised smart card, which serves also as an identity card, with the holder’s date of birth.

Disposable Paper Smart Card: This is the simplest form that is suitable primarily for incidental visitors, on single journeys or as a one-day travel pass. In some cities like Rotterdam and Amsterdam, it is possible to combine the journey and bring along a bicycle at additional cost. It is disposable but the unit cost of travel per trip is higher than that charged by anonymous or personalised smartcard. They can be purchased from ticket vending machines, from the driver or the operator’s ticket office. The card already carries a travel product and cannot be used as an e-purse.

3.6.2 How does the public transport smart card work?

Possession of a valid ticket

The smart card is a ticket and the new way of paying for travel on the public transport system. All smart cards, publicity literature, accessories and equipment have a common logo to create branding for easy public recognition. The cards are inter-operational and are accepted nationwide. However, the card cannot be used for group travel. Each traveller over the age of 4 has to have in their possession a valid ticket. Passengers can choose one of two options: purchase of a travel product (e.g. single ticket or season pass) or use as an electronic purse, with a given amount in euros on the card. Loading is executed at the special ticket vending and add-value machines, or at the service counter. Having completed the journey – or if the date of a product (for example, a weekly ticket) expires – the travel entitlement will be deleted from the card.

Zero fare is charged if the check-in and check-out (CI-CO) procedure is performed correctly at the same station within 20 minutes so that people can accompany passengers to say goodbye, or to help with the luggage. The maximum travel time on each single journey is 120 minutes. After the permitted time allowance, the price for the trip and an additional amount – equivalent to the maximum fare in that region – will be charged when the cardholder checks-out at the station. When a personalised smart card is reported lost or stolen, the relevant information will be recorded in a blacklist and subsequent use will be blocked. Because the smart card has validity and legitimacy nationwide, the e-purse function on the card issued by any operator can be used in other areas and all forms of public transport across the country. The NS Extension ticket is available as a supplement to a NS day ticket, monthly travel pass, monthly season ticket and annual season ticket. This is particularly useful for passengers when their work journeys involve trains and bus, tram or metro travel.

In line with the pricing practice of the strip ticket system, each journey has a base unit charge upon boarding the first vehicle, plus kilometre charge for the actual distance travelled. PTAs can decide on their own base price and kilometre charge but, in the first year of operation, all PTAs accept similar rates with slight variations to reflect local operating conditions. Where passengers have to interchange between vehicles, the base charge has not to be paid a second time if interchange takes place within 35 minutes. However, this does not apply when passengers change from bus/tram/metro to the train system because NS operates under a different arrangement. In addition, in a very small number of service areas, technical difficulties and/or absence of mutual agreements between operating companies has led to an anomaly that the base fare is charged again, even when interchanging takes place within 35 minutes. Efforts are currently being made to remedy this situation.

Check-in check-out requirement

The smart card ticket is simple to use. The passenger only has to follow the CI-CO procedure. When travelling, the passenger has to touch, or bring the card near to, the card reader (within 10 cm). The card reader will show a green light, emit a signal (a piping sound) and a text message will appear, confirming the ticket is valid. If the card has insufficient funds or is damaged, a red light will show, along with a piping sound of a different tone and a warning message. When checking out, the reader will also shine a green light, give a piping sound for correct handling, followed by a text message to provide information on the trip cost and the amount of money remaining on the card. On the metro system in the Rotterdam and Amsterdam regions the smart card is the key to open the gate, and the passenger can proceed directly to the platform. When the passenger leaves the metro station, check-out is by touching the card with the card reader to open the gate installed at the exit.

As a general rule, to ensure correct payment of fares and to encourage passengers to follow the CI-CO procedure, all urban and regional operating companies have chosen to deduct EUR 4 (equivalent to the maximum fare) each time the card is checked-in. When the card is checked-out, the apparatus and the computer software in the back-office will calculate the exact fare for the journey made and refund the amount if the trip cost is less than EUR 4. If the passenger forgets to follow the check-out procedure, the maximum fare has already been paid and the operator has not lost revenue. For NS, because the rail network is extensive and the average fare is much higher, the standard fare deducted at the origin station is EUR 10 for a personalised NS-issued smart card and EUR 20 for other smart cards. Check-out at the final destination station will calculate and show the correct fare on the reader screen. If the journey is less than the standard fare deducted the balance will be reloaded to the card, with screen information on the remaining sum available for the next journey. Should there be disagreement regarding the functioning of the card reader, or the amount of fare charged, the staff at the station or at the gate will provide assistance. There are also card readers at metro and railway stations that will give details of the last 10 transactions made. In some cities, information is provided in a paper print out at no cost. If the smart card is defective, or the fare charged is incorrect, the passenger can apply for a refund by filling in a form, obtainable from resale outlets or downloaded from the web, and be reimbursed within 3 weeks.

The same CI-CO rule applies to all passengers on all the buses, trams and light rails. On buses and trams, the card readers are located at the entrance and exit doorways of the vehicle. To ensure smooth passenger movement, additional card readers are often installed at suitable locations by the doors. For light rail transit systems, the card carders are normally located on the platforms. For the railways, the common practice is to have an array of readers at the stations and/or on the platforms. The initial strategy from NS is to have a closed regime, with gates at main stations similar to that adopted in Rotterdam and Amsterdam. Further review and additional financial appraisal indicates that a more pragmatic approach should be adopted to ensure cost effectiveness. Only a select list of rail stations and platforms would adopt a closed regime. Ticket control would be done by the conductor(s) on the trains and teams of roving controllers with hand-held computers to ascertain validity.

Facilities to encourage acceptance and usage

To encourage the use of the smart card, many PTAs and operators, with the support of the Ministry, had undertaken publicity drives by offering the first wave of buyers a substantial discount; EUR 3 for an anonymous smart card and EUR 1.00 or EUR 1.50 for a personalised card. For promotion and marketing purposes, RET had also experimented by issuing free personalised smart cards for registered elderly citizens who are Rotterdam residents for a limited period. The campaign was successful in enticing passengers to purchase smart cards in advance. For monthly and annual season ticket holders, the personalised smart card will be issued free of charge after having paid for the season pass. In the case of NS, it was decided at an early stage that all rail season ticket holders, and customers with an annual pass that gives discount for rail travel, will have their pass automatically embedded with the smart card function. In addition to developing a good customer-provider relationship, large-scale purchase and usage means creating a critical mass to verify the robustness of the apparatus, to test the efficient working of the gates, to determine the accuracy of the software system in the back office, and to provide up-to-date information on fares charged and passenger kilometres travelled.

Another attractive feature to provide ease of use and convenience for the passengers is the auto-loading facility that TLS had reached agreement on with the banks. Firstly, the passenger needs to be in possession of a valid personalised smart card. The passenger can then choose to enter into a business agreement with their bank for auto-loading. When the remaining balance on the card is low, say less than EUR 5, an agreed amount of money (fixed between EUR 10-20) will automatically be transferred from the holder’s bank account to the smart card. This avoids that the cardholder has insufficient money in the e-purse to pay for the trip. The maximum amount of credit available on smart cards is currently EUR 150.

For personal mobility management, the provision of accurate and detailed information regarding travel patterns, trip frequency and journey costs is useful to the passengers. Holders with a personalised smart card from TLS can go to its website, open an account, lock into his/her travel transaction file with a personal access code to have an overview of all the public transport trips made with a given smart card during a chosen period. The records can be printed for personal use as well as for the declaration of travel expenses by employers or for tax purposes. It is easy to use and incurs no extra cost. Confidentiality and data protection fall under the rules and regulations laid down by the College of Protecting Personal Data.

3.7 Cost-benefit analysis of the Smart Card Project

To support decision-taking, evaluation studies had been undertaken to provide guidance. In the feasibility study phase, operators were required – by the responsible PTAs – to prepare a business case to establish the financial viability of introducing smart card ticketing in their operating areas. For the government, the size and scale of the project would represent a major capital investment, with wider socio-economic implications for the community. In order to determine the effects on passengers and operators and to identify the broader impacts on the national economy, a study was commissioned by the Ministry. Cost-Benefit Analysis (CBA) methodology was chosen, and the study was carried out in accordance with the guidelines in the Guide Book for the Evaluation of Infrastructure Projects (the *OEI leidraad).* The methodology provides a consistent and integrated framework to appraise the socio-economic impacts in a structured and transparent manner**.**

Additional efforts were given to identify all the relevant actors and to estimate the costs and benefits that could be attributed to various groups of stakeholders in different time horizons. The results were then tested with alternative migration scenarios'. As such, the study examined not only the overall effects for the nation but also to identify incidence and to determine the likely distributional impacts (who would gain and who would lose). On the basis of competitive tendering, the consultants Hypercube Business Innovation in Utrecht and SEO Amsterdam Economics (University of Amsterdam) were assigned to undertake the study. The CBA findings were regularly presented to a Joint Consultative Committee with representatives from the stakeholders. The final report was published in November 2003 and the findings were presented to the Dutch Parliament for informed debate and definitive decision-taking.

3.7.1 Results and findings from the main CBA study

The effects of the project were estimated on the basis of a projection of the future development of the project compared with a situation without the card, but making allowances for likely changes in society and in the public transport market. To calculate the overall costs and benefits, all the effects had been monetised and the outcomes expressed in euro (€). In cases where market prices did not exist, the standard values in *the OEI-guide* were used. The economic life of the smart card technology in the Netherlands was taken to be 15 years, on the ground that information and communication technology (ICT) would have a relatively short shelf life. It was considered to be prudent to err on the side of caution. All the relevant costs and benefits were estimated for the period 2003-2017. Annual costs and benefits were assumed to be constant and were subsequently discounted with a discount rate of 7 percent. At the time of the study, risk-free public projects in the Netherlands would incur a discount rate of 4 percent; a premium of 3 percent was added for possible risks. Annual discounted figures were then added together to obtain the net present values (NPV) of costs and benefits.

For passengers, the most important direct benefit was time saved in ticket purchase (NPV EUR 490 million was the minimum estimate and EUR 610 million the maximum). Passengers would be safer because fewer people travel without a ticket. A decrease in fraudulent travel would reduce the probability of harassment and molestation. This advantage amounted to EUR 60-70 million. Additional welfare was attributed to extra passenger trips because public transport would become faster, safer and cheaper in the non-peak periods, yielding a benefit of EUR 290 million in value.

Table 3.1. **Benefits and Costs attributable to the Smart Card**
(NPV in million euros)

Benefits	Minimum	Maximum
Direct Effects	**1 530**	**2 010**
Passengers	840	970
Reduction in ticket purchase time	490	610
Reduction in molestation	60	70
Value of extra mobility	290	290
Public Transport Operators	690	1 040
Less fraudulent travel	380	480
Fares differentiation	240	480
Other cost savings	70	80
Molestation of vehicles / at stations	0	0
Indirect Effects	**90**	**110**
Other applications of smartcard	80	100
Reduced purchase time for employers	10	10
Improved location climate	0	0
External Effects	**60**	**70**
Reduction in molestation	40	50
Environmental effects	20	20
Relief to congestion	**0**	**0**
Savings under existing ticket system	**1 780**	**2 030**
Total Benefits	**3 460**	**4 220**
Costs	**Minimum**	**Maximum**
Introduction costs	-210	-260
Chip card costs	-2 280	-2 540
Extra capacity costs	-210	-240
Total Costs	**-2 700**	**-3 040**
Balance (Benefits-Costs)	**420**	**1 520**

Public transport operators would benefit by reduction in fraudulent travel, increase in fare receipts and fall in operating expenses. The balance would be a positive sum of EUR 380-480 million. The new ticketing technology would also make it possible to introduce with ease fares differentiation by mode or by time of day, e.g. between peak and off-peak. Travel demand elasticity studies showed that passengers react to price changes, particularly the elderly, and for trip purposes such as recreation trips and social visits. When carefully designed and given sufficient time for adjustments, fares differentiation could reduce the operating costs. For example, a significant shift of passengers from peak travel to the off-peak periods would reduce the number of vehicles and staff needed. The benefits were estimated to yield EUR 240-480 million.

Implementation of the smart card would bring positive indirect effects to the national economy in the order of EUR 90-110 million. Knowledge and technical expertise gained in public transport Information and Communication Technology (ICT) could be transferred to other sectors (indirect effect). There could be spill over effect to create a positive economic climate, e.g. for companies to set up branches or for business to expand in the Netherlands (*forward linkages*). However, these are conjectures that could not be estimated with precision and were, therefore, excluded in the CBA balance sheet.

The external effects would be limited in extent, scope and size. Less molestation effectively would mean a reduction in the costs for employers of the passengers affected, a plus sum of EUR 40 million. The environmental effects would be two-sided. Part of the growth in public transport usage (15 percent) would be at the expense of car use. The environment effect would be positive because public transport has higher occupancy rate and is environmentally less damaging per passenger kilometre. However, the growth in patronage would also lead to an increase in vehicle kilometres. In balance, the net effect would be positive, valued at EUR 20 million. There would also be a slight reduction in traffic congestion and improvement in service reliability, but these effects were not included because of inadequacy in our knowledge and technical difficulties to give reasonable estimates.

The largest single benefit was cost savings attributed to withdrawal of the strip ticket system. The costs of implementing smart card ticketing were the costs of the smart card itself (EUR 2 280-2 540 million) and the introduction costs (EUR 210-260 million) in the transition period when both ticketing systems operate in parallel. Opposite these costs were the savings in charged costs accredited to the strip ticket system (EUR 1 780-2 030 million). An additional sum (EUR 210-240 million) would also be needed because operators had to increase their operating capacity by purchasing new vehicles and recruit additional staff to meet the increase in ridership. Total benefits would be EUR 3.5-4.2 billion, whereas total costs EUR 2.7-3.0 billion. The overall balance is a surplus of EUR 0.4-1.5 billion. In conclusion, the expected total benefits of the smart card project implemented nationwide would be higher than the expected total costs involved. Therefore, the project in its totality would be a profitable investment for the nation.

3.7.2 Additional analyses in the evaluation process

Actor analysis

Actor Analysis is an integrated part of the evaluation to determine which different stakeholder groups in the community – in what way and by how much – would be affected. Operators together would enjoy the most benefits, by nationwide implementation gaining between EUR 380 and EUR 870 million. Passengers as a group would benefit substantially by EUR 260-390 million. Employers of passengers would also profit because of faster and safer trips for their employees, but by a smaller amount EUR 20-30 million. The balance of costs and benefits for the "central services units" which were responsible for revenue collection and apportionment would be negative. They incurred cost outlays (e.g. to reconstruct the rail stations, to install gates and to put in cameras) in order to generate benefits for other stakeholders. Savings came from not having to finance the questionnaire surveys and fund the research efforts to determine apportionment of revenues between operators. The balance of costs and benefits for the central government was EUR 10 million.

Detailed statistical analyses indicate that companies operating on a relatively large scale, not in urban areas and adopting a closed station regime[1], would be most likely to score a better benefit/cost ratio. Economy of scale plays a role because a high proportion of the costs involved would be fixed

1. Stations where passengers have to validate their tickets on boarding and debarking.

costs. In urban areas, the costs in equipping all vehicles with smart card apparatus are relatively high and these have to be recovered from journeys with short average trip length. Operators of railways and metros can use the smart card to facilitate the introduction of a closed station regime, thereby attaining larger reductions in fraud and higher fare revenue gains.

Table 3.2. **Distributions of Benefits and Costs between Actors in 2003-201**
(NPV in million euros at discount rate 7%)

Actors	Minimum	Maximum
Public transport operators	380	870
Passengers	260	390
Employers of passengers	20	30
Central Service Units	-410	-210
Concession granting authorities	50	300
Central government	10	10
Other business sectors (indirect effects)	80	100
Other social partners (external effects)	30	30
Total (The Netherlands)	**420**	**1 520**

Sensitivity analyses

Migration period and implementation path: The original assumption was 3 years. Passengers could make their first trip with the smart card on 1 January 2005 and use the strip ticket for the last time on 31 December 2007. Throughout the migration period, both systems would be in use side by side. A delay of 12 months, taking up to 4 years, would reduce the positive balance by EUR 90 million, whereas a faster tempo with a migration period of 2 years would generate EUR 70 million extra.

Rate of discount: 7 percent was used, with an economic life of 15 years. Applying a 10 percent discount rate (likely for commercial projects with similar risk profile) would reduce NPV of the benefit/cost balance by EU 470 million. A 4 percent discount rate (normal for publicly funded infrastructure projects with minimal risk) and assuming a project life of 30 years without an end term (a recommended practice in the OEI guide would yield an additional surplus of EUR 460 million.

Card penetration: On the basis of 8 million smart cards for the whole country and a penetration rate (which measures the density of possession and use) that varied by 20 percent each way, the outcomes would be an increase or shortfall by EUR 100 million.

Card price: If the card price was reduced from EUR 7.50 to EUR 5, operators' revenue would fall from EUR 280 to EUR 180 million. Should the purchase price be raised to EUR 10, the positive revenue effect would increase from EUR 280 million to EUR 380 million. [Changes in the purchase cost per card would have important financial consequences for the business case, but not for the CBA calculations, because the transaction is a transfer payment and is seen as a redistribution effect between actors.]

3.8 Actual experience and current state of play

The strip ticket had a history of 31 years before final withdrawal. Since the decision to introduce the smart card system in June 2006, it has taken 5.5 years for the smart card to become standard use across the nation. There are currently over 8 000 sale outlets. A Report to Parliament, on 27 March 2012, recorded that TLS had 13 million smart cards in circulation, with some 13 million transactions per week. In 2011, a total of 1.3 billion transactions were reported. The trend of usage is also increasing over time as a result of the annual season tickets in urban and regional transport, in its old form, gradually phasing out. [Under the present planning, annual season tickets (*Jaar*-abonnement) offered by a small number of operators will be last on sale in December 2012.] Old season tickets have to be replaced by the purchase of new tickets, or passes, that conform to the smart card standards and technical specifications. Moreover, it is now possible to purchase the Dutch smart card via the website www.ov-chipkaart.nl and pay by credit card or Paypal from Belgium, Germany and Luxemburg for use in the Netherlands. Personalised card holders enjoy the same facility with easy direct access to their transaction account on-line as Dutch consumers do. A national telephone number to have access to Customer Services is also available in these countries.

Press releases and annual reports issued by the operating companies indicate performance improvements in several areas. Fraudulent travel had been substantially reduced. In the Rotterdam region for example – prior to the introduction of the smart card – over 10 percent of travellers in metro stations did not have a valid ticket. Following introduction of the smart card, and the enforcement of a closed station regime, the rate came down to 1.5 percent. Similar trends were observed on the buses and trams: non-paying passengers fell to 4.13 percent in the trams and 1.36 percent on the buses. In the financial year 2011, the incidence of non-payment fell even lower, 3.14 percent (tram) and 0.36 percent (bus). RET made a profit of EUR 10.4 million and recorded 6 percent growth in overall traffic. Rotterdam metro itself reported a 7 percent growth in profit and the closed station regime reduced total fraud from 12 percent to 1.69 percent. User satisfaction with RET had increased from 6.9 to 7.1 out of 10 between 2010 and 2011. These positive results could not be totally attributed to smart card ticketing, but improved operating performance was a major contributing factor. In the Amsterdam region, similar successes were reported.

There are also disappointments and lapses in progress along the road to full implementation. Nationwide introduction was originally scheduled for the end of 1997, but the date for formal withdrawal of the strip ticket had to be postponed several times in response to complications in reaching agreements, difficulties in enforcing agreed changes, and delays in solving technical problems. In the early years of the project, the absence of strong leadership, clear lines of responsibility and the difficulties of co-ordination gave rise to delays in decision-taking. This was combined with the identification of technical problems and occasional unwarranted incidences; for example: inadequate supply of smart cards to meet sudden rush in demands, teething problems with the software programmes, length of time needed to refund incorrect fares deducted, and delays in the installation of hardware. The disruptions and technical hitches might be small in scale, local in nature, brief in duration and limited in geographical coverage; nonetheless, the cumulative effects and impacts on implementation could be significant, with an adverse effect on public confidence. If concerns were not dealt with adequately and identified problems resolved promptly, there would be frustration. Individual incidents could escalate and sometimes lead to poor publicity which could undermine public confidence and put at risk stakeholders' commitments. The underlying cause of the discontent had to be tackled and an appropriate course of action taken to produce proven records of success.

The most controversial issue, in the Dutch experience, is card security. The problem came to a head when the first generation of the Mifare Classic chip was cracked by hackers and the incident was widely reported in the mass media in January 2008. This finding was substantiated by an independent study at Nijmegen University. Steps had to be taken immediately. TNO (a Dutch research institute) was engaged by TLS to undertake a security analysis of the risk claims made against the Mifare card technology. The report and the findings were presented to the Minister of Transport In view of the gravity – politically – of the problem, the urgency to retain trust and the need to ascertain the TNO findings, the Minister commissioned an independent study by Royal Holloway University of London to provide counter-expertise. The Holloway report, along with the professional judgement of the study team, was presented to Parliament. The findings were accepted. Soon afterwards, the same study team from London was asked to prepare a supplementary report to produce a "road-map" to increase card safety. It is recognised that the robustness of the smart card (and its encryption algorithm) has to improve and a migration plan to a new generation of scientifically more-advanced smart card technology is needed. A decision has been made that the Mifare Classic card will be replaced over time and new cards are now in circulation in the migration mode.

The Dutch experience has indicated that important lessons can be learnt from regular passenger surveys and consumer satisfaction studies. These have been deployed as a decision-supporting tool to monitor progress and to evaluate actual users' experience. In addition, passengers' attitudes studies (including those of non-users) have been used to identify both the preferences of the public and the facilities that would promote public acceptance and increase usage. These research results are shared and the findings communicated to the consumer councils and user organisations. For the more serious problems, official commissions have been set up to identify the nature of the problem, the likely solutions available, and the real options preferred such that the critical path can be identified and recommendations made. Commission Kist was set up to determine independently the neutrality of fare revenues per decentralised government in the before and after situation. Commission Meijdam was set up to study three issues: double interchange fares between operators, simplification of the CI-CO procedures, and changes in fares structure such as lowering the check-in price from EUR 4 to EUR 3. These are topics of importance to improve the performance of the smart card and to eradicate the technical anomalies that remain in urban and regional travel. The Kist reports have made important contributions to enhancing public confidence and to finding appropriate solutions to problems identified.

In conclusion, the fact that the strip ticket has now been officially withdrawn and smart card ticketing has been put in place across the nation is an indication of the potency of the smart card technology. Future prospects will depend on the ability of the stakeholders and partner organisations to introduce appropriate improvements quickly and to resolve the identified technical and organisational problems in a cost-effective manner.

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PART II: BETTER NETWORK DESIGN FOR SEAMLESS PUBLIC TRANSPORT OPERATION

4. PHYSICAL INTEGRATION OF THE PUBLIC TRANSPORTATION NETWORK

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4.1 Introduction

4.1.1 Background

The number of passengers using express buses for regional trips has decreased continuously since 1990, while the number of private cars being used for long-distance regional trips remains at a high level despite the opening of the KTX (Korea Train Express) in 1994. The fact that the share of private vehicles is higher than 40 percent for long-distance trips of more than 200km needs to be improved, not only for the convenience of passengers, but also for energy savings and a decrease in emissions.

Figure 4.1. **Changes of Express and Outer City Bus Users**

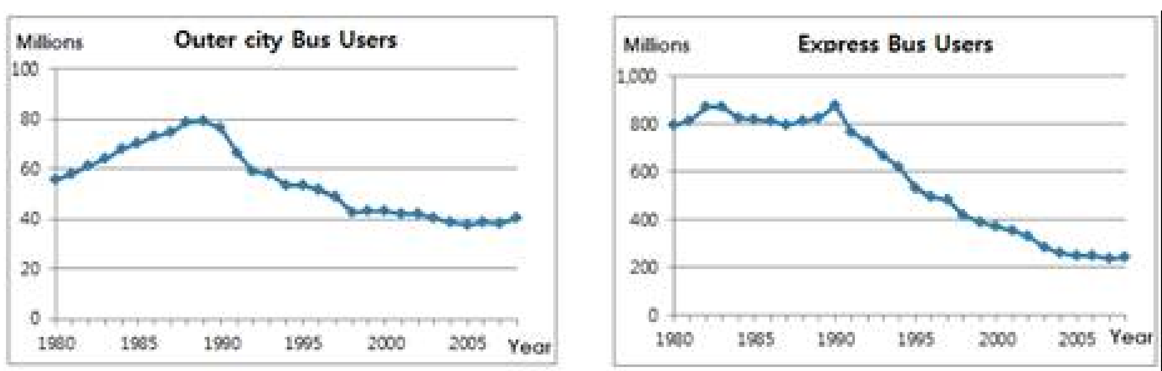
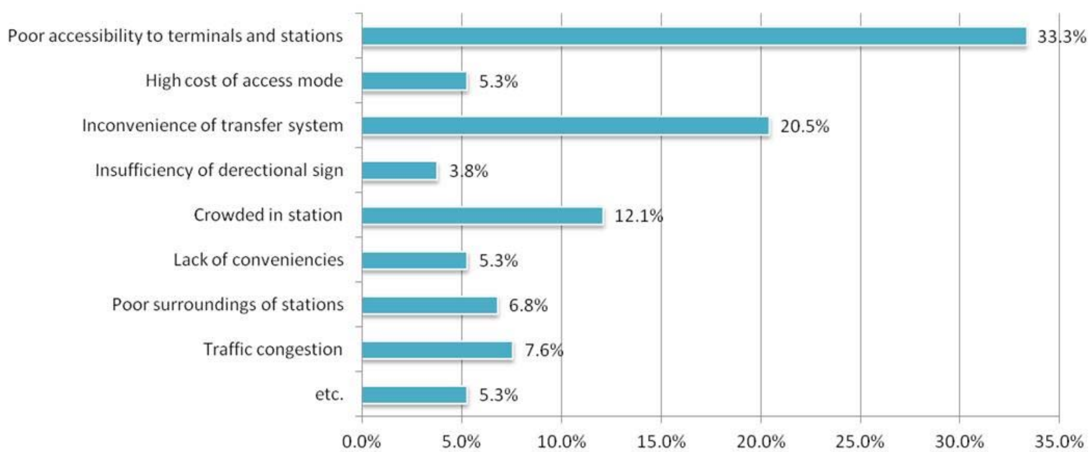


Figure 4.2. **Changes of Public Transportation Passengers**

The reason for people using private cars for long-distance trips is because regional high-speed travel modes, including KTX and express buses, do not provide transport connectivity and transfer systems. A survey carried out showed that more than 50 percent of respondents believed the greatest disadvantages of using KTX included poor accessibility and the inconvenient transfer system at KTX stations. Travel times, compared to distance travelled, was also a problem for express buses due to the large number of operation systems.

Figure 4.3. **Problems for Using KTX**



Source: Questionnaire Survey by KOTI(2012)

4.1.2 Objectives

From this background, it becomes evident that transport connectivity and transfer problems should be solved through the physical integration of public transport network. For these purposes, this paper includes as follows:

- status-quo of current public transportation network
- concept and directions for physical integration of public transportation network
- Korea's model for physical integration
- Stepwise tasks and implementation measures for physical integration of public transport network.

4.2 Status-quo of current public transportation network

4.2.1 Current situation

As the KTX network expands, the nation is becoming a one metropolitan city in Korea. However, the lack of accessibility to, and from, the KTX station is the main reason for not attracting private car users for long-distance regional trips. This is evident from the fact that 65.8 percent of passengers are using private cars or taxis to access Chunan-Asan KTX station, and 68.5 percent for Gwangmyung KTX station. On average, transfer distances at rail stations and bus terminals in Korea are 357.9 m and 227.6 m respectively. Rail stations and bus terminals both lack moving-walkways, escalators and elevators. In addition, the time schedules between the main and feeder lines are not harmonized with each other. This causes increases in waiting times, which results in an increase in total travel times.

Table 1. Table 4.1. **Average Transfer Distance at Rail Stations and Terminals**

Access Modes	Indoor				Outdoor			Average Transfer distance
	aisle	Moving walk	stair	staircase	stair	staircase	sidewalk	
Auto	158.5m	5.0m	8.1m	15.5m	1.8m	0.0m	131.2m	320.2m
Rail	189.2m	39.8m	19.9m	24.6m	0.2m	0.0m	66.4m	340.1m
Bus	126.8m	0.0m	15.7m	12.2m	2.1m	0.0m	111.3m	268.0m
Average	146.3m	7.3m	12.9m	17.9m	2.1m	0.1m	99.1m	285.7m

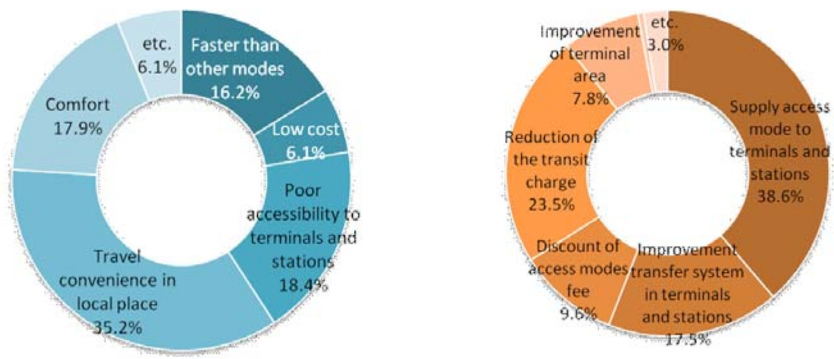
Source: KOTI, Master Plan for Transit Center Complex in Korea, 2011

Expressway transfer centres have been in operation in Korea since 2009. However, the locations were not properly chosen from the perspective of users and they cannot provide appropriate services. Coordinated feeder lines, time scheduling, reservation systems are all strongly recommended to be installed soon.

4.2.2 Problem causes

The main causes of the problems are the lack of hub facilities for transport connectivity and transfer. Generally, public transport networks are composed of link and node. Until now, the government invested mainly in expanding links such as railways and highways, to the detriment of nodes like rail stations and bus terminals. Rail stations and bus terminals had been built without consideration of connectivity and transfer for users. As a result, transfer times have increased due to the great distances between rail and bus stations. Because of these problems, private cars are considered more convenient than public transportation for long-distance trips.

Figure 4.4. **Reasons for Auto Use and Improvement Items for Public Transportation Use**



Source: Questionnaire Survey by KOTI(2012)

4.3 Concept and directions for physical integration

4.3.1 Concept of physical integration

The basic concept of the physical integration of the public transportation network is to develop transport connectivity and transfer facilities for improving the provision of convenient transfers among transport modes. Transport connectivity and transfer facilities can be implemented in the form of transfer centres as a way of developing transfer hubs. A transfer centre is a complex of transfer facilities, combining rail station, bus depots and terminals, ticketing booths and passenger facilities, transfer paths, and other facilities. Passengers are guaranteed connectivity and optimum transfer convenience between modes. Generally, the physical integration of public transport networks is completed in the form of a hub and spoke type of integrated public transport system.

Figure 4.5. **Physical Integration Concept**

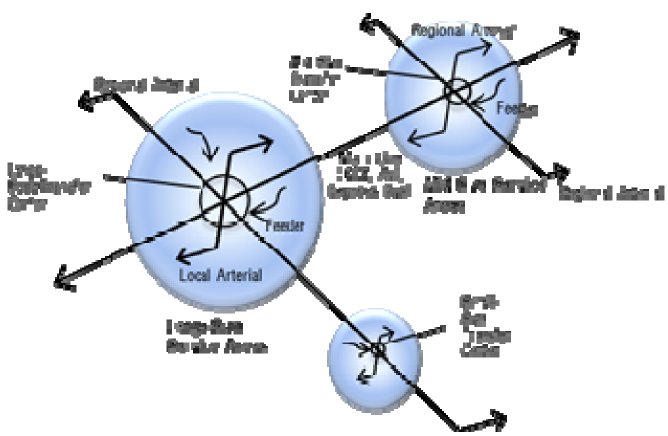
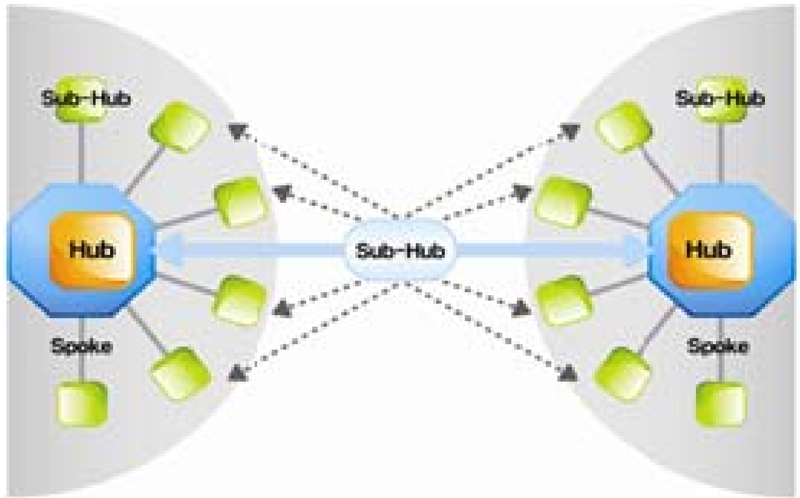


Figure 4.6. **Hub and Spoke Concept**



4.3.2 Directions for physical integration

The basic direction for physical integration of public transport networks for regional trips is to develop super-hubs, hubs, and sub-hubs – depending on the roles and functions of each node where transport connectivity and transfers occur. Physical integration makes it possible to organize hub and spoke transport systems and to implement seamless transport connectivity and transfer systems.

A super-hub can be developed at the KTX station, while bus terminals and rail stations in large cities can be developed as a transfer hub. In addition, bus terminals, rail stations and highway rest areas can be developed as sub-hubs for transport connectivity and transfer among modes.

Physical integration seeks to shorten transfer distances and times through facility design. This could be possible by introducing feeder buses, monorails, etc. into the transfer hub, as well as by enhancing vertical and horizontal moving conveniences.

Figure 4.7. **Conceptual Design of National Hub & Spoke-type integrated PT system**

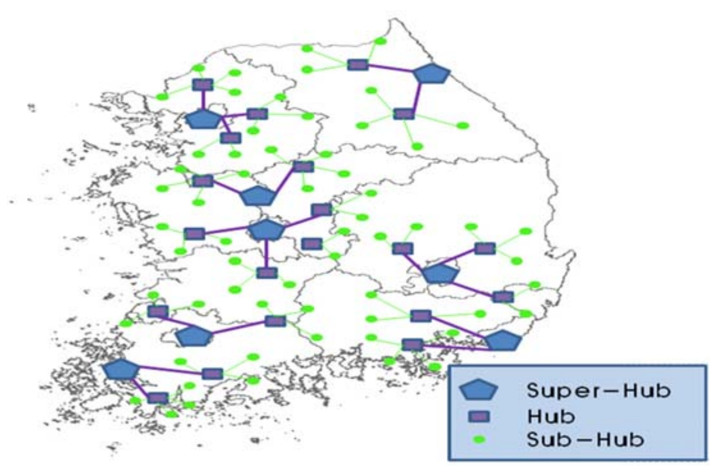


Figure 4.8. **Kokura Station, Japan(left) and Linkoping, Sweden(right)**

4.4 Korea's model for physical integration

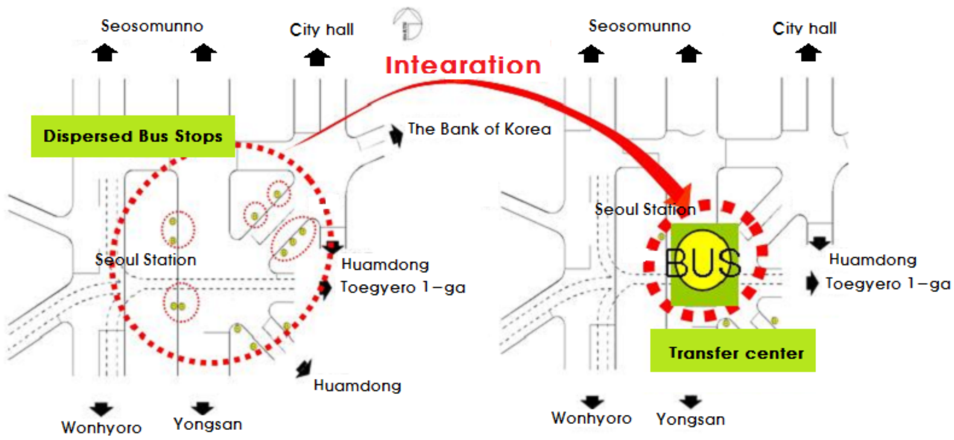
4.4.1 Seoul station transfer Centre

In urban areas in Korea, only one type of transfer facility has been installed: park and ride areas, which are located near subway stations. However, these park and ride areas have not functioned as transfer facilities; rather they have been used as a type of garage for parking. Seoul authorities began reforming public transport systems and establishing bus transfer centres in July 2004. Currently, four major transfer centres have been installed and are functioning as transfer facilities between trunk and feeder bus lines, as well as between buses and subways.

The bus transfer centre is one of the basic transport facilities to improve service quality and maximise utility of public transport systems by providing convenient transfers among public transport modes. Generally, a transfer centre is a complex transfer facility combining rail stations, bus depots and terminals, ticketing booths and passenger facilities, transfer paths, and other services related to transfers. Passengers are guaranteed connectivity at transport nodes, where transfer frequency is higher between modes such as subways, buses, taxis, automobiles, and bicycles.

The purpose of the transfer centre at Seoul station is to create eco-friendly and pedestrian priority spaces, and to improve transfer convenience among public transport modes by constructing a transfer system integrating the KTX, buses and subways, as well as connecting exclusive median bus lanes near the station. Nine out of twelve depots which were previously dispersed around the Seoul Station area were relocated to the median lane near the Seoul station. Relocated bus depots now provide convenient transfers to subway lines 1, 4 and the KTX station. A pathway was installed, directly connecting subway lines 1 and 4 with bus depots and taxi stands. Additionally, a pedestrian crosswalk was constructed in front of the Seoul Station concourse. The influx of bus route patterns was also changed and most buses now pass through the transfer centre, thus maximising transferability between modes.

Figure 4.9. **Before and after of Seoul station transfer centre**



4.4.2 Expressway transfer centre

KOTI (The Korea Transport Institute) observed that intercity, or inter-regional, bus lines could improve on the rest areas other than by providing refreshments for passengers and brief maintenance for vehicles. Inter-regional buses from all over Korea stop at certain rest areas on major express highways before dispersing to their final destinations. Passengers could thus take advantage of such stops if they were able to transfer from one line to another. KOTI suggested installing transfer centres at the rest areas as a way to maximize benefits of inter-regional lines. Currently, six transfer centres have been installed at rest areas and are operating successfully. The results are clear that, by maximising the utility of their networks, the service quality of inter-regional bus systems has improved dramatically. The Korean government has therefore decided to build further transfer centres at rest areas, and is also considering installing these on conventional highways.

Express highway transfer centres represent a paradigm shift from a hub-and-spoke system, focused on existing large cities, to a new sub-hub-and-spoke system focused on express highway rest areas. Previously, passengers were obliged to make extra trips to the nearest hub terminals in order to transfer to their final destinations; and sometimes they had to pay higher fares for making backward trips from these destinations. However, with express highway transfer centres, passengers can minimise the costs of extra trips to hub terminals while maximising the utilities of inter-regional bus routes. Rather than travelling backwards, passengers can now move directly toward their final destination by changing at sub-hub terminals in transfer centres located in rest areas.

Figure 4.10. **Location of expressway transfer centre in Korea**

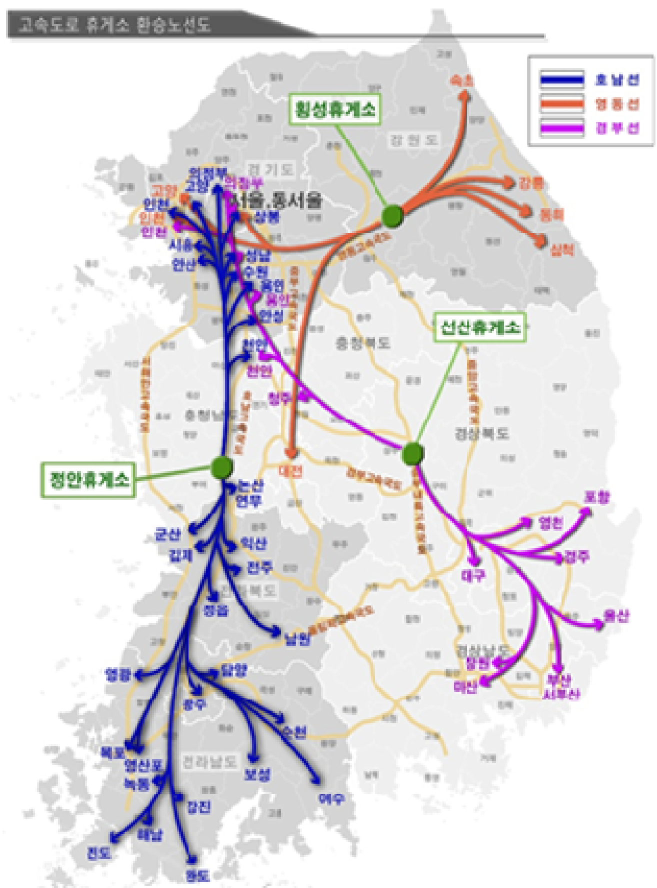


Figure 4.11. **Outer and inner landscape of Hoengseong**

4.4.3 Research and development for seamless transfer system

Facility design, operation and information technology, as well as legal and policy measures for a seamless transfer system have all been developed through a 5-year R&D project driven by the Korean government. The project was implemented, under the leadership of KOTI, from 2006 to 2011. As a result of the project, the layout criterion for an external facility was developed, based on the "weighted average transfer distance". A national integrated transport systems efficiency act was also introduced as a legal basis for the development of the transfer facility and 8 pilot projects were selected by the government.

Figure 4.12. **Stepwise procedures of R&D project**

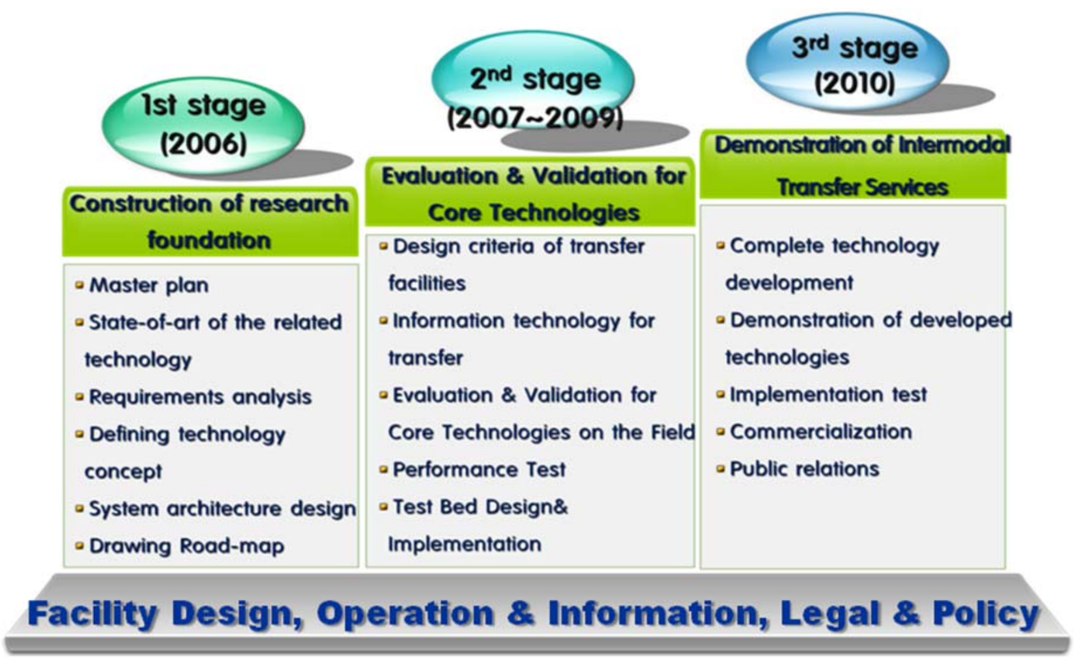


Table 4.2. **Layout criteria for external facility of transfer facility**

LOS	Transfer Distance	Transfer Time	Core
A	60m or less	1 min. or less	100
B	60m - 120m	1 min. - 2 min.	90
C	120m - 180m	2 min. - 3 min.	80
D	180m - 240m	3 min. - 4 min.	70
E	240m - 300m	4 min. - 5 min.	60
F	300m or more	5 min. or more	50

Note: Transfer path length (m)=walkway length (m)+α* stairway length(m)+ β*people mover length (m), here, α: 2, β: ½,(α= ½ if an escalator exists).

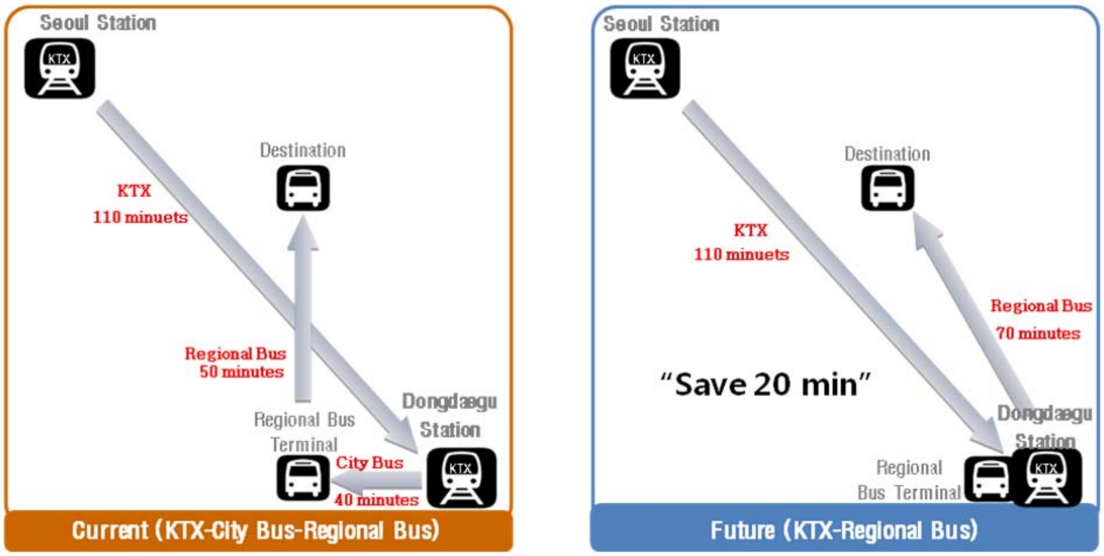
4.5 Stepwise tasks and implementation measures

4.5.1 Stepwise tasks for physical integration

The maximum speed of the KTX is 300km/h – far faster than by car. In this respect, at least, KTX has the competitiveness. However, the KTX station is not the end of the journey. It is generally impossible to avoid riding a feeder line in order to get to one’s final destination.

As shown from the previous study, the KTX station has poor accessibility as well as an inconvenient transfer system. However, the physical integration of the KTX station may be implemented in three steps. In the first step, it is necessary to relocate bus terminals near the KTX station in order to secure as many feeder lines as possible. At the same time, transfer distances and times should be as short as possible. For this purpose, specific designs and arrangements for transfer facilities and bus stops should be presented. Relocating terminals and shortening transfer distances can reduce both transfer time and inconvenience. However, additional waiting times may occur where the arrival and departure times of both the main line and feeder lines are not properly scheduled. It is important, therefore, to eliminate unnecessary waiting periods through the appropriate scheduling of arrival and departure times.

Figure 4.13. **Current and future Dongdaegu KTX station**



Existing expressway transfer centres have increased the accessibility to express buses by remote small towns with low operation frequencies. However, this is limited to express bus operations. Physical integration of expressway transfer centres may be implemented in two steps. First, it is necessary to increase the number of transfer centres – not only on expressways, but also on national highways – in order to increase the chances of using regional buses in small and medium cities. Second, the transfer centre should be improved so as to permit access to, and from, local bus, taxi, and other feeder lines. A new design concept should be presented for this purpose.

4.5.2 Implementation measures

To implement tasks for physical integration, various measures should be considered. The implementation measures are as follows:

- Draw up a comprehensive master plan for physical integration, based on a detailed field survey on transfer facilities.
- Designate a hub-like transfer facility, based on the master plan, and commence improvement project.
- Construct operation and management centre for facilities.
- The law and principles relating to developing transfer hubs, as well as the designation system, should be improved.

4.6 Conclusion and recommendations

Seamless transport connectivity and transfer system is a critical factor in converting car users to public transport for long-distance regional trips. The physical integration of the public transport network is considered to be one of the most important factors of seamless transport. This study deals with the status-quo of the current network, its concept and direction, as well as Korea's model, stepwise tasks and implementation measures for physical integration.

In addition to the above, other ideas for increasing the use of public transport should be given serious consideration. Firstly, transfer hubs should be coordinated with land development. Secondly, public and private partnerships should be introduced. Thirdly, governmental support is very important for physical integration. The latter should be implemented simultaneously with an integrated fare, payment, and information system. Lastly, various measures should be introduced in order to increase transfer passengers as well as visitors to transfer hubs.

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5. KEY FACTORS OF NETWORK DESIGN FOR SEAMLESS, INTRA-REGIONAL PUBLIC TRANSPORT

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5.1 Introduction

5.1.2 Network design – undervalued factor of public transport success

The importance of network planning and design for public transport success has not been properly recognised in conventional public transport research and development. Existing textbooks on public transport only partially deal with this topic, and observations of real-world public transport systems can reveal large potentials for system improvements in terms of efficiency and customer satisfaction through better practice in network design and operations.

Network planning and design is a complex and continuous task, both in the short- and long-term perspectives of planning and operations, in many different geographical and social settings. The scope for planning also depends on the institutional setup and political ambitions, in particular the balance of roles between planned regulations and market forces. To have complete coverage of all important aspects of network design, a full textbook will be needed. This paper presents thoughts and comments on some of the most important design factors for the creation of successful intra-regional public transport networks. The main topics are:

- simplicity and ease of use;
- the network effect and connectivity;
- optimal frequency;
- speed of operations and travel;
- quality access for sustainable transport.

To support the argument, practical examples from mainly small- and medium-sized urban regions in Europe are mentioned, in addition to some references to research reports. It is evident that network planning must be supported by appropriate and comprehensive transport policies and land use planning at both local and regional levels, but a discussion of these topics would require another paper.

5.1.1 Objectives to guide network design

All reasoning about good practice must have some reference points for the definition of what constitutes 'success.' This paper considers two main tasks for the public transport system in modern society:

- Competitiveness in relation to the car; i.e. an environment friendly, cost-effective and attractive alternative to the car – on the course to a sustainable society which is significantly different from today's strong car-dependency in affluent countries.

- Social welfare and accessibility for all; i.e. social inclusion and full access to society's activities for all groups of the population, including persons and households without access to a car, and others with reduced mobility resources and abilities.

Both objectives must be reached with limited use of resources, so efficiency is the third measure of success for the public transport system.

5.2 Simplicity and ease of use

5.2.1 Simplification is essential in a dynamic, competitive market

Potential public transport customers ask themselves: Is it practical, attractive, easy and safe to go by public transport for this particular journey? To succeed in the market competition, the public transport system must offer positive and clear answers. To create the required trust and goodwill, the system must be simple, easily legible and user friendly on all segments of the journey from door to door. Simplification has become an important trend in high quality network development in recent years, and the motives for this are very strong.

Knowledge of the public transport service is crucial for travel choice. People will not make much use of public transport if they do not understand the services the system can offer them in different situations, times and locations.

Public transport users are transient customers. The total volume of demand might be rather stable, but this hides the very large turnover of persons using the system. People move their home, change work places, shopping habits and leisure activities. Some customers die. At a particular point in time, a large part of the users are new to the system, and the turnover in the market is high. Operators like Oslo Public Transport (Nielsen, Lange et al. 2005) and Metrolink in Manchester (Knowles 1996) work on the assumption that annually some 10-17 percent of their customers leave the system and are replaced by new users. So there is a continuous need to explain the system to new customers just to stay in business.

People are most inclined to change their travel habits when they have moved to a new place of residence or changed jobs. The large section of the population who are changing their travel patterns and habits, are those most sensitive to new information and least informed about the public transport system they might choose to use.

Occasional users represent a large demand potential, which might be exploited if the barriers to use can be significantly reduced. Legibility and simplicity are probably two of the main reasons for the common notion that rail systems manage to attract more passengers than a similar bus service.

Many car users believe the service is worse and more expensive than it is (several studies by W. Brög and colleagues). They often base their travel decisions on misconceptions of the system, and they normally lack the broad insight one often needs to consider public transport as an alternative to car use. Simplification of the system will help to open their minds.

The coordination of land use and public transport requires a clear network structure to facilitate and encourage public transport-conducive location and activity choices by households, businesses and public institutions.

The simpler the system is designed, the easier the product is to market and inform about, and the cost-effectiveness of all such measures will increase. In recent decades, easier travel on all parts of a regional, multi-mode network through simplified fare and payment systems has had a significant effect on public transport demand in many European urban regions.

There are also good operational reasons for simplifying the network. Once they are established, simple networks are easier to plan, develop and operate. Uncertainties and confusion about the service are reduced.

5.2.2 Develop a two-tier network structure

The main concept that emerges from these considerations is that different modes, lines and services should be integrated into a single, user-friendly, and two-tier public travel network, with a combination of:

- a stable and simple network of lines of all relevant modes, with fix-scheduled services and frequencies high enough to satisfy large sections of the travel market, and
- a flexible, demand-responsive service catering for all other public transport services that are needed to satisfy customers in low density areas, at quiet traffic periods, and for people that are not able to use the scheduled line services or who have certain defined citizens' rights to public transport services to schools, studies, health services, social institutions, etc.

To make this network the main passenger transport alternative for the sustainable society, the system must become far more user-friendly than usual today, i.e.:

- so simple that everybody can understand and use the services without time-consuming studies or long experience;
- so conspicuous that all services are easy to find, both in cities and elsewhere, even in rural districts;
- offer continuous and integrated travel chains from origin to destination;
- payment and information designed for bother-free travel
- reliable, stable and safe for everybody;
- universal design of all elements, including the information systems, so as to minimise all users' need for assistance.

The greatest challenge is to satisfy all these requirements within a realistic budget and other external conditions. Efficiency is a key requirement. It is important that efforts of improvement are concentrated on the most important factors, and different measures should support each other to give better results. A successful project can often start a positive chain of events, where increased patronage generates more income from passengers and induces more political support for the funding of improved quality and new proposals.

5.2.3 Recognise the value of user friendliness and branding

Branding is a powerful tool for consolidating users' and communities' trust in the system. User friendliness and branding is an important key to business success and shareholder values of world leading businesses, such as Apple's Iphone and Ipad, Samsung's smart TV sets and phones, and so on. The business success and commercial values of these companies have been created through a combination of user friendliness, trendsetting modern design and powerful branding. As an example, the value of the name and brand of the Swedish, world-leading furniture and home decoration outlet IKEA has been valued at 8.5 billion euro – an indication of the enormous value of the company's customer relations and goodwill (estimated value at a sale of the rights to a daughter company, August 2012).

The value of brands rest on a bedrock of consumer confidence, and they create customer value because they reduce the effort and the risk of buying goods and services. It reflects the opinion the world has of the business or product, which forms the attitudes of customers and informs their decisions. 'The crucial point is not what you are, but what the world believes you are' (www.BrandClinic.se).

Some cities and operators have recognised the value of branding in public transport, but in most regions there is a large potential for greater market penetration and goals achievement through the simplification and branding of the public transport system.

5.2.3 A symbol of quality and modernity

When the ambition is to take a significant share of the travel market from the car system, public transport must reflect this goal, and show to everybody that society wants us to travel by public transport. Therefore, the public transport system must be characterised by a general quality of design, operation and maintenance which gives it social recognition and status. Travel by public transport must not be looked upon as a third class option – only appropriate for those sections of the population who have no other choice. In the sustainable society, the opposite must be the case. The public transport service should be developed into the obvious first choice of urban citizens and modern life.

The means to this are similar to those of Apple and other life style affecting businesses: modern design and high-quality user friendliness in all aspects of technology and service, from modern vehicles and infrastructure design to payment and information systems, marketing and customer relations. The basis for all this is a distinct, unified and cost-efficient public transport network that is easy to communicate to everybody. Three well-known examples from urban public transport history can be mentioned: the London Underground, the BRT system and master land use plan of Curitiba, and the TransMilenio BRT renewal of the public transport system of Bogota.

5.2.4 Practical, trustworthy and value for money

The symbolic and emotional aspects of travel choice are important, but still the basic challenge is to make public transport more practical and trustworthy, and to give the users and the general public taxpayers more value for their money. Again, simplification is a key to achieve this. In Europe, cities like Munich, Zurich, Copenhagen and Nantes, and small towns like Lemgo (D) and Schaffhausen (CH) demonstrate practical examples of this.

Dziekan (2003) has found that the use of public transport requires a large emotional and intellectual effort of information collection and problem-solving during all stages of the journey. For all non-users this is a significant barrier against the use of public transport, especially for the non-routine journeys. Dziekan and Thronicker (2004) state that it is necessary to have a single, comprehensive and easy to read map or diagram to give the user an overview of the total system with all modes, lines, stops and interchange points that serve the urban area, irrespective of the operator. This requirement is crucial, since it is impossible to fulfil if the system consists of many lines on the same, or parallel, routes in a dense network with many different types of services, express routes, special peak period services, special shopping buses, and so on.

Howes and Rye (2005) analysed ten different cases of urban networks and five transport corridors in different north western, European urban regions. They concluded that in order to increase usage amongst both existing users and current non-users of their public transport systems, medium sized cities should (p. 92):

- ‘speed up their core services, preferably by converting them to some form of segregated rail-based mode, or otherwise by simplifying the routes and introducing bus priority;
- simplify routes more generally; focus on high frequency on core corridors;
- start with corridors, because these are easier to grow than networks as a whole;
- both the above measures will improve reliability, which is also a key quality factor;
- cut fares through the provision of integrated season tickets;
- integrate services across modes;
- provide high quality modern, clean, safe vehicles, stations and stops.

Reduced parking availability/increased parking prices, traffic calming, traffic congestion on key road corridors paralleled by rail-based services, and a land use planning framework that works to assist public transport will all lead to greater patronage increases and modal shift, although they may not necessarily be defined as what the citizen would want from their public transport system.’

In smaller towns, cost-effective multiplication of patronage was achieved in the 1990s by network and service redesign in 14 towns in Germany (Land Nordrhein–Westfalen 1999):

- simple and readable network with pendulum lines through the city centre;
- all lines are coordinated in the city centre;
- fixed-minute timetables for all routes at all times, plus demand-responsive taxi services at night;
- the same, fixed timetables at weekends as on weekdays;
- high quality bus stops with full information of the total service at all stops;
- simple priority measures for buses in the road system;
- attractive and comfortable, high profile, low-floor buses;
- a simple, user-friendly fare system;
- strong and continuous information and marketing.

A study of success factors in Swedish small towns (Rube 2007) has very similar conclusions.

5.2.5 The pitfall of ‘tailoring’ services

The call for user friendliness and stronger market orientation of public transport creates a ‘pitfall’. Full on-the-road market competition for public transport services (as in the UK outside London) easily results in a complex network of uncoordinated lines and services, and inefficient use of the total resources for the public transport system. Also, planned tailoring and differentiation of services to particular, small market, segments of existing demand usually lead to a complicated service supply.

Instead, planning advice should move from these strictly demand-oriented ideas towards the supply-oriented model of network development. Then the idea is to provide a simple, planned, 'ready-made', and well-structured network of different modes as an offer to the market – similar to the idea of creating new demand patterns through product or supply development in the tourism and entertainment industries. Instead of trying to equal the services offered by individual transport, it is more fruitful to look upon the role of public transport as similar to that of the road network, which is present irrespective of actual demand. Instead of focussing on existing travel demand patterns, the idea is to develop the market in interplay between potential customers and public transport supply and service design.

Public transport is a travel service where the basic idea is to make use of economics of scale by offering people a choice of travelling together on predefined transport services. Attempts to offer tailor-made transport similar to the individual use of the motor car will not succeed in fulfilling this purpose.

5.2.6 A simple framework for travel and location decisions

In order to influence the urban structure and transport demand, the public transport system must establish a geographical network structure so strong and robust that it can stay more or less unchanged for many years. To be successful, the public transport system must form the backbone of urban structure and development, and have a stable and high quality service over many years. This stability, more or less guaranteed by the public transport and land use planning authority of the area, is a precondition for influencing urban property development and land use. It is the key requirement for the creation of an urban structure that supports public transport as a major mode of transport.

The long term effects of rail infrastructure and transport systems have been well known for many years. Indeed, much urban development in the first half of the 20th century (and earlier) was based on the accessibility provided by new railways, tram lines and metro systems. In the early days of buses and motor cars, even bus lines created a similar interactive effect between land use value and public transport supply and demand. In today's urban areas, with much stronger competition from the motor car, the strength of the basic public transport structure is more important than ever before.

The request for network stability can only be satisfied if the network is robust enough to incorporate the need for short term adjustments in frequency, capacity, connecting and disconnecting lines and branches. The network should also have the ability to be extended into new areas of urban development without having to redesign large parts of the existing structure. Even conversions of transport corridors between bus and rail should ideally be possible without completely altering the network structure of the urban region.

5.3 The network effect and connectivity

5.3.1 Exploit the network effect

Ideally, the public transport network would offer fast, direct links from everywhere to everywhere, just as the car does for those who have this option. But in practice, public transport must work by concentrating passengers onto selected corridors, and inevitably this leaves many journeys without a direct connection. Obviously, the need to change between vehicles and services is a strong disadvantage and barrier against the use of public transport. Still, it is important to understand and exploit the positive opportunities that are represented by the 'network effect'.

Apparently, the factual, quantitative evidence of this effect is rather limited. Obviously, the network effect depends on the assumption that travellers are willing to transfer between lines. In cities and places where both the line network and the transfer points are designed to accommodate this, such changes are being made in large numbers. Data gathered by Tarzis and Last (2000) suggest that there is an association of higher levels of transfer with higher public transport modal shares, which may be interpreted as a network effect. One obvious explanation is that it can be highly advantageous for passengers to substitute a fast mode (such as rail) for part of their journey, instead of a slow mode (such as bus). Indeed, only by doing so will public transport offer an acceptable alternative to the private car for longer journeys.

Unfortunately, much of the research on willingness to transfer is based on hypothetical, stated preferences by users of systems where transfers between lines are unattractive and complicated. Since most regions have very few high-quality interchanges, most of the survey respondents in customer preference studies have little experience of properly integrated networks. A Swedish study of passengers travelling by bus to Arlanda airport Stockholm (Sjöstrand 1999) concluded that the experiences of travellers are of great importance to their evaluations. The group of respondents who were used to changing buses at a high-quality interchange evaluated it as 7 minutes extra travel time, while those who were used to direct travel evaluated such a hypothetical transfer at 22 minutes extra travelling time in a bus.

Further research is needed to quantify the effects on demand that can be referred to as the network effect.

A theoretical example, first described by Mees (2000), is useful for the understanding of the network effect, and is presented in the appendix. By the use of increased operational resources to strengthen a network of lines, instead of adding to the frequencies of existing, more or less parallel services, it is possible to achieve a much stronger demand effect than conventional elasticity demand models indicate. The theoretical case was supported by evidence from a detailed, comparative study of the public transport systems of Melbourne and Toronto over several decades of urban growth up to 1990/91. He concluded that the main explanations for the relative success of public transport in Toronto compared to Melbourne were:

- the high quality of Toronto bus services in the suburbs and their excellent integration with rail, and the poor bus service and lack of integration with rail in Melbourne;

- the integrated system of Toronto also resulted in a much more intensive and cost-efficient use of the rail infrastructure, when compared to the more extensive Melbourne rail system;

- the bus and rail combination in Toronto proved more attractive to the population in Toronto than the more extensive park & ride facilities that had been developed in Melbourne, partly as a result of the poor bus and rail integration.

To Europeans with experience of the integrated public transport systems of urban regions in countries such as Germany and Switzerland, the conclusions are no surprise. But it is interesting that Mees demonstrated the importance of the network effect in cities with a medium to low density, and with a more car-oriented urban structure than usual in Europe.

How the network is presented to the public can significantly affect the effectiveness of the public transport system (Tarzis and Last 2000). At the extreme, if passengers are not told about interchange opportunities, they will not plan their journeys to make use of them. More subtly, the way in which the public transport network is promoted to the public, and the role set out for interchange within the network, will have a profound influence on how passengers use the system. In cities like London and

Paris, the Underground or Metro maps are designed to direct transferring passengers to stations and lines with appropriate capacity and ease of transfer.

5.3.2 The network effect depends on frequency

Exploiting the network effect requires a minimum level of service frequency on the lines which cross each other at the transfer points. With only low frequency lines, waiting times for transfer are too long to make public transport journeys with one or more interchanges an interesting travel option for people who are not forced to make this type of journey. With some high frequency ‘trunk lines’ the situation improves, but it is only when you have a network of high frequency services the system really stands a chance of competing with the car as a real travel alternative for other journeys than direct, radial trips to and from the central area of a city or region.

In Europe, the public transport network of the Zürich region is often considered the most successful urban transport system, with a level of per capita patronage well above that of comparable regions. The long established, dense and integrated network of trams, buses and trains (and boats) with high frequency, stable lines and long operating periods, is an important factor behind the high level of public transport use in a modern, rich country. In the smaller towns and rural parts of Switzerland, as well as in many German small towns, short waiting times at transfer points are achieved by timetable coordination and so called pulse scheduling of buses and trains.

5.3.3 Minimise transfer barriers

Transfer is an inescapable feature of the majority of possible journeys that can be made through the public transport network. Reducing barriers to interchange will enable individual passengers to gain more benefit from the network, and will increase the attractiveness of the public transport ‘offer’ relative to the car.

There is a great difference in travel time, comfort and orientation effort between the really good and the, far too usual, bad solutions at interchange points. In Australia, researchers have found that, typically, some 30 percent of the generalised travel time effort on urban journeys is spent on transfers. The weighted time effort of a transfer can often vary between 32 and 4 minutes, depending on the quality of the transfer facilities, and the frequency and time coordination of services (Currie 2007).

This shows that public transport users and stakeholders have much to gain from high quality solutions at the transfer points. Within a city or region, many high quality interchanges are necessary to create the network effect that makes it possible to take full advantage of a simple line structure with few, but high frequency, lines. If the critical transfer points do not function well, there will be a strong demand for more low frequency direct lines. This will result in the fragmented, complex and continuously changing network of lines that is typical of many cities and regions around the world. In addition, the possible benefits of investment in rail infrastructure will be significantly reduced. A low or medium quality bus-based public transport system is then often considered to be the only economically sustainable alternative.

According to Tarzis and Last (2000) the key benefits from the systematic improvements of interchanges are:

- reductions in disutility from reducing unpleasantness of interchange experiences of existing users;
- reduced journey times from rerouting where previously interchanges discouraged use;

- fulfilling a necessary condition to make possible an increase in public transport mode share, especially where it is traditionally least competitive, such as for orbital journeys;
- reduced pressure on crowded radial sections;
- increased flexibility for operators and planners to offer a mix of public transport modes to suit local circumstances.

There are a number of factors concerning location, design and information of interchange points, fares and ticketing systems that may be used to improve network connectivity, but further comments on this is outside the scope of this paper.

The strongest network effect will be achieved if well designed interchanges are developed at all places where two or more lines cross each other, so that transfers will create a number of new travel opportunities. Most of these points will be simple road junctions, so it is important that traffic engineering and management is strongly directed to take proper care of public transport users in the detailed design of urban streets and roads.

The largest transfer points will be major interchanges and meeting places between the public transport system and the urban land use structure. This will be regional and local centres of activity that combine the interchange function with being major traffic generators in themselves. These points will very often have high density concentrations of work places, commercial activities and public services as well as medium to high density residences.

The most important issues of physical design of large interchanges are:

- walking distances should be as short as possible when changing vehicles;
- elevators and escalators are required for comfort and speed when a change of level is required;
- visibility between main destinations inside the interchange improves orientation and safety;
- the accessibility needs of disabled and elderly persons (and passengers with luggage, prams etc) should be a prime concern;
- weather protection, natural and artificial light, and cleanliness and good maintenance are important factors for the users' feeling of comfort and safety.

To provide seamless travel to the customer, according to Keller et al (2000), it is necessary to have strong regulation (legislation), forcing all transport operators to closely cooperate. Also the financing of interchanges is a cardinal question. Having a public authority owning all infrastructure and private operators paying for their use leaves flexibility in operations and control over the quality of the infrastructure.

5.3.4 Avoid unnecessary transfers between lines

Even when all interchanges are upgraded to high standards, the need to change will still be a significant inhibitor to travel by public transport, and should be avoided if it is possible, bearing in mind the limited operational resources and other network considerations mentioned in this paper. The most important measure that can be taken to reduce the need for transfers, is to create long lines that connect important travel origins and destinations – such as densely developed housing areas, local and regional centres, concentrations of work places, etc. By connecting two such lines in a well designed interchange, a significant additional part of the region can be reached by one transfer only.

Furthermore, the concentration of resources to fewer lines with higher frequency, the creation of pendulum lines through city and suburban centres, removal of parallel lines in the same markets, and the integration of all services irrespective of operators and concessions, will reduce the number of lines in a region, and the need for transfers.

As illustrated in the appendix, two groups of long lines crossing each other may in theory cover all origins and destinations in a region by a combination of direct journeys and journeys with one transfer. In practice, urban form and development, topography and infrastructure will dictate modifications of the network. The public transport system will also need several modes and lines with different stopping patterns to cater for the different demands of the short and long distance travellers. Very different capacity demands in various parts of the region also require the splitting up of the network into some different types of lines and modes.

5.3.5 The direct line pitfall

In regions with little network integration, it is common to argue that a system of direct lines is the only strategy that is able to attract car users. As commented by Mees (2000), the idea is that the motor car is the ideal mode of urban transport, and that public transport should try to offer a service as similar to the car as possible. The idea usually leads to a large number of bus lines running parallel and in all sorts of directions in a complicated tangle of low-frequency services, and heavily congested bus routes in the city centre in order to serve all suburbs and rural districts with their own direct lines to the city centre. However, the direct line principle will normally be in conflict with other aspects of supply and demand, in particular the limits to the total resources available for operating the public transport network.

The arguments for the alternative, very different, network strategy have been presented above. In addition, the direct line strategy can be compared with a strategy based on the principle of ‘one section – one line’ (Nielsen et al. 2005). As long as the operational resources are the same, the aforementioned disadvantages of the direct line strategy are unlikely to be offset by the benefits of more lines that offer direct travel opportunities without change. In relation to waiting time, the only advantage of the “direct line” strategy is that diagonal journeys between certain branches of the network may be made without transfer, if the user is able to learn the timetables and adjust her/his activities to this. But this is achieved to the disadvantage of the high frequency for journeys between other areas at either side of the interchange or city centre. In addition, the aim of a long term stable network is very difficult to achieve if the direct line strategy is the main concern.

In the real world, line structure and timetables will be designed so as to give the best direct and high frequency services to the opposite travel corridors, so that transfers will only be necessary for the less likely combinations of origins and destinations.

5.3.6 Create a network effect also in small towns and rural areas

The network effect is not only achievable in big cities with a possible grid pattern for the network, as illustrated by the theoretical example in the appendix. In many cities with a population of some 100 000–200 000 or more, the urban structure and travel demand might allow for one or two ring lines. If possible, the ring line(s) should have a frequency and travel speed that makes it attractive to travel across the city without having to travel all the way to the city centre. By developing high quality interchanges at strategic locations with a concentration of activities, a fairly attractive network can be achieved.

In smaller cities with typically less than 100 000 inhabitants, most journeys are short, and the demand for public transport is insufficient to support a high frequency orbital line outside the central parts of the city. Then all public transport journeys between different suburbs must be made through the city centre, either directly on a through running ‘pendulum’ line, or by transfer in the city centre. A network effect may still be achieved if the service frequencies are high in all major corridors of the city region, and the interchange is a high quality one.

Often, in small and medium sized cities, the means to higher frequency and demand can be the creation of a network where several lines follow the same common route through the central parts of the urban area, with a common coordinated timetable. Or the network can be successfully redesigned with a backbone of a few trunk lines designed on the principle of ‘Think tram – use bus’, as in the Swedish town of Jönköping.

In small towns, there are few corridors with sufficient demand for high-quality public transport; here, the coordination between regional and local lines will become more important for the possible creation of a network effect. The town centre is the only major interchange in the town in addition to the common stops of several lines in each of the transport corridors.

In villages and rural districts there is no basis for a separate local network. All public transport, except demand-responsive and other flexible services, is based on the regional lines serving the rural district and connecting to the nearest larger town and/or transport hub. Here, frequencies are so low that timetable co-ordination is necessary to achieve a network effect in the regional system. The answer is timetable coordination through the creation of integrated pulse schedules in the district catchment area of local centres and transport hubs.

5.3.7 Aim for a complete national network

Eventually, the aim should be to create a continuous public transport network for the whole country. Currently, Switzerland seems to be the country closest to that goal, which is interesting since this is a federal, decentralised state with 26 rather independent cantons having the main responsibilities for public transport and regional development and land use structure. The national website, www.Swisstravelsystem.com, invites everyone to inform themselves of a comprehensive public transport network, covering all public transport modes in Switzerland. In addition to a common travel planner with all timetables, they have an integrated ticketing system. This includes ‘unlimited travel in 41 towns and cities’ as well as national, regional and private rail services, buses and boats on the country’s many lakes.

It is also interesting that there is a very heavy sale of various period cars for simple travel and efficient fare collection at the national and regional levels. For instance, in the Geneva region the public transport customers can be divided into three equal groups: 1/3 use annual passes, 1/3 a monthly pass, and only 1/3 pay by a single ticket[2]. When the technical safety challenges of mobile payment soon are solved, no money collection, ticketing machines or card readers will be needed on buses or rail vehicles, and large savings on fare collection and passenger inconvenience can be made.

In other countries, with a less developed main line network, a sparser development pattern and less per capita use of public transport, the biggest challenge for the creation of a national network may be the organisation and design of the necessary integration of scheduled and demand-responsive services.

2. Information from study visit at Dir. General de la Mobilite, Geneve, Sept 19 2011.

However, all national networks will need a certain level of planning powers, either through central government control or initiative, or through a well organised cooperative body, where benefits and costs of the network and passenger incomes can be justly distributed. A purely unregulated open market is unlikely to deliver this type of solution.

5.4 Optimal frequency

5.4.1 The importance of service frequency

A line in the main public travel network should not only be a line on the map; it must provide a significant travel service. The stable structuring element of the public transport network is the geography of the lines. The frequency of the service on each line is the necessary flexible tool for adjustments to demand variations, and the available level of economic support for the service. The frequency can vary over time and along the length of the line. However, it is useful to define a minimum frequency for a service to be included in the main network.

Numerous studies have shown that a high service frequency (short headway) is a key factor in the market competition with the car. The Transport Research Laboratory (TRL 2004, chapter 7.7.) concluded, after a review of 27 different studies of the service elasticity of bus patronage, that the short run elasticity of demand (in an urban British context) is 0.38, with a standard deviation of 0.14. The long term elasticity of bus demand is significantly greater, 0.66, with a standard deviation of 0.28. They also found that the short term demand elasticity for rail travel was almost the double of that of the bus services, 0.75, with a standard deviation of 0.13. The results are of the same order in other studies, and it is unusual to find average demand elasticities in relation to service frequency above 1.0. From a business point of view, this implies that the costs of increased frequencies will usually not be covered by increased traffic income from the fares. The social benefits not reflected in increased fare revenue must be paid for through public support, and this is often a strong barrier to such service improvements.

However, through good knowledge of the market and appropriate design of the travel network, one can find market segments that are more responsive to service improvements than the average figures indicate. It is also well known that customers will walk longer distances to stations and stops where services run more often. This extends the scope for network rationalisation without any loss of patronage. Furthermore, the relationship between service frequency and demand is not linear. When frequencies are increased within an existing line structure, there is a case of diminishing return in relation to demand. By limiting the production volume on different lines to an optimal level of service, as discussed below, a stronger network of travel opportunities may be achieved at a given level of total production and costs.

5.4.2 Look for optimal frequencies

Even if high frequency is an important condition for market success, there is no need to go beyond all bounds. Here the concept of optimal frequency is a useful planning tool. The definition of this level of service will require comprehensive analysis, depending on the context, available resources, city size, time of day and week, etc. But in many situations one might assume that the optimal headway is some 5-10 minutes between departures. Longer headways will result in too long waiting and transfer times, and a need to consult the timetable before the journey begins – especially for journeys that include transfers between different lines.

On the other side, shorter headways will cost proportionately more to run, without giving significant reductions in waiting times. In addition, the tighter traffic may gradually cause increasing problems of congestion and environmental conflicts, especially if the line is operated by standard diesel buses in narrow streets in high density (residential) areas and city centres.

For capacity reasons, headways between trains, trams or buses often come down to 2 minutes or less in large cities and in networks with only one or two public transport corridors through the city centre. At this traffic density, congestion starts to develop on rail lines and at stations, tram- and bus-stops. There are disturbances between vehicles, between boarding and ascending passengers and between buses, trams and pedestrians at level crossings.

With separate right-of-way and segregation of buses and trams in city streets, and strict traffic control in heavier rail systems, it is possible to operate the system at even shorter headways. But in general, long term planning should use design criteria that have some security margin for the occasional traffic fluctuations and small operational disturbances that will always be part of the daily operations of urban transport.

When the optimal level of service has been reached in the main transport corridors of the city region, one should look for the possibility of moving services to corridors of secondary importance that can make better use of the operational resources by increasing frequencies up to the optimum level.

To deal with the congestion problems in city centres, it is common to spread out the location of bus- and tram-stops. But this makes the system more complicated to use. The central interchanges, which have the best service level in terms of destinations and frequencies, become the worst places for the transfer of lines as far as walking distances, orientation, traffic and safety conflicts, etc. is concerned. Cities try to make heavy investments in their central interchanges, but very seldom manage to fully overcome the problems of lack of physical space to incorporate the complex mixture of too many lines and vehicles and people at the same time. In many cities and regions, a more attractive and efficient alternative would be to create a larger number of moderately sized interchange points.

5.4.3 Three classes of service level

As a tool in the planning and design of the simple and easy-to-use public travel network, one might divide services into three different classes in relation to service frequency:

1. Forget the timetable.

2. Fixed minute timetable.

3. Service on demand only.

It seems possible to identify some sort of a threshold between ‘forget the timetable’ and a ‘fixed-minute timetable’. In a study of changes in a London bus service from 20-minute headway with large buses to 10-minute headway with minibuses, the effect on travel behaviour was analysed. In the first case, most customers planned their journey departure time, while in the latter most of them arrived at the bus stops independently of the timetable (White et. al. 1992). Further evidence from different cities and regions, and at various changes of service levels, would be useful in finding the right service level to aim at. The above mentioned ‘optimal’ frequency level of some 6-12 departures per hour is a reasonable starting point for the definition of service level 1.

We also have some evidence to suggest that the border between service level 2 and 3 should be at one departure per hour. In Norway, there are some very positive experiences from introducing fixed hourly bus services in rural districts and small towns. In some areas with low density development and little existing demand for public transport, the provision of a fixed-minute, hourly bus service was able to generate sufficient new traffic to support a service level well above conventional expectations, both in local small town traffic and in the regional express bus market. Obviously, this effect is associated with the system simplification of the all day, fixed-minute scheduling.

The fixed minute timetable is also a very common feature of regional and intercity train services, which fits well into the specification for service level 2, between one and 6-12 departures per hour.

The three service levels have different challenges in the daily operations. At service level 1, it is important to operate with equal intervals in order to avoid overcrowding, delays and convoy formation. For such lines one should introduce a strict traffic control system to secure even intervals between buses, both at bus stops and at crossings with other street traffic. This will also help to smooth out traffic flow in congested streets. A separate right-of-way will very often be justified, on rail or on rubber wheels.

At service level 2 the challenge is to keep running on the fixed timetable, which may require separate bus lanes and/or priority signalling at junctions. At service level 3 travel demand is too weak, and the public subsidy too small, to justify fixed services with large or small buses. A more flexible, demand-responsive, operation will often be the most cost-effective type of service. More research and practical tests are needed to establish the various conditions and reasons for preferring such services instead of a fixed service with more than one hour between departures.

Long distance services are a different matter, not dealt with here.

5.4.4 Concentration and coordination of resources

In order to succeed in the market competition with the motorcar, much of the public transport resources must be directed towards the main transport corridors. The concentration of resources to high quality routes is necessary to create an efficient and competitive line system for the majority of public transport users, even if this in many cases will result in longer walking distances for some customers. As far as possible, these trunk routes should be served according to the ‘one section–one line’ principle as argued by Nielsen, Lange et al. (2005), and most clearly demonstrated in traditional metro networks and in modern tram and BRT systems in French cities like Grenoble, Nantes and Rouen.

The principle of making as few lines as possible has already been mentioned. By avoiding short lines, customers will get more opportunities for direct journeys, and the system’s time losses will be reduced. The removal of parallel services and pendulum lines through city centres and other local centres and interchanges will normally significantly improve the network attractiveness and efficiency.

Sometimes one can achieve more by moving given operational resources from a corridor carrying heavy traffic to a different area or section with potential for more traffic. The classic situation is the suburban corridor where buses run parallel to a rail service with potential for improvements. Then sufficient capacity may be provided through the use of longer trains or increased frequency on the rail service, and the buses might instead do a better job in the network by providing improved local and feeder services in the suburbs. Although this increases the need for transfers between bus and rail, it will improve the attractiveness of the whole network. Analysis of travel distances, speeds of the two modes, the urban structure and local travel market, will help decisions on the choice of solutions.

In most cases, separation of bus and tram should be preferred. This will concentrate the passenger demand along a route on one mode only, which can be run on a higher frequency. The tram infrastructure can be more intensively used. Separating buses and trams also simplifies technical solutions in the street and at stops, particularly when platform heights, or vehicle widths, are different. Trams can also more easily be incorporated into pedestrian zones when they are separated from buses and cars. On streets and roads with mixed traffic often bus and tram stops will have to be located differently. Then, passengers in the corridor will have difficulty in making use of the combined high frequency of buses and trams.

5.4.5 Trunk lines and routes

Efficient use of the different properties of alternative transport modes is essential. In recent years, many cities have upgraded the quality of their public transport system by the development of high quality trunk lines or high quality corridors. The idea is to combine several types of improvements to one or more major bus (or light rail) lines or corridors in the city region. Usually many of the following measures are used in combination:

- A simple and clear line structure, reducing to a minimum the number of line variants and deviations in routes and timetables.
- Fast and direct priority routes, with simple timetables and reliable operations.
- High frequency services over most of the day, week and year.
- Highly profiled lines through the design of vehicles and stopping places, information and signs; and simple network maps.
- Real time timetable information to the passengers at waiting places and on board vehicles.
- Ample capacity and passenger comfort in low floor vehicles.
- Simple ticketing systems that reduce stopping times and passenger hassle to a minimum.
- High quality design of stopping places and interchanges for efficient service operations, passenger comfort and enrichment of the urban environment.
- Low levels of noise and air pollution emissions.

The high frequency service is an important aspect of the concepts of trunk lines and quality corridors. For modern light rail systems, the idea of the high quality line or corridor is self-evident. However the same principles are also being introduced in cities that want to upgrade their bus systems significantly, through the creation of high quality bus corridors or separate bus ways. The latter may even include various forms of guided bus systems.

5.5 Speeding up the system

5.5.1 Speed is the key to efficient operation and attractive service

The operational travel speed of the vehicle is a key factor in all public transport operations. The speed of travel affects the system's attractiveness, demand and income from the fares. But it also affects the turnover of vehicles and drivers, the number of vehicles needed to provide a given frequency, and the costs of operations. Therefore, it should be evident that every possible effort should be made to speed up the operations. In principle, only the need to stop for the picking up and setting down of passengers should be allowed to slow down the speed of travel.

The task of speeding up public transport operations must be shared by several parties, and the divided responsibilities often form a major obstacle to successful high quality public transport. To bring out the full potential, all of the following measures should be attempted:

1. Priority treatment of buses and trams through traffic management measures, including significant changes in the use of existing road space.

2. Priority systems at traffic signals.

3. Strict controls of priority lanes and signals.

4. Ticketing systems that minimise the time needed for boarding passengers at stops.

5. Optimise the location and distance between stops, and the access roads near the stops.

6. Appropriate differentiations of local and regional public transport services to speed up travel time for the longer journeys by express bus or rail.

7. Design of vehicles that minimise the time needed at stops, by low floor, wide doors (several if possible) and suitable interior layout, which also contribute to passenger comfort and accessibility for handicapped and elderly persons, people with prams, etc.

8. Platforms at stops fit for the type of vehicles in use, fixed places for entering and disembarking passengers and clear information that contribute to short stopping times, including straight stops without the sideway movements – and delays due to passing car traffic – of conventional designs.

Numerous practical examples of these measures can be found in European cities and elsewhere. Traffic management which reduces capacity and speed for car traffic might be controversial, but is efficient if the objective is to change modal split since this will make buses or trams more competitive against private cars. The best examples are those which are guided by a strong political and professional ambition to develop a high quality, reliable, punctual and efficient public transport service, even when this implies a reduced role and priority to car use. In some cities, for instance Karlsruhe and Freiburg, considerations of congestion and environment have been decisive in the design of public transport networks with virtually no regular buses running through the city centre. Obviously, these decisions are linked to the cities' choice of making their tram system the backbone of their public travel network.

5.5.2 Attainable speed

By the use of formulas from basic science, it is easy to calculate attainable speed as a quality goal and reference for the situation in any public transport system. Other things being equal and without external disturbances, the speed of travel is a function of the distance between stops, the time used for boarding and disembarking, the maximum speed of operation on the line, and the rate of acceleration and deceleration at stops. The latter will be decided with particular regard to passenger safety and comfort inside vehicles. With the aforementioned factors in mind, the following general comments can be made (Nielsen. Lange et al. 2005).

For regional traffic on separate rail tracks a commercial speed of some 65–70 km/h is attainable if the average distance between stops is some 2.0–2.5 km. But if the distance between stops is reduced to some 800–1000 meters, the average speed will drop to 40 km/h, with little need for trains or light rail vehicles that travel faster than 100 km/h.

For express buses in regional traffic (as opposed to long-distance buses) on urban motorways the practical maximum speed can be set at 80 km/h. In order to serve some important local centres and interchange points in the corridor towards the inner city, the average operational speed easily drops to 52–58 km/h, even if the buses have full priority over cars in the road system. Often such lines also have sections for local collection and distribution of passengers at one or both ends, which may bring the average speed along the whole line down to 50 km/h before any delays from traffic congestion are included.

In urban traffic with a maximum speed of 50 km/h, an average distance between stops of 600–1 200 meters will result in a commercial speed of some 36–31 km/h, if there are no delays due to traffic congestion or other causes. Stopping distances of 550 meters or below mean that the average operational speed can never be above 30 km/h, even if all other sources of speed reductions are removed.

In central city shopping streets and local residential roads, both a maximum speed of 30 km/h and shorter intervals between stops may be applicable. On these parts of the line the attainable operational speed may be reduced to 19–20 km/h without significant delays due to traffic lights, passenger congestion, etc.

From such facts, one might define a set of indicators for benchmarking the operational speed of a specific public transport service. In practical operations, cities and public transport operators will normally have difficulties in reaching the average speed levels mentioned here. It is important that planners analyse the reasons for the gap between the theoretically attainable and actual operational speeds of different lines and modes, locate the problems, and start working on those speed improvement measures that can be realised in the local operating environment.

5.5.3 Optimal distances between stops

Optimising the distances between stops, and between lines, in an urban setting is a far more complex business than the definition of attainable speed. Decisions on these factors of network design can be supported by mathematical modelling and optimisation with different user preferences and travel distances as important variables, in addition to data that describe the actual structure of the region in question. Here are only a few comments on this topic, based on some simple examples.

Five minutes of normal walking may be considered a useful measure of an acceptable maximum walking distance to public transport stops in a typical area of a medium sized city. This is the equivalent of a 400 metre circle around the stops, with no barriers in the catchment area. If the urban area to be served is continuously built up, the whole area would be satisfactorily covered if we have a public transport network with some 800 metres between the lines and some 600 metres between stops. The average walking distance would in this case be approximately 300 metres, corresponding to 3 minutes of normal walking.

However, there is a complex relationship between the distance of the total journey, the walking distance, and the distance between stops that affects the speed of the journey on the public transport vehicle. Obviously, the walking distance is more important on short journeys than on longer ones.

For a 4 km long journey in a continuously developed 800 metre wide urban development area, the minimum average time for walking and riding will be achieved if the distance between stops is 700 metres. If the journey is 8 km long, the minimum travel time will demand a stopping distance of 900 metres. But, usually, passengers experience the time spent walking as a greater burden than the time spent riding in the public transport vehicle. If the walking time is valued as high as three times the in-vehicle time, the optimum distance between stops would be 500 metres for the 4 km long journey, and 650 metres for the 8 km journey (PLANK 1981).

When developing the public transport network, it seems sensible to give some priority to the competition between the car and public transport, rather than competing with walking and cycling. One must also make allowance for the fact that operational costs go down when the commercial speed increases, so that increased speed can 'buy' higher frequency. Both factors are clear arguments for greater spacing of stopping places than the initial basic figure of some 600 meters. Most cities and regions operate today their local public transport systems with much shorter distances between stops, through the use of traditional rules-of-thumb. European cities seem to practice longer distances (hence faster operations) than American and Australian, and they have in general a higher market share for public transport. Still, studies like the one mentioned here indicate a further potential for improvements. In most cities and regions, faster travel by public transport can be provided at lower cost of operation if a significant number of stops can be relocated or closed down.

In the real world, urban development is not homogenous. Open, undeveloped areas are found inside city boundaries, and some areas are more densely developed. The road system, topography and other barriers also affect the location and spacing of public transport stops. By adjusting locations for a best possible coverage of travel destinations and origins in the city, the average distance between stops will be somewhat longer than the theoretically optimum for the homogenous city.

The possibility of developing several different types of public transport services complicates the matter further. The optimum stopping pattern depends on the length of the total journey from origin to destination. Therefore the public transport network is made up of a combination of local city lines and suburban and regional lines with much longer distances between stops.

The choice between a high frequency local service and a faster, but lower frequency regional and suburban service will depend on the local situation. A comparison of total journey times for the theoretically attainable commercial speeds estimated above indicates that a local high frequency service that operates at some 30 km/h will be preferred for journeys of a distance up to 10–15 km in the central parts of an urban region. The national travel survey of Norway indicates that more than 60 percent of car journeys, and some 25 percent of car mileages, are so short (Strand, Nielsen et al., 2009).

Unless demand is so strong that both local and regional services can be operated with high frequencies, it is important to coordinate the timetables for local and regional lines in the same corridor, so that local lines can serve as feeders and distributors for the regional services.

5.5.3 Beware of the 'satisfy everybody' pitfall

Many existing public transport networks are marked by the common pitfall of designing public transport for short walking distances. The consequences of this idea have a strong negative impact on the system's ability to offer a high quality service that might attract car users.

Planning public transport services for very short walking distance often result in many inefficient lines with low service frequencies, and a network that is difficult to promote and inform about. Such systems operate at slow travel speed, due to many stops as described above. Often they also have inefficient route alignment, resulting in long and uncomfortable travel times for non-local journeys, slow speeds and increased mileage and costs of operations, and extra challenges for customer orientation and marketing.

The usual argument expressed in favour of such solutions is to take care of elderly and handicapped persons, often in situations where car-oriented road systems and land use plans have not been designed for efficient and sustainable transport. But the objective of accessibility for all citizens can be better served by the two-tier network strategy advocated in this paper, offering a combination of local demand responsive services for those in special need due to reduced walking abilities, and a major net of lines and infrastructure designed for universal accessibility.

5.5.4 Simple and easy for all is also efficient

The apparent conflict between the objectives of car competition and access for all citizens is much smaller than what is often implied in the design and operations of existing public transport services.

A faster and more structured network, with marginally longer walking distances, is more efficient than traditional solutions, so there will be more resources available for the demand responsive local services and the upgrading of access to the system. Further, platforms, low floor vehicles, wide doors and information to reduce stopping time, will also make the system more user-friendly, even for people with reduced abilities. And all parts of the public transport network will be open for all users, without discrimination of certain groups.

If the physically fit will not accept the slower speed of travel on local demand-responsive services that cater for elderly and handicapped persons, they can walk or go by bicycle to the faster and more efficient trunk line services. And this would improve their fitness and reduce society’s cost of health care.

5.6. Quality access for sustainable transport

5.6.1 Develop a quality access strategy

The appropriate alternative to the short walking distance principle is the development of a quality access strategy. This implies that all sustainable access modes must be improved in many parts of cities and regions.

Walking and cycling must become much more attractive, both as access modes to public transport, and as separate modes for the benefit of reduced motor transport (even fewer very short public transport journeys), personal and public health, less environment disturbance and reduced energy use for transport. The public transport feeder systems must become more attractive, and access to public transport by private car should be improved where more sustainable solutions are not available.

The quality strategy will be easier to implement if transport and land use is made to uncouple the car-dependency of most modern regions, through more sustainable land use and transport solutions which should include many more, and bigger, car free zones – not car-based traffic system designs that still dominate most detailed planning advice and guides.

It might be useful to remember that a sustainable transport system is like a tree – without twigs and leaves, the trunk will dry out and the tree will die. Without the appropriate access system, the local public transport system will receive only a small share of the motorised travel demand, and this will affect the patronage of the regional and national public transport network. Journeys to be found on national trains or regional buses start and finish at houses along local streets and roads, and the chain is no stronger than the weakest link.

So, making walking attractive and efficient is a key factor even for the development of the public transport network. The effect of walking distance on patronage and modal split has been studied in many cases, while the importance of the quality of walking routes and their environment has not been quantified to the same extent. In the Oslo region, a stated preference study found that the average potential and actual public transport customer valuated walking time on a similar level as the time spent waiting at the stops (Nossum, 2003). This means that in situations where the total of walking and waiting time (half interval) is constant, users will prefer the alternative with the highest frequency, and not the alternative with the shortest walking time. This confirms the observation from other research, that people walk longer distances to more frequent services. A full review of this field of research concerning the valuation of walking in different situations and environments would be very useful for public transport planning.

Short walking distances to the stops can to some extent be achieved by locating the stops at the right places near important travel destinations. Improved conditions for walking can also be achieved by making the pedestrian routes accessible, safe and comfortable, protecting them from excessive noise, dust and air pollution, and leading the walking routes through interesting urban streets or beautiful parks, green corridors or natural environments. The more attractive the route, the longer distances people are willing to walk.

The requirement that even handicapped persons should be able to use the public transport system cannot be satisfied only by improving stopping places and vehicle access. Also the access roads to the stops and on-the-road information must be without barriers and obstacles to wheel chairs, prams, those with reduced walking ability and impaired sight. The objective of universal accessibility means that the details of the road system are important, including all-year maintenance of the pedestrian network.

For those with travel destinations more than a few hundred meters away from the bus or rail stops, the use of a bicycle will cut down the total travel time, without the space and traffic challenges of cars close to stations and stops. The speed of travel by bicycle is 3–4 times that of walking. This means that, within the same access time to a rail or bus stop, the land area covered can be in the order of 10 times greater for a cyclist compared to a pedestrian. Comfortable and attractive routes for cycling to, and from, public transport stops will stretch out the catchment area of the system and make the bike-and-rail and bike-and-bus combinations more attractive as an alternative to the motorcar.

Safe and easy parking of bicycles at railway stations has been seen to stimulate the use of bike-and-rail. Many cities and countries are building bicycle service facilities also at light rail and major bus stops. To increase the use of bicycle infrastructure, they are also promoting bicycle use. This includes city bicycles and marketing activities to support more sustainable travel choices by citizens and organisations.

For citizens who cannot, or do not want to, walk or cycle to get to the main public transport system, the main alternative should, as far as possible, be the local demand responsive services, including ordinary commercial taxi transport. In rural districts, and at the outskirts of urban areas, ‘park and ride’ and ‘kiss and ride’ will often be the most attractive alternative for travellers.

5.6.2 Dismantling car dependency

The quality access strategy should be seen in the light of the type of total transport system we want to have in the sustainable society of the future. If the goal is to reduce, or even dismantle, existing or developing car dependence of a city or region, a few more radical design concepts will probably be needed. Economic and administrative measures to support such a turnaround are not likely to be the only answer to this challenge.

As far as the physical design of the urban transport system is concerned, it is clear that short walking distance *to the car* is one of the strongest aspects that support the car-based society. Existing planning regulations and practices often require developers to include large volumes of car parking in the buildings or on private lots, and planning authorities often find it appropriate to design and locate parking places much closer to travel destinations than what is considered necessary for the location of public transport stops. This normal practice gives the car user a large advantage over the public transport user in terms of total travel time, effort, access and incentive to travel.

The key to a substantial change of modal split is therefore to increase the distance between car parks and garages and the buildings and premises they serve. This would have a double or triple effect on the competition between car use and the other modes. First, car use would become less attractive, and a number of short trips and car journeys of minor importance for the user will disappear or be replaced by walking or cycling. Other journeys will be moved to public transport. Second, the concentration of car parking at the edge of housing estates, institutional areas, shopping areas, parks and so on, will reduce car traffic in local streets, and more or less car-free environmental areas can be developed. This will give more road space for high quality public transport, walking and cycling. Third, these improvements of operating conditions and quality, and the growth in patronage and income from passengers, will strengthen the economy of the public transport system, which in the next turn can be used to further improve the services.

Through these simple mechanisms, the whole transport system can come into a positive feed-back circle in the process towards greater sustainability. This will stimulate urban life styles that are independent of car use, and then indirectly affect long term urban development and location decisions.

Outside cities, in their suburbs and out into the rural districts, the location and use of car parks cannot be controlled in the same way. When direct access to the public transport system is not available or attractive enough, going by car is a well established access mode to and from rail and bus stops, and takes two basic forms.

Park and ride is the usual term for journeys where the car driver and accompanying car passengers use public transport for at least one stage of the journey. The solution requires car parking places near the rail or bus stop. It is most successful in the market when a fast, frequent and high quality public transport service is combined with parking regulations and fees at the other end of the journey, normally in the city centre. Good access from the road system to the parking places is also desirable. Often the park and ride facilities outside the city are provided free of charge to the public transport user (included in the ticket). But at stops in densely developed areas and more central locations, the cost of land, and multilevel car parking, will make this a less interesting option. A more cost-effective alternative may then instead be to use the area occupied by car parking to build more houses and concentrate transport-intensive functions near the stations.

Kiss and ride is the less used expression, where the public transport passenger is collected and/or brought by a car driver in the family or some other person. This alternative does not have the same large demand for parking space as park and ride, but generates approximately twice as many car trips per transferring public transport passenger as park and ride.

In addition to the use of parking location as an instrument for a more sustainable transport system, one can also re-arrange the use of existing main road capacities in urban areas. On a limited scale, this has been done in many cities around the world.

A particularly impressive example of this strategy has been implemented in Nantes. There, one of the main arteries has been redesigned by converting two of four lanes into a high quality busway in the middle of the formerly heavily trafficked road leading into the inner city. This new BRT line, with separate bus lanes and stops, is built and operated with the same quality standards as the city's modern tram lines, and has achieved a similar level of demand in its catchment area as the trams. At the same time, the capacity for car traffic has been halved, so in peak-hours car users have a choice between slow car traffic or fast and cheaper public transport for journeys between the suburbs and the inner city. The modal split has changed significantly in favour of going by BRT, and the park and ride sites at the outer end of the BRT line are much used. The new BRT line has also induced a rationalisation of the old bus lines in that part of the city. The new use of the old main artery for cars now can carry many more persons to the inner city than the former car-prioritised solution. So this type of transport policy can contribute to the vitalisation of inner cities.

5.6.3 Integrated land use and transport planning

To be fully successful, public transport development and network planning must be integrated with regional and local land use planning. This is a big topic by itself, so here are only a few comments on some aspects which are strongly connected to the design of the public transport network.

In addition to the commercial speed discussed above, the route alignment is of crucial importance for successful public transport operations. It affects strongly the attractiveness of the service, public transport demand, and income from fares, as well as the costs of operation.

Within a single urban district the costs and running times can vary by a factor of up to 400–500 percent for different land use layouts and road systems. In practice, this will make the difference between local success and complete failure to serve the area by public transport. The importance of this aspect of urban and transport planning is not always understood, and this is probably an important explanation for some of the decline in public transport market share in the last decades.

The public transport lines should, as far as possible, follow the natural directions of travel in the area they are serving. This will give most of the passengers a direct and attractive route to their destinations for both short and long journeys, many without any need for transfers. This will also make the lines easy to understand and remember, and information and marketing simpler. If for some reason the main direction of the line must be changed, it is best to do that at points where many people get on and off, such as an interchange or in the city centre.

At the more detailed district level, the route alignment should be carefully designed. The alignment of the route through residential and industrial districts, through road junctions and roundabouts, local centres, interchange points and stopping places and on and off major roads and local streets – all are decisive in determining the costs of serving an urban district.

In districts where the land use plan and road system has been designed without taking proper care of the requirements of the public transport system, the planner should look for possible improvements in route alignment and efficiency, such as short busways, bus ramps, bridges or new underpasses. Many such infrastructure projects can be very profitable if they allow significant improvements in service level and/or reduced operating costs.

Still, many existing urban planning guides contain advice developed to deal with the challenges of the car-based society and traffic systems. It is essential that these planning ideas are revised to deal better with the challenges of the future sustainable society. This implies that public transport should become the backbone of development and land use, and walking and cycling the most important modes for access and local travel.

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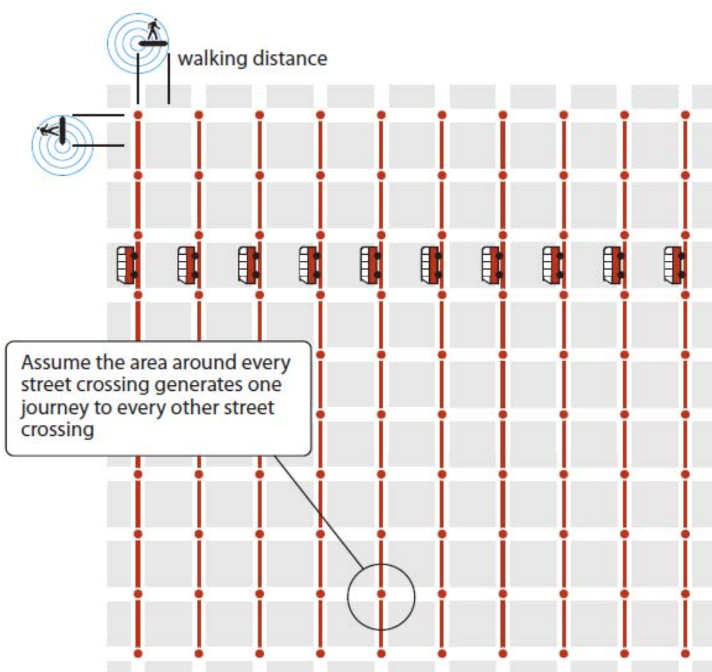
APPENDIX

'Squaresville' – the ideal network case

How the network effect might significantly influence travel demand, is probably best understood through Mees' (2000) theoretical example of 'Squaresville'. Text and figures adapted by Nielsen, Lange et al. (2005, p.86).

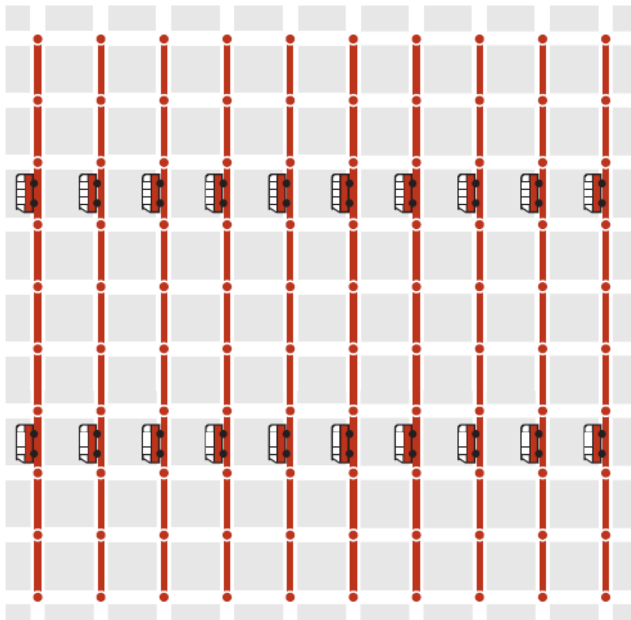
As shown in figure A1, the hypothetical city of 'Squaresville' has a grid-iron street pattern. The streets are well suited for a bus service since they are 800 meters apart. Squaresville is a homogeneous city with a travel demand that is entirely dispersed. Assume that the area around each of the city's street crossings generates one journey to every other street crossing; 9 900 trips per day in total. For the whole of Squaresville, the ten bus lines can only serve 900 trips in the city, which is less than 10 percent of the total trips of 9 900. Assume that the public transport service presently attracts one-third of the journeys it can theoretically serve. This gives 300 trips per day by public transport, which is a modal share across the whole city of only 3 percent.

Figure A1. **Squaresville with ten bus lines running north–south.**



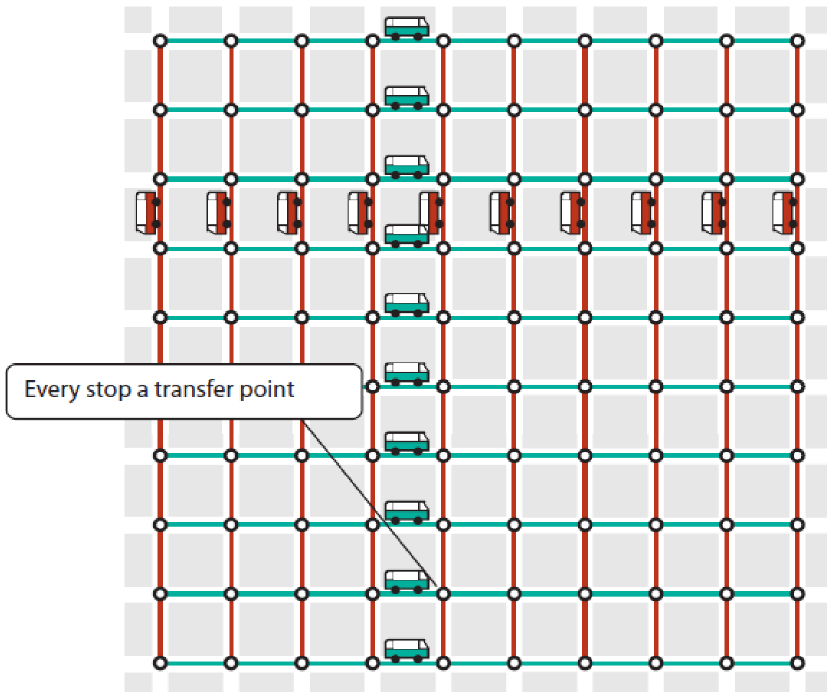
Imagine that services on the existing bus lines are doubled in order to induce more people in Squaresville to use public transport, figure A2. According to traditional transport demand modelling the elasticity of demand might be assumed to be some 0.5. This means that a 100 percent increase in service will produce a 50 percent increase in demand. The result will be 450 public transport trips per day and a modal share of 4.5 percent. Since the operational costs are likely to increase by more than 50 percent, the cost-recovery through fares is likely to fall.

Figure A2. **Squaresville with ten bus lines running north–south double frequencies on all lines.**



Imagine that the extra operating resources instead were used to run ten new bus lines in the east-west direction, as shown in figure A3. This would create a grid network of twenty lines. The number of trips that are directly served would double to 1 800; the 900 initial north-south journeys and the 900 new east-west journeys that can be made without transferring between lines. But if passengers are willing to transfer (we will later return to this condition), then all 9 900 trips between all blocks can be served by this network; 1 800 directly and 8 100 by transferring. Assume that the modal share for journeys involving a transfer is half of that for direct journeys, i.e. one-sixth of these trips that can be attracted to public transport. This gives a total number of 1 950 public transport trips per day (1 800/3 + 8 100/6). The modal share has increased dramatically from 3 to 20 percent.

Figure A3. **Squaresville with twenty bus lines running north–south and east–west.**



This gives a theoretical elasticity of demand that is 5.5, rather than the traditional figure of 0.5. Increased revenue from the fares should more than cover the extra costs of operation and vehicle occupation would rise. We will by no means claim that this ten-fold increase in demand is a figure to be found in the real world. Nevertheless, it illustrates the significance of the network effect for public transport demand if at least some of the theoretical potential is exploitable in a real situation.

PART III: NEW TECHNOLOGY TO FACILITATE SEAMLESS PUBLIC TRANSPORT OPERATION

6. INFORMATION AND FARE INTEGRATION: MOBILE ALL TRANSIT

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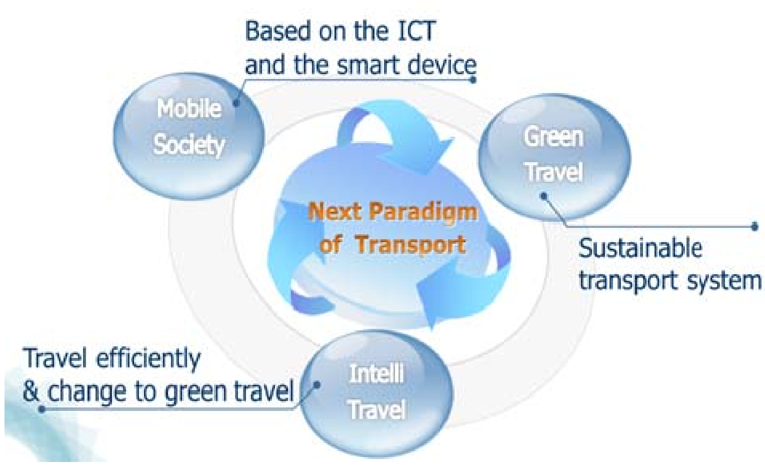
6.1. Introduction

Korea has established the world's highest level of IT infrastructure and has equipped the transportation sector with highly developed IT services and global competencies to develop its status as a powerful integrated transport system (ITS) nation. However, it has not been able to act promptly on the smart IT paradigm that has happened so swiftly over the past couple of years. Thus, concerns have come to light regarding the full skills of Korea's IT industries. In the field of transportation, these include high-speed mobility, information and real-time information based on globally known smart IT, V2V/V2I communication with properties of dynamic networking and Vehicle-IT technology industrialization in which sensor network is fused are being actively processed. The governments of major nations have been preparing for the smart ITS era by making overall changes in their transportation systems in order to prepare for converting to infrastructure based on vehicle-IT cooperative systems. Investment and development for future cooperative ITS systems have been suggested based on such developments as Intelli-Drive from the United States, CVIS and COOPERS from the EU and Smartway of Japan. Our government is now also working on converting the ITS system base into a cooperative system.

Figure 6.1. **The change of transport environment**



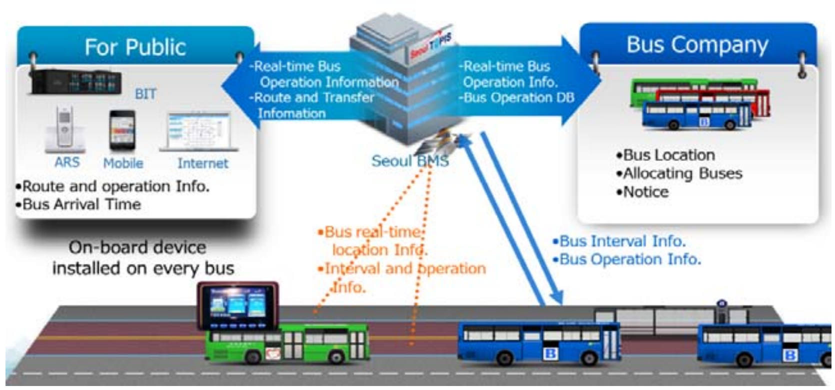
Citizens' expectations and standards have grown due to diverse media influences as well as technological developments, but actual service cannot sufficiently meet those requirements. For example, integrated and transit systems for transportation such as railroads/subways/buses have caused irrationality and inconvenience, resulting in wasted expenses and time. These elements have become part of the reason for the reduction in the share of public transportation use. In the informational society, appropriate data must be provided on public transportation systems depending on individual users' requests and, through such information and service, the selection of the transportation system must be widened. As a result, integrating transportation and ease of organisational operation in municipalities, the provision of a simplified system for citizens is the fundamental objective of the reorganisational efforts. For this reason, new policies that can improve the environment of public transportation and spur the emergence of value added in public transportation information are needed

6.2. Current promotion of public transportation information system

6.2.1 Bus Information System (BIS)

As mentioned earlier, 50 municipalities nationwide have established bus information systems (BIS) in Korea and provided bus information services (city bus information, arrival information in bus stations) in 59 cities. This has resulted in improved punctuality and safety in bus operations. Punctuality in bus arrival times was improved by 35% in Seoul City, and bus accidents decreased by 24% between 2004 and 2005 from 657 to 496 cases. In addition, following the introduction of BIS, complaints regarding delays, failures to respect headways, and buses not stopping at stations drastically decreased in Ulsan city between 2004 and 2006. Metropolitan cities as well as 52 nationwide municipalities (39 transportation sections) now provide bus information services between municipalities. In 2011, plans were introduced to expand BIS to cover wider metropolitan regions (Namyanju~Gapyeong and 5 other sections) and integrate the system in Changwon city.

Figure 6.2. **Bus management system**



6.2.2 Nationwide public transportation information service (TAGO)

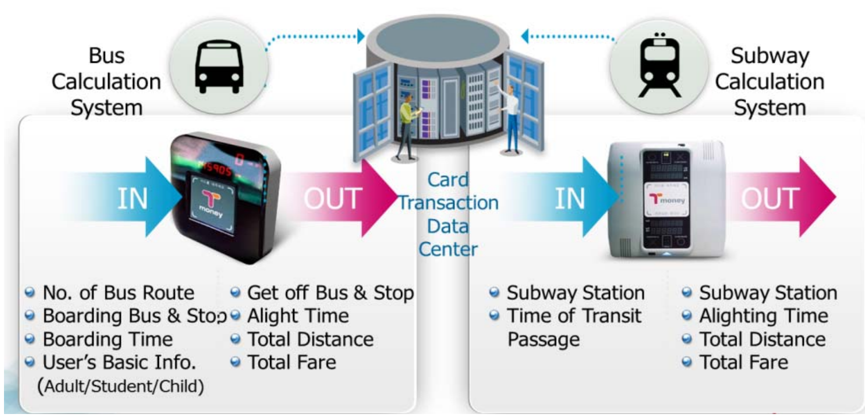
TAGO collects, integrates and combines real–time communication and operation information from different transportation modes (roads, buses, railroads, subways, aviation, ships, etc.). The service also processes the information into various contents, and provides it via the internet, mobile devices, or even through kiosks in order to increase convenience for citizens using public transportation. This project was processed by the Ministry of Land, Transportation, and Maritime Affairs between 2005 and 2011. The major service is provided through the webpage of TAGO (www.tago.gokr) and includes sections such as 'utilising public transportation' and 'utilising city bus'. The 'utilising public transportation' menu features information about fares, journey times, transit information, total distances covered by buses, railroads, aviation and ships, as well as easy-to-view maps of the overall routes. The 'information on each transportation' menu provides details for each transportation mode e.g. city/intercity buses, subways, high-speed buses, KTX and railroads. Other data cover aviation, ships, city tour buses, information about traffic stands, road communication and accidents. This information integrates and updates the BIS system for 40 municipalities and 13 information systems of relevant organizations. Consultation of TAGO has been rising continuously and the number of users increased, for example, from 130 million in 2007 to 340 million in August 2011.

However, from the perspective of providing real-time information, there is no merged information of transit transportation details. Thus, departure times and transit times cannot be checked and integrated reservation functions or payment systems for each transit mode are not available. It has also been difficult to find optimised measures for transit modes or routes through search route algorithms due to the expansion of service range and the increase in usage. Consequently, possible transportation modes, journey times and fares quoted may be different from those actually in operation. For bus routes operated in remote areas or suburbs, fares are frequently changed. Therefore, there are difficulties in implementing regular updates and in the maintenance of public transportation operation management databases.

6.2.3 Present condition of transportation cards

Since the introduction of transportation cards in 1996 in Seoul City, 70 percent of nationwide areas, including 114 out of 165 city buses and railroads in cities and districts, have adopted transportation cards and their usage has exceeded over 90 percent in metropolitan areas. Within each region, 1-4 prepaid transportation cards can be used, but the types of cards used in each region differ. For example, transportation cards used in metropolitan areas cannot be used in Busan and Gyeongnam regions, making it inconvenient for users. Currently, many charging card products with in-built transportation card functions are being issued by credit card companies, thus relieving the inconvenience between different districts. However, travellers who use prepaid transportation cards cannot use their cards in other districts and face the drawback of not being able to receive transit discount benefits. Based on figures from 2009, the usage ratio for each transportation card in metropolitan areas was 48 percent for prepaid transportation cards and 52 percent for charged transportation card for buses. For subways, 43 percent of usage was for prepaid transportation cards and 57 percent for charged transportation cards. Thus, 3.2 billion transactions are occurring daily. In terms of facilities accepting transportation cards in 2010, there were about 10 000 railroads, 20 000 buses and 10 000 taxis. Furthermore, increasing numbers of transportation card terminals are being installed in taxis

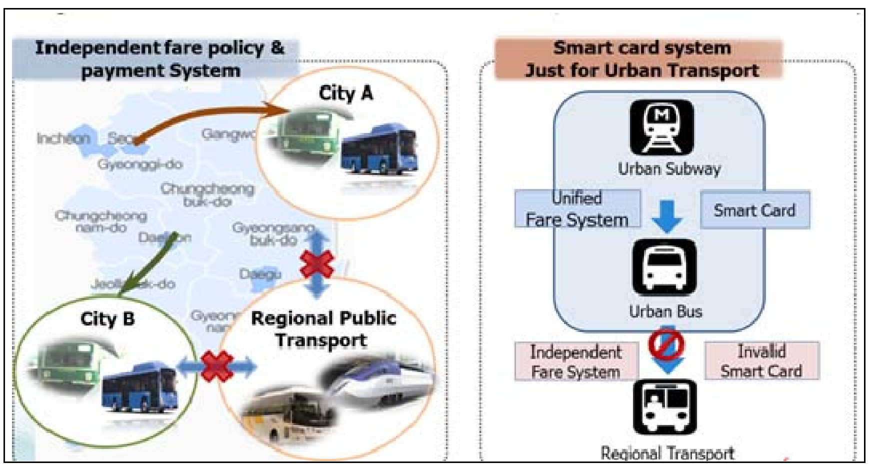
Figure 6.3. **Smart card system**



6.2.4. Limits in the current payment system for public transportation system

Current public transportation and payment systems have so far targeted buses and subways within the city using individual payment systems. In addition, transportation for different regions uses different operation and payment systems for railroads, high-speed buses and intercity buses. The smart card system is aimed at city public transportation such as buses and subways as its payment subjects. Thus, when using these transportation modes, transit discount or free transit benefits can be provided when taking city public transportation such as buses and subways. The public transportation information and payment systems that have been in operation so far have the following limits. First, limits of available transportation measures can be counted. There is a need to expand the range of regional transportation measures from limited card systems covering city public transportation such as buses and subways to regional transportation modes such as railroads and high-speed buses. This is essential in order to boost user convenience. Second, the public transportation information system and environment payment system being operated separately for each city and region can impede the implementation of national payment policies needed to address greater demand for public transportation This can in turn serve as a brake to actively responding to and implementing the requirements of government, operators and users with regard to the payment products for public transportation.

Figure 6.4. **Limitation of current systems**



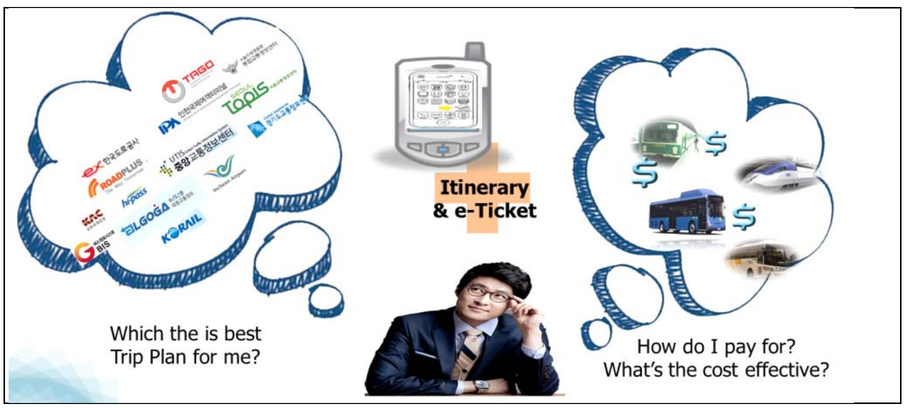
6.3. Nation-wide reformation of the integrated public transformation system for one nation one transport city

The core point of this plan is to reform Smart IT for such as buses, subways, railroads, aircrafts, ships, etc. based on the overall action of the ecology and the information network-platform-terminal-contents that are based on the Hub & Spoke. In order for this to be fulfilled, with nation-wide users as the targets, there must be a physical and logical combination of the regional individual and group-run Bus Information System (BIS). In addition, there must be service expansion through the networks' vehicle interchange points as the centre and linkage node of the service location and foundation. Furthermore, the nation-wide public transformation system and network-based integrated and dispersed information gathering/processing/supplying system's modernisation must be expanded.

In order to reform the national integrated public transformation system, there must be changes within the areas of operational systems, information sharing system, and even the fee paying system. First of all, the operational system section must be reformed from a system in which operational information is managed according to the public transformation levels into a system in which national public transportation information can be operated and managed in real time. By combining the reservation system and payment system – which are managed according to the modes of transportation – users must be able to make reservations and payments via an easy-to-use business system that is suited to purpose. Likewise, if the public transportation modes and facilities are reformed in a Hub & Spoke system, not only will citizens be provided with an environment in which the IT-based smart integrated public information system can be used, but also an innovative public transportation service.

In 2012, in order to increase the competitiveness of public transportation in comparison to cars, the Korea Transport Institute has performed a nationwide public transportation integrated research programme. Work is also being carried out in this study to examine the integration of transportation information and the cost payment system. This is known as "Mobile all Transit", which considers how to integrate into mobile technology the many means of transportation information and cost payment. When using an international airline path, you can use "Mobile all Transit" to pay for two tickets which are from two different airlines at once, and the outcome is very similar to getting an Itinerary & e-Ticket issued. This means that users will be able to depart at the time they wish when travelling long distances, while the waiting time for connecting lights will decrease. It will also enable users to search for affordable public transportation and routes and make the appropriate payments. Once implemented, the mobile product system will bring greater convenience and thus promote user uptake. Although each area or region operates with different transportation modes, users travelling long distances may also receive the benefits of transfer discounts or free transfers in addition to greater payment convenience if the integrated payment system is applied to the national public transportation system. This will inevitably increase competitiveness for long distance travel.

Figure 6.5. **Concept of mobile all transit**



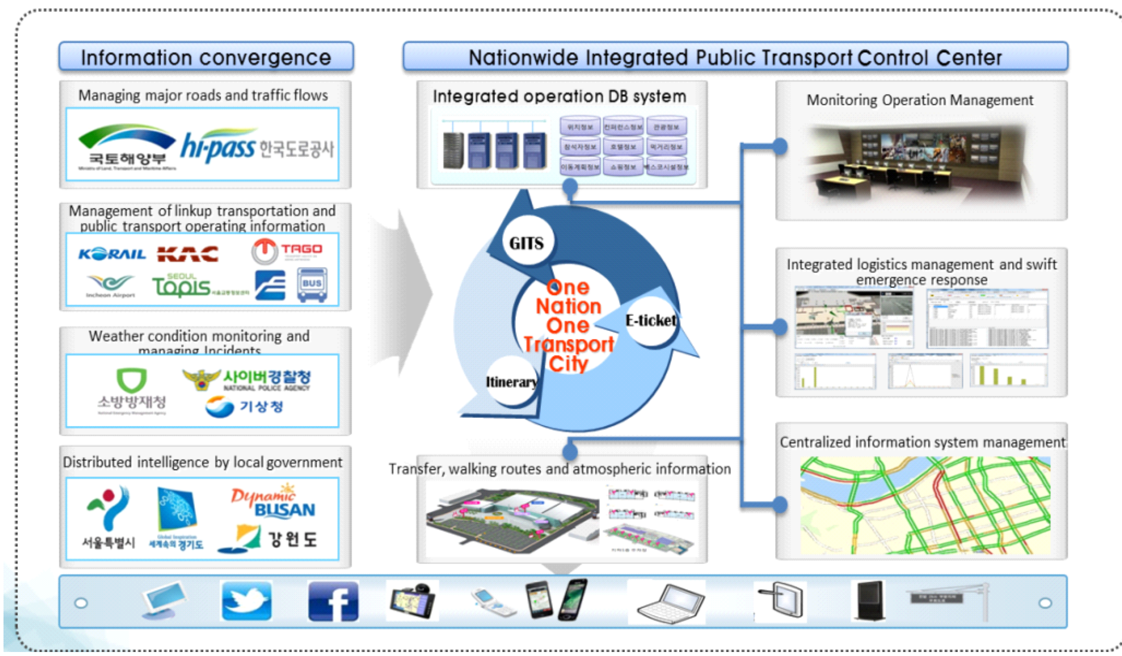
6.4. Future directions of nationwide public transportation integrated information system and payment system

In order to accelerate the deployment of the nationwide public transportation integrated information system, it will be necessary to develop major aspects. These include: an integrated information system of public transportation, the establishment of an operation centre, the mobile-based integration information service of public transportation and content development, as well as the mobile-based public transportation integrated smart card.

First, in order to establish the integrated information system for public transport, nationwide collection of real-time service data is necessary for all public transport modes such as buses, railroads, aviation, and ships as well as para-transit modes including Car-Sharing and Bike Sharing System.

Unique ID is granted to nationwide transportation measures, including vehicles and public transportation facilities. Through the harmonisation of a number of systems with regard to bus stations and fixed facilities, the standard node-link format of nationwide Hub & Spoke public transportation is restructured. The database system for public transportation and maintenance is also structured. The existing public transportation information systems (e.g. TAGO, Garatagi, etc.) and non-integrated measures, such as rural buses and semi-public transportation measures, need to be structured through an integrated information system.

Figure 6.6. **Establishment of national transportation control centre**

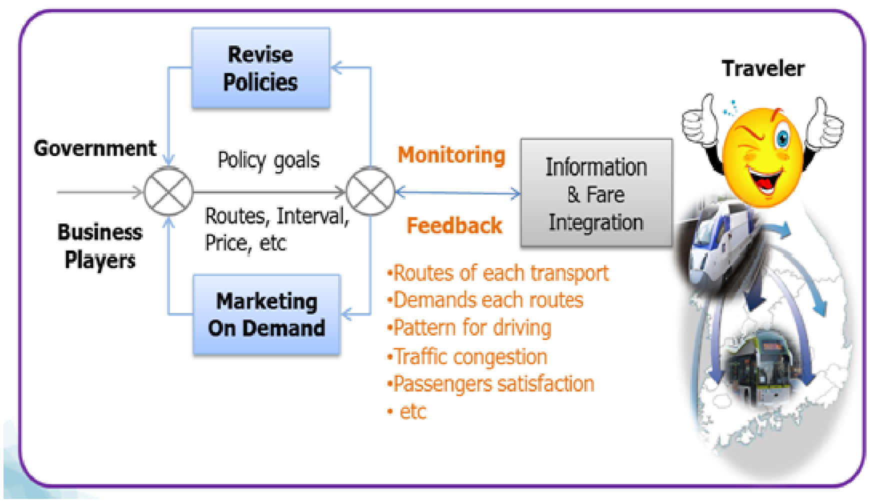


The collected information system will provide diverse public transportation measures and schedules as well as integrated information regarding transit routes that suit users' needs and schedules. In addition, by developing an integrated transit information provision algorithm that applies the itinerary service and e-ticket system currently implemented by airlines and travel agencies, nationwide transportation will be able to incorporate existing public transportation measures.

In order to establish the functions of a nationwide public transportation integrated information centre and ranking, centralised-type and wide-area/regionally dispersed-type are set as rankings to define the functions of the integrated information system. In addition, by establishing the operation plans and integrated information measures of the centre, measures for creating integrated information with other systems and relevant agents should be provided. Furthermore, integration between the information system of nationwide public transportation measures and payment system can enable operating data of transportation measures and demand data of public transportation to be collected. When operational data for transportation modes, boarding data for passengers, and data on income per each route or vehicle are collected, the transportation network can monitor people and transportation movements. As a result, decisions can then be made on reasonable public transportation policies based on the data obtained. Integration between information and payment systems is realistic and can help establish government policy to foster greater efficiency. Moreover, it can provide a monitoring system to allow for the operation of public transportation routes desired by operators. This can ultimately bring greater satisfaction amongst public transportation users, and a sustainable and developing nationwide public transportation operation system will thus be made possible.

Lastly, in order to travel freely nationwide on public transportation, the functions of the new transportation card functions should be expanded beyond those of the existing ones issued by individual operators. For more convenient use, mobile integrated smartcards should be fused with e-ticket and payment functions. The nationwide public transportation integrated information system is targeted for use across the country and implies the inclusion of an integrated fare system. This means that users can be provided with transit discounts for nationwide public transportation. In order to implement this, policies regarding the legal system and safeguards with regard to the preservation of shares in the financial burden should be implemented in order to build an agreement between public transportation operators. In addition, maintenance issues need to be built into the process, while cards processed by the Ministry of Land, Transportation, and Maritime Affairs should be complemented with the necessary technological standards to ensure the implementation of a nationwide public transportation payment system. These measures can help to minimise financial waste and foster improvements in terms of infrastructure and the replacement of cards when necessary.

Figure 6.7. **Nationwide demand management**



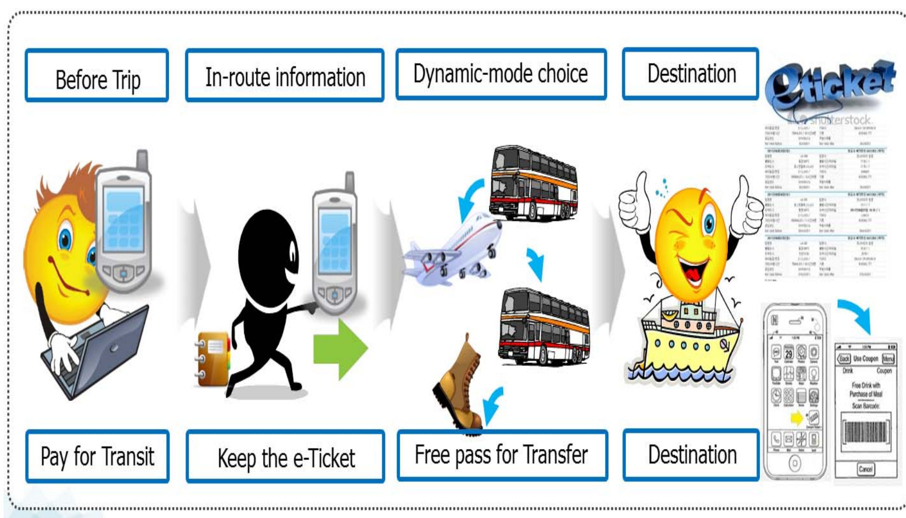
6.5. Future research directions

The transportation information and payment systems mentioned earlier can attain several effects of synergy. First, on the basis of nationwide public transportation demand data, the government can make improvements in the integrated route system and control operations. This ensures that government finances allocated to public transportation can be used effectively. Second, operators can monitor users' needs and demands with a view to actively shaping public transportation projects and optimising management of public transportation routes. Third, users will receive real-time information service updates which will help to avoid any inconvenience with public transportation. And fourth, since affordable fares will be offered, users will be able to travel by public transportation in more convenient terms and conditions. The Korean Transport Institute has planned to provide users with news of the mega-project in 2012 to equip them with the information they need to ensure that they choose public transportation as a more comfortable and convenient option than private vehicles.

Figure 6.8. **Connected travellers and multi-mode in mobile society**

Alongside the integrated public transportation information and payment system, further research is planned to consider issues such as route systems, integrated transit systems, integrated payment systems and administrative integration. Through various technologies which apply smart IT to nationwide public transportation, sustainable and user-friendly public transportation policies can be implemented and smart itinerary and mobile e-tickets be easily issued for use by the public. These smart IT trends aim to bring about significant changes in our lifestyles, just as past industrial revolutions have influenced our society. In addition, it is expected that this technological revolution will raise the general standard of living to new levels.

Figure 6.9. **Mobile all transit: find the most efficient use of public transport**



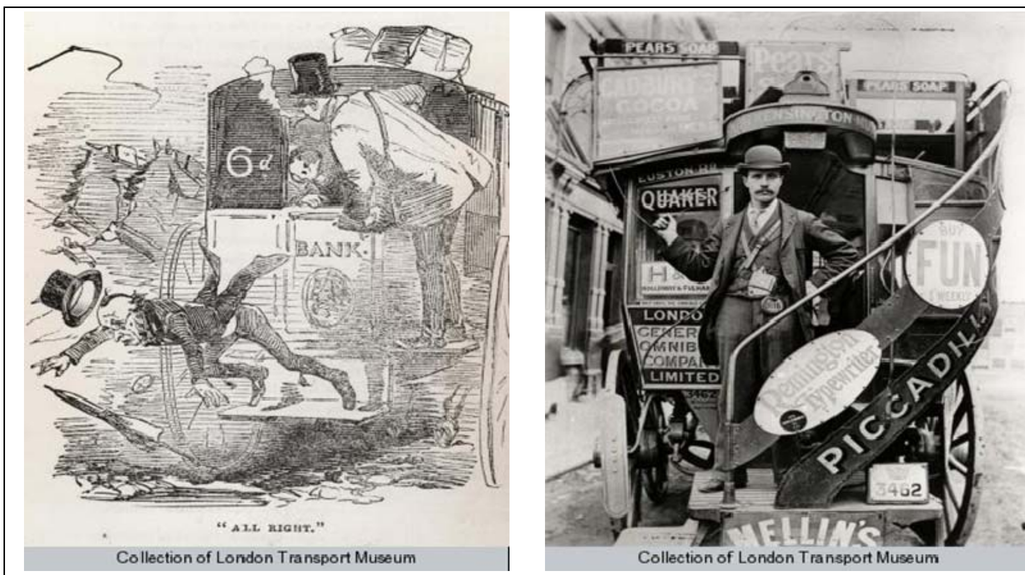
7. THE FUTURE OF THE OYSTER CARD IN LONDON

7.1. A history of ticketing in London

There was no ticketing when buses were first introduced in London. To use the bus service, passengers simply paid fares in cash to a conductor. However, it soon became necessary to introduce other forms of payment or ticketing to prevent potential fraud by conductors. Rich conductors were commonplace in the mid-19th century! The picture on the left in Figure 7.1 below depicts just such a conductor, wearing a top hat and umbrella, being unceremoniously thrown off a coach in 1845. Ticket machines were therefore invented to minimise potential fraud by conductors. The picture on the right in Figure 7.1 below of a conductor carrying a ticket machine in 1895 shows that while the main reason for introducing ticketing was to prevent possible fraud by conductors, it also helped to reduce fare evasion by passengers. This is still an important principle that explains why ticketing is necessary in public transport systems.

The other important principle of ticketing is to speed up process times. Ticketing should not hamper the punctuality of coach and bus movements, and should not take up too much of passengers' precious time either. Modern ticketing technologies, such as the use of automatic ticket dispensing machines and advance ticket purchasing prior to boarding, have been introduced with the aim of reducing both boarding and waiting times.

Figure 7.1. **Coach conductors in 1845 and 1895**



If we look at the more recent past, a unique and innovative ticketing system in London, known as the Travelcard, was first introduced in 1983. This system divided London into six zones, according to their distance from the city centre, and Travelcard holders were allowed unlimited use of the underground system and bus network within designated zones. The introduction of this scheme helped to boost passenger numbers, particularly during off-peak times. In 1989, the use of Travelcards was extended to the national rail network after London Transport reached a revenue-sharing agreement with British Rail. In 1998, London Transport launched the Prestige project aimed at using public-private partnerships to upgrade its ticketing system, although the project was later terminated. Private operators were simply not interested in investing for the future and not flexible enough to accept change.

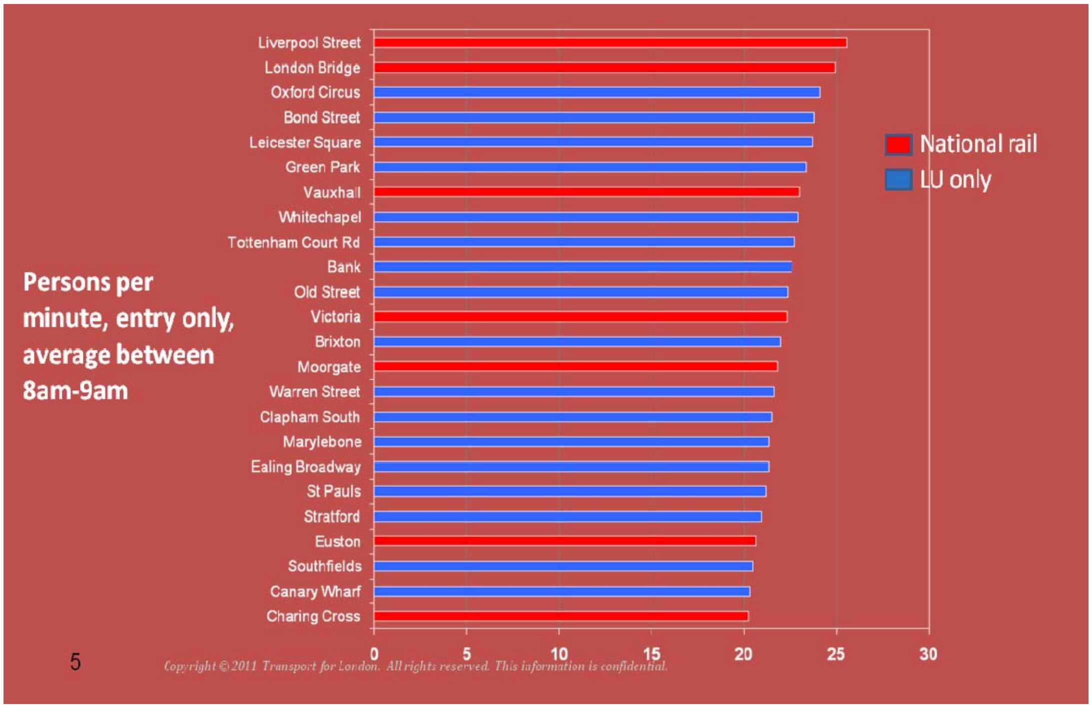
In 2003, the Oyster card, a smartcard for transport in London, was first launched on the market, mainly to increase gate capacity in stations. London Transport saw the Oyster card as a cheaper alternative to expanding stations to meet increasing numbers of passengers. It was not originally intended to reduce the cost of ticketing. In 2004, the Pay-As-You-Go (PAYG) Oyster card was launched, eliminating the need to work out the cheapest fares for given trips. This service caps the cost of a single fare for a given trip to the cost of an equivalent Travelcard trip. Customers simply touch their Oyster card on a reader to gain access to underground trains or buses, and the system ensures that they always pay the minimum fare for their trips. This service increased the number of journeys by 3 to 5 percent in off-peak times, and between 2007 and 2010 was also extended to the national rail network. While it took some time to reach an agreement with the nine different railway operators concerned, the latter quickly found that the new service increased their revenues as more people used rail services during off-peak times and fare evasion was reduced.

7.2. Benefits of the Oyster Card

The Oyster card is a comprehensive multi-operator, multi-mode smart integrated ticketing system. It can be used for travel in the underground trains, buses, national railways, trams, boats, and dockland railways run by various operators in the London area. To date, over 50 million Oyster cards have been issued and used for 83 percent of all trips.

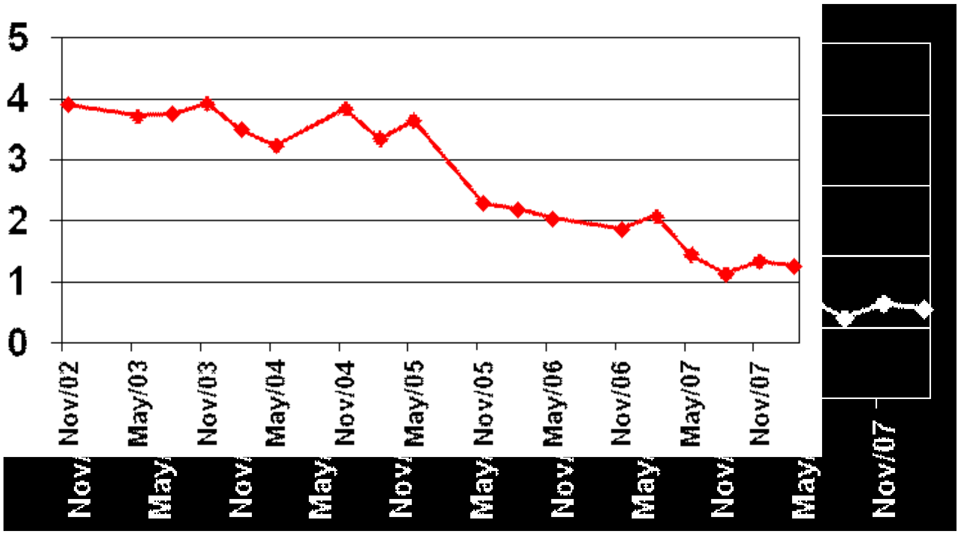
Preferential use of Oyster cards for trips offers a number of advantages to operators. It increases gate throughput rates in stations and reduces boarding times on buses. Figure 7.2 shows the number of passengers passing through ticket gates per minute in a number of busy stations in London. The highest gate throughput was reported at Liverpool Street station with over 25 passengers a minute. This is remarkable, considering that with conventional magnetic stripe tickets gates can only accommodate a maximum of 15 persons a minute.

Figure 7.2. **Increase of gate throughput by the Oyster system**



The introduction of Oyster cards has also dramatically reduced fare evasion. As Figure 7.3 shows, revenue losses on London Underground due to ticket irregularity fell from 4.0 to 1.5 percent between 2002 and 2007, saving around 40 million pounds a year. This is due to the requirement to swipe the Oyster card when alighting at the destination to avoid having to pay the maximum fare. The removal of the threat of counterfeit magnetic stripe tickets by the introduction of the Oyster card has also helped to reduce fraud.

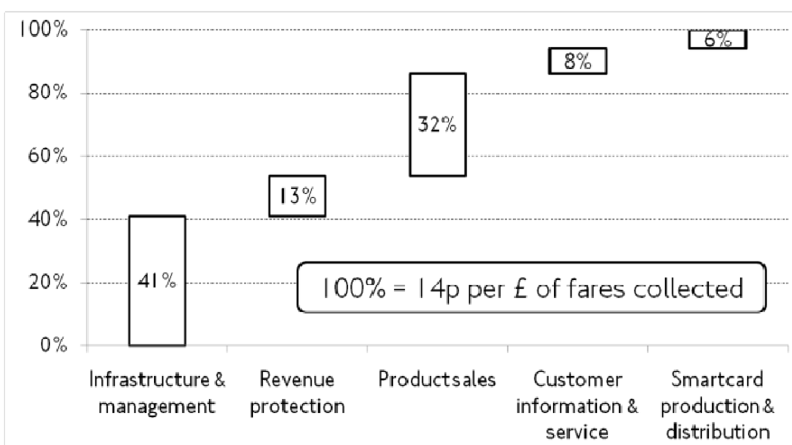
Figure 7.3. **Revenue losses on London Underground due to ticket irregularities (percent)**



7.3. Areas for improvement

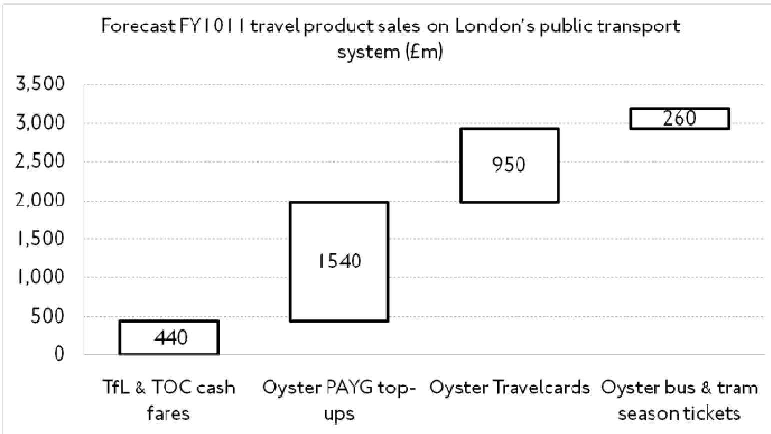
However, the Oyster card system needs to be improved in terms of both the cost of collecting fares and customer satisfaction. It is estimated that around 14p in every pound (GBP) of revenue is spent on collecting fares. This is uncomfortably high for Transport for London (TfL), which has set itself the target of reducing the cost of fare collection to 10p in the pound. According to a study by the Massachusetts Institute of Technology, this would save an estimated 400 million pounds a year. TfL is also eyeing further cost reductions in the areas of sales, customer information, as well as production and distribution. Figure 7.4 shows a breakdown of the cost of fare collection.

Figure 7.4. **Breakdown of the cost of fare collection**



A more convenient service needs to be designed for infrequent travellers. Oyster PAYG users, who are usually people who do not travel on a daily basis, contribute the most in terms of earnings, accounting for about half of total revenues (as shown by Figure 7.5). The number of such non-commuters is likely to rise in the future as typical working hours continue to evolve. Revenues from regular commuters account for merely a third of total income.

Figure 7.5. **Travel product sales on London's public transport system**
(million £)



In particular, the reimbursement of fares as a result of emergency situations needs to be improved. For example, sudden power failures in the London Underground system can result in passengers having to walk through pitch-black tunnels to return to street level, but still having to pay the maximum fare because they are unable to swipe their card on ticket readers when exiting from the station. When such incidents occur passengers are obliged to contact customer service centres in order to get a reimbursement, which is very annoying for passengers and is an area which needs to be improved. This kind of problem arises as a result of current practices with regard to storing data. The amount of money left on an Oyster card is stored on the card and cannot be modified by the central management centre, which means that a refund can only be made when the card is touched onto a reader.

Passengers find Oyster PAYG cards useful because they no longer have to calculate the cheapest fare as the card does it for them automatically. They still need to manage the balance left on their card, however, in order to be able to board trains. Before travelling they must always check that they have enough money on their Oyster card to cover the cost of their trip. The satisfaction levels of Oyster PAYG users would rise significantly if they no longer had to manage the balance on their card. And lastly, Oyster cards only work in the London area. Many visitors to London will be unable to benefit from Oyster cards if they fail to buy them, and are perhaps reluctant to buy them as they are unsure whether they will ever use them again.

7.4. The future for Oyster cards

The future Oyster system will address all these areas for improvement. TfL is transforming the current front-office system into a back-office system based on bank cards. This means that Oyster cards can be incorporated into existing credit and debit cards (as shown in Figure 7.6).

Figure 7.6. **Integration of contactless credit and debit cards into the Oyster system**

In the new TfL transit fare collection model, the readers installed in the ticket gate only check certain information stored on the bank cards swiped. Is the card valid? And is the card on the "deny" list? If the card is valid and is not on the deny list, then travellers are welcome to board trains or buses. The readers do not check whether the card is valid at that particular station at that particular time, or whether the balance on the card is sufficient to pay for a minimum journey, as in the conventional Oyster system. This will reduce transaction times significantly. While the passenger is travelling, the system checks to see whether the card has been stolen or no longer has any credit left on it. If either of these prove to be the case, then the deny list will be updated to include the information for that card. Lastly, at the end of the day, all travel data or swiping records are processed to calculate fares according to the journeys made by card holders. Caps may be considered or even discounts applied, if necessary, at this stage.

This system has a number of advantages over the conventional Oyster system from the standpoint of transport operators. It helps to reduce risk and data management costs. Operators no longer need to update 7 000 lines of fare tables in 22 000 readers checked manually on the spot, but are able update this information more conveniently in the back office at lower cost.

From the passengers' point of view, the system also offers unparalleled ease of use. First of all, passengers no longer need to worry about the balance on their Oyster cards provided that they have a valid credit or debit card. Paying a fare is just like buying any other good with a credit card. People can use the service simply by swiping their card on the reader without having to enter a pin code or sign a receipt. They will pay the bill later once the purchase shows up on their bank statement.

Secondly, refunds can be made without passengers having to visit a customer centre. If, for whatever reason, passengers need a refund, they can have this made directly to their bank account because the TfL operator can check their details in the back office. Even in the event of a power failure in the London Underground system, as described above, passengers can have their fares refunded without having to go to a customer centre. This would be a significant improvement compared to the existing system.

The last (but by no means least) benefit of an account-based ticketing system is the possibility of introducing a global system for ticketing transport services. For example, credit card holders normally resident in Paris would be able to travel on London underground trains or buses without using a ticket machine. They will not necessarily have to spend time transferring money onto an Oyster ticket. They can just turn up at a station and pass through the ticket gate using an account-based bank card to gain access to trains. This kind of integrated ticketing service could be made available worldwide, irrespective of modes and operators, based on bank card protocols. This would be a real innovation for passengers.

7.5. Discussion

Transport for London is planning to introduce a contactless bank card system in the near future. However, there seems to be some concern over this new system and the security of payment transactions, in particular, is a high priority. That said, the security of bank card payments is primarily the responsibility of banks rather than public transport operators, and to date the credit card payment system has not posed any fundamental security issues. There seems to be no reason why paying fares by means of contactless credit card would be any less secure than payments made by other means.

The disclosure of confidential information is also a concern for public authorities. Detailed information on individual journeys can be exploited for commercial purposes, and can also lead to possible breaches of privacy. This needs to be prevented. However, analysing travel and trip data can also help with the development of measures and solutions not only for public transport, but also for the transport system in general. While data relating to individuals needs to be carefully controlled to ensure that data are not exploited for private purposes, the use of such data should be allowed in studies aimed at obtaining collective information for public goods while at the same time ensuring that privacy is protected.

To ensure social inclusion, conventional Oyster cards must continue to be offered even after payment by bank card systems has been introduced. Not all public transport users are entitled to have bank cards, which are only issued to adults with a bank account. In this respect, Oyster cards must continue to be made available to non-bank card holders, including children and low-income groups.

Payments by mobile phone are also increasing, and this trend is likely to accelerate once the use of near field communication (NFC) technology becomes more widespread. This is a particularly useful means of fare payment for public transport users. Non-bank card holders should perhaps be encouraged to use NFC-based mobile phone systems to pay for tickets to allow them to enjoy all the benefits of bank card payments, including contactless payment.

A survey in Seoul, Korea – where contactless credit card payment has been available for use on public transport networks for over five years – revealed that passengers found credit cards to be far more convenient than smartcards for paying fares, because they no longer had to worry about topping up the balance on their smartcards. There were also very few cases reported of security problems with credit card payments for public transport services, or mistakes in fare calculation.

As a general rule, credit cards surely offer public transport users a more satisfactory way of paying fares, as the Seoul survey shows. However, the existing system will still need to be kept in place even when new payment systems, including NFC mobile phone systems, are introduced, and this may add to the financial burden on society.

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ITF-KOTI Joint Seminar

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International Transport Forum

Seamless Public Transport for All

‘Seamlessness’ is a virtue for public transport. It requires integration between routes, schedules, and fares across the different modes providing passenger services. This is never easy as it requires cooperative institutional arrangements, integrated network design and the negotiation of cost and revenue sharing agreements.
This report examines policies to make public transport more seamless on the basis of examples of best practice from Europe and Korea.

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