Key factors of network design for seamless, intra-regional public transport

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Objectives of public transport

Social welfare – accessibility for all

Competitiveness in relation to the car

Special emphasis

Universal design of all elements
Door-to-door services for certain user groups with mobility problems

Convenient, fast and attractive enough to replace car use
Express services for long journeys
Coordination with car restrictions

Common strategies

High quality fixed, scheduled services in an integrated travel network with universal accessibility, information, comfort and safety for all users

High quality access systems for walking, cycling and motorised transport, including demand-responsive services in low demand situations

... within strict requirements of efficiency!!
Replacing journeys by car – by trip length

% of car trips

% of vehicle-km

Cumulative trip length by car

0 - 2 km 2 - 5 km 5 - 10 km 10 - 20 km > 20 km

Source: TØI-report 1002/2009; National Travel Survey, Norway
The solution: A new public travel service for everybody – in the context of a comprehensive policy for sustainable transport and land-use

The FINAL solution: Seamless journey – a challenge of organisation and system design!

Source: www.port.se/final
This presentation

Comments on the most important network design factors
1. Simplicity and ease of use
2. Optimal frequency
3. The network effect and connectivity
4. Speed of travel
5. Quality access strategy

Examples from small and medium sized urban regions in Europe

Appendix with additional points
1. Simplicity and ease of use
The crucial question: Is it attractive, easy and safe to go by public transport?

System simplification is essential!

- Knowledge of the public transport service is crucial for travel choice
- The users are continuously changing
- Occasional users represent a large demand potential
- Many car users believe the service is worse and more expensive than it is
- Every year a lot of people change workplace, home, activity and travel patterns
- Simple and clear PT offer is easier and cheaper to market and operate, and the barriers to use can be significantly reduced

“Less is more” is the key design slogan
Successful product and service design

Branding and user friendliness – the world-wide important key to business success and shareholder values of world leading businesses, e.g.

- Apple’s Iphone, Ipad, etc
- IKEA

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.

This is also the case for public transport services, e.g.

- Oslo Airport Express train
- Norwegian Air Shuttle

User friendly, easy to understand and remember!
Symbol of modernity - A bus is not ‘only a bus’

Photo: Gustav Nielsen

Source: Breithaupt 2006
Showing that society wants us to travel by public transport

Nagoya, Japan

Rouen, France

Source: Breithaupt 2006
The pitfall of ‘tailoring’ services

A dense, normal frequency network most of the day

Express lines in peak periods

Reduced and low frequency network on holidays

Evening and night lines

Service lines for the elderly and disabled

III: Truls Lange, Civitas
The ‘Ready-made’ approach

A basic high frequency network most of the day

Same network, reduced frequencies on holidays

Same network, higher frequencies in peak periods

Same network, reduced frequencies evenings and nights

Local lines and demand-responsive services for all users

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The ‘Ready-made’ approach

A simple framework for travel and locational decisions!

One stable, easy-to-use network for all at all times

Ill: Truls Lange, Civitas
The ‘Make it simple’ approach in Copenhagen

Photo: Gustav Nielsen
The ‘Make it simple’ approach in a small town

Lemgo, Germany
2. Optimal frequency
The importance of service frequency

Numerous studies have shown that a high service frequency (short headway) is a key factor in the market competition with the car.

Conventional approaches to elasticity of demand for public transport services, mainly based on marginal changes in vehiclekm (TRL, 2004):

- Short term; bus services: \( e = 0.38 [+/- 0.14] \)
- Short term; rail services: \( e = 0.75 [+/- 0.13] \)
- Long term; bus services: \( e = 0.66 [+/- 0.28] \)

\( e < 1.0 \) means that it is difficult to finance the frequency improvements that the market wants.
Waiting time as a function of service frequency

Waiting time equal to half of the interval

No network effect

Forget the timetable – network effect

No significant reduction in waiting times

Increasing congestion and environmental problems

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Optimal frequency?

No network effect
Forget the timetable – network effect
No significant reduction in waiting times
Increasing congestion and environmental problems

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Three classes of service level

1 - Forget the timetable

6-12 departures per hour?

2 - Fixed minute timetable & integrated scheduling

1 departure per hour?

3 - Service on demand only
The pitfall of adding new lines vs. the principle of concentration of resources

**Before**
Two low frequency lines that run in the vicinity of each other

**After**
… replaced by one line with doubled frequency.

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Concentration of resources: BRT with similar user quality as light rail

Nantes, France

Photo: Gustav Nielsen
High frequency through the coordination of timetables on common route sections
3. The network effect and connectivity
The network effect depends on frequency

Exploiting the network effect can give a much better market response than conventional demand elasticity indicates!

- Low frequency, weak connections
- High frequency radials, still weak connections
- High frequency network, strong connections

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The network effect: Squareville example

Ten bus-lines running north-south

Serves 900 of 9900 journeys between all districts

Assume 30% of journeys served are made by PT

Result: 300 PT journeys = 3% of all journeys between districts

The network effect: Squareville example

Ten bus-lines running north-south, double frequency

Serves 900 of 9900 journeys between all districts

Assume service demand elasticity = 0.5

Hence: Double frequency will result in 450 PT journeys = 4.5% of all journeys between districts

The network effect: Squareville example

Twenty bus-lines running north-south and east-west

Serves 1800 of 9900 direct journeys between all districts. Assume 30% of these journeys served are made by PT.

+ Assume 15% of journeys with interchange are made by PT.

Result: 1950 PT journeys = 20% of all journeys between districts

Theoretical elasticity of demand = 5.5 !!?
Minimize transfer barriers

Example Australia: Perceived Bus Travel Time

Typical Weighted Bus Travel Time

Transfer Issue

Represents over 30% of total perceived travel time
Evidence shows transfer penalties can vary considerably with quality of the transfer location:

Unprotected Area, Open Air, Uncoordinated Transfer, Low Frequency
32 Minutes

Protected Area, Covered, Coordinated Transfer, High Frequency
4 Minutes

Utility of Transfer Includes:
Walk transfer time (weighted)
Wait transfer time (weighted)
PLUS a fixed transfer penalty

Simple and efficient interchange design to exploit the network + integrated fare & info!

Lund, Sweden

Bad Salzuflen, Germany

Lemgo, Germany
The Zürich model success

- Zürich – PT demand
- Frankfurt – car ownership
- Zürich – car ownership
- Frankfurt – PT demand

Graph showing trends from 1970 to 1998.
A pitfall of selective mode focus - The [light] rail pitfall

Bahnhof Strasse, Zürich

Photo: Gustav Nielsen
The modal integration approach in Zürich

Probably Europe’s most used PT network.
Over 100 years of improvements of an integrated network of rail and bus.
Buses are serving the largest area!
Adjusting the network to size and form of the urban area

a. Squaresville
b. Medium size city
c. Large town
d. Small town
e. Village
f. Station or express bus stop

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The co-ordinated pulse timetable approach

By coordinating lines and timetables (pulse timetables) we can multiply travel opportunities and simplify travel planning in low density districts and regions.
The co-ordinated pulse timetable approach
Welcome to Public Transport in Switzerland

There is a train, whenever you need one, already at the airport. A bus, to take you farther, or another train. And a boat, if you wish to enjoy the beauty of one of the lakes. Or a little red train to bring you up to the mountains. A whole system of it, working like a Swiss watch. And so many places to see, in that beautiful little country! That’s the Swiss Travel System. To have it all, with one pass.
Integration of scheduled and demand-responsive services – the most difficult part!

Swedish study

Concept for the Lillehammer region, Norway

Source: TØI-report 882/2007
4. Speed of travel
Efficient operation: No traffic delays!

Cost per buskm; NOK

You can save 30-40 % of operational costs (?!)

And capture more passengers!

Source: Bus cost model TØI; ill: Truls Lange, Civitas
Green traffic signals when they are needed!

...and messages to the customers about when the bus will arrive!
Karlsruhe: Stop only to pick up and set down passengers

Tram and Tramtrain through the city, more punctual than main line trains – even in rush hours!
Straight into and through the city centre

Göttingen, Germany

Ålborg, Denmark

Bayreuth, Germany

Århus, Denmark

Photo: Gustav Nielsen
Simple and easy for all is also efficient

Photo: Gustav Nielsen

Freiburg, Germany
Roundabouts – no problem!

Nantes, France (plan)

Source: Certu-BHNS/Semitain

Roundabout with traffic signals, Nordhausen, Germany

Photo: Gustav Nielsen
Finding the optimal distance between stops

- 400 m
- 600 m
- 800 m

400 metres 5 minutes walk

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Public transport - speed

Formulas

\[ T = t_{\text{hpl}} + 2 \cdot t_{\text{stop}} + \left( S_{\text{hpl}} - 2 \cdot S_{\text{stop}} \right) / V_{\text{max}} \]

\[ V = S / t \]

\[ S = \frac{1}{2} \cdot a \cdot t^2 \]

\[ V = a \cdot t \]

- \( T \) = time per interval
- \( S \) = distance, m; \( S_{\text{hpl}} \) between stops, \( S_{\text{stop}} \) for acc./ret.
- \( t \) = time, seconds; \( t_{\text{hpl}} \) at stop, \( t_{\text{stop}} \) in acc./ret.
- \( V \) = speed, m/sek
- \( V_{\text{max}} \) = speed limit
- \( a \) = accel./retardation, 0.8, \textbf{1.0} or 1.2 m/sek\(^2\)
Travel speed – a function of distance between stops and top speed limits

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Attainable speed; a quality goal and reference

<table>
<thead>
<tr>
<th></th>
<th>Average distance between stops</th>
<th>Attainable operational speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional, main or light rail service</td>
<td>2.4 km</td>
<td>64–69 km/h</td>
</tr>
<tr>
<td></td>
<td>1.8 km</td>
<td>58–60 km/h</td>
</tr>
<tr>
<td>Regional buses, combination of express and local, full stopping service</td>
<td>1000 m</td>
<td>45–50 km/h</td>
</tr>
<tr>
<td>Urban bus, light rail or metro service</td>
<td>600 m</td>
<td>28–31 km/h</td>
</tr>
<tr>
<td>On busy city centre streets with 30 km/h speed limit</td>
<td>400 m</td>
<td>19 km/h</td>
</tr>
</tbody>
</table>

Suggested theoretical attainable commercial speed levels for the benchmarking of typical urban public transport lines, without delays from congested car traffic, fixed traffic signals etc. Average figures for lines of 5–50 km.

Source: HiTrans, Nielsen et al, 2005
Combining regional express lines with local, full-stopping services

Concept for the Oslo region, Norway

Regional lines stop at all hubs they run through
Local lines stop at all stops they pass

Short, local journeys  Long, regional journeys
5. Quality access strategy
Tree character of sustainable, public transport

A sustainable transport system is like a tree – without twigs and leaves, the trunk will dry out and the tree will die

- Example Kanton Graubünden in Switzerland:

  + Walking, cycling, etc
The ‘satisfy everybody’ pitfall

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The common pitfall of designing public transport for short walking distances

Planning for short walking distance often result in:
• Many lines, with low service frequencies
• Slow travel speed due to many stops
• Inefficient route alignment

The alternative quality access strategy means:
• Make walking radically more attractive!
• Make cycling radically more attractive!
• Make more attractive public transport feeder systems
• Make many more, and larger, car free zones

Sustainable cities must have sustainable transport solutions – not car-based traffic system designs
Making walking attractive and efficient

Freiburg, Germany

Fredrikstad, Norway

Photos: Gustav Nielsen
Urban planning affects real walking distances

400 m circle around a stop

31 % of area within 400 m walking

64 % of area within 400 m walking

Source: www.humantransit.org
Integration of bicycle and public transport!

Area within 10 min. access time:

On foot – 2 km²

By bicycle – 32 km²

Source: McClintock & Morris, 2003
A flexible second-tier system in low density suburbs

Wunstorf, Hannover region, Germany

Photos: Gustav Nielsen
Leaving cars at the outskirts of cities

Freiburg, Germany

Cambridge, UK

Photos: Gustav Nielsen
Integrated land use and transport planning

Houten, Netherlands

Photo: Gustav Nielsen
The pitfall of separating public transport from land use planning

100% Yes
Straight line with few, but centrally located stops

150–250% Avoid
Bending line, with many stops at short intervals

250–450% Avoid
Ring lines with many stops on the border of the area to be served
PT straight into residential areas - Freiburg

Vauban

Rieselfeld

Photos: Gustav Nielsen
Conclusion

Network planning philosophy and the choice of strategic network design principles are key factors behind public transport success or failure:

1. Simplicity and ease of use
2. Optimal frequency
3. The network effect and connectivity
4. Speed of travel
5. Quality access strategy

Success depends on putting the customer first in the design process – and using high quality engineering services to create and deliver a simple, attractive and efficient travel network for all citizens.

High tech is not the critical factor.
Success criterion: Wedding on the bus

Source: Breithaupt 2006

TransMilenio, Bogota