

# **From “distance-based” price discrimination to “use-based” price discrimination: tracks to improve fare box revenue in urban public transport**

*Catherine Bouteiller<sup>1</sup>, Transport Economics Laboratory, Lyon, France*

*Bruno Faivre d’Arcier<sup>2</sup>, Transport Economics Laboratory, Lyon, France*

## **ABSTRACT**

The aim of this paper is to initiate a discussion on how to improve urban public transport fare box revenue by increasing quality of revenue and especially adequacy of “distance-based” fares to the public transport network and the urban form of the city. What are the determining factors of an appropriate fare policy? Are customers’ expectations fully taken into considerations into fare grids? We consider that “use-based” fare policy can respond to the search of friendly use network, seamless strategy for a better mobility in the urban area and equity of customers regarding their social conditions and their use of the network. Public transport business model must take into account fare policy as a variable of the economic performance of the system.

We will analyse the public transport network and fare grid structure in 10 cities corresponding to different types of urban morphologies: mono centric (Tokyo, Singapore), composite (Seoul, Paris, London, Madrid, Toronto) or poly-centric (Amsterdam, Copenhagen, Berlin). Our study consists in comparing “distance-based” fare system chosen by these cities, through 3 scores. By studying “distance-based” price discrimination such as distance based, zone based or cells comb based, we will have elements to understand how delivering the appropriate pricing system contributes to a better use of the public network in a given spatial form of the city. Then we will focus on “use-based” price discrimination through combination of 4 scores relying on the analysis of 4 criteria: time period, number of trips, mean of payment, mode use.

Fare grids can be a tool to respond more accurately to the changing needs of the different urban schemes and to customers’ expectations. But the study of fare grids enhances the complexity of combination of fare possibilities offered by fare management tools to implement “use-based” fare discrimination. We will go further with the idea that not only fare grids are a lever to improve fare box but also a determinant element in network usability and orientation of demand.

*Fare grid, fare box, urban planning, monocentric cities, composite cities, poly centric cities, price discrimination*

## **INTRODUCTION**

For 10 years, fare box ratios have been constantly decreasing in France (-31% to -36% according to network sizes) and public transport commercial revenue covers operating costs by 35% only (GART, 2012). In April 2012, a few experts set off reflexions on public transport business model and debts (Bonnafous and al, 2011). Public transport business model has to explore all tracks to improve revenue. Fare discrimination strategies deserve to be studied among other solutions.

The observation of French trends (GART, 2012) over the last decade shows a constant raise in terms of kilometric supply (+13% to +37%). But raise of patronage do not follow the trend (+8% to +15%) and surprisingly average price for day tickets fell by 11% in real terms, and 18% for annual season ticket. Monthly season ticket is the more common fare and its decrease varies with the size of considered network. At the same time fare recovered per trip is always getting lower. This trend should be reversed. French public authorities, but Paris, have been implementing massively flat fares that they consider as a friendly use solution.

Looking at what’s happening in Europe or in a few cities around the world, practices appeared to be different: flat fare is not the norm. Fare discrimination has been introduced through fare management systems that allow combination of fares. Simplicity of the tools (smart cards) and marketing; offer seamless use of the networks

This paper analyses price discrimination in 10 cities around the world. Fare grids have been studied through a methodology that split up price into three components: “distance-based” fare, “use-based” fares and “passenger-based” fares. The two first dimensions will be studied in this paper:

Distance-based price discrimination reflects a situation where price depends on characteristics of the trips and network capability to respond to spatial demand of trips (zonal fares, kilometric, cells zonal). Questioning distance-based score will lead to analyze pertinence of the distance-based grid chosen by the PTA. These relationships are not often studied as mentioned: “despite their importance to the public user experience the literature on the relationship between fare structures and public transport network design is surprisingly sparse” (Dodson et al, 2011).

Second component of fare studied in this paper is “use-based” price discrimination. Use-based price discrimination is a terminology that associates ticket based strategies and use based practices in relation to the willingness of the customers to travel in special periods, using combination of specific modes, paying with their preferred supports. Use-based price discrimination will be approached through four dimensions of usage: time of use, number of trip use, mode use and mean of payment use.

Passenger-based price discrimination will not be studied as it is very commonly practiced and well known by public transport authorities: it is a segmentation relying on demographic groups: senior, student, unemployed...It refers to social rebates.

Public transport authority’s challenge as far as fare strategy is concerned “is to determine a tariff structure that reconciles the user’s need for an affordable public service with the commercial interests of the operators, while at the same time pursuing the authority’s social and spatial objectives” (Mezghani, 2008).

First part will explore conformity between city morphology and public transport organization, showing that passengers flow characteristics will be key information to choose the appropriate distance-based fare grid structure.

Second part makes an evaluation of distance-based fare grid by studying relations between fare and distance to the center for a monthly season ticket. Public transport authority may use distance-based grid to give priority of development to specific areas thanks to specific profile of fares.

Third part offers a methodology to estimate capability of Public Transport Authorities to make price discrimination on “distance-based” practice or “use-based” practice of the network and gives a mapping of the cities.

## **I – THE INFLUENCE OF URBAN MORPHOLOGY ON PUBLIC TRANSPORT NETWORK DESIGN**

First we will consider the evolutions of main forms of urban planning and their link to public transport network and fare structure through literature.

### **I-A URBAN PLANNING RESEARCH HAS PRODUCED SEVERAL STUDIES ABOUT CITIES**

Three main urban forms have been defined: a few indicators as pattern of daily trip, average built-up density and density profile and gradient allow categorizing cities. (Bertaud, 2004). This paper will use the following terminology and definitions of urban forms.

#### *Mono-centric structures*

These structures were described by (Alonso, 1964) and very often studied (Coffey, 2006 - Mori, 2006). Mono-centric cities are built around a unique strong CBD (Central Business District). They “maintain a unified labour market by providing the possibility of moving easily along radial or rail from periphery to centre” (Bertaud, 2004). This model is described as “a Central Business District (CBD) that contains all employment and retail activity, and so is the focus of both work and non-work travel. The CBD is surrounded by industrial and residential land uses, with densities decreasing away from the centre as households seek to locate at a distance that provides a trade-off between commuting costs (linearly related to distance) and housing costs.” (Weber, 2003)

In these cities we could sum up main passenger flow characteristics as:

- Radial distribution for strong commuting pattern to the CBD, (Levine, 1992).
- Small distance trip inside CBD, all passengers travel about the same distance.
- Long distance trip (depending of area size) for workers commuting through suburbs to city centre (Bertaud, 2004).
- Place of car park in the CBD is a good indicator of mobility policy in mono centric cities.

#### *Polycentric structures*

These cities have a structure with no dominant central city but several interacting main cores generating different travel behaviours (Cervero and Kockelman, 1997). Bertaud characterizes polycentric model describing cities where “functions were very much in the same way as a monocentric city, jobs, wherever they are, attract people from all over the city. The pattern of trips is different, however. In a polycentric city each sub-centre generates trips from all over the built-up area of the cities. Trips tend to show a wide dispersion of origin and destination, appearing almost random”.

In these cities, main passenger’s flows are very specific (Levine, 1992):

- Short distance trip in suburbs and cross commuting (Van der Laan, 1998).
- Very strong need of interaction between modes to connect all suburbs: bike/train / park and ride.
- Strong integration between sub networks of the metropolitan area as demonstrated in the Ramstad area (Clark and Kuijpers-Linde, 1994).
- Place of car use must be considered in suburbs.

### Composite model

“Poly-centric” cities defined above, corresponds also to cities called “polynuclear” (Lemoine and Predali, 2007). Between “polycentric” cities and “monocentric” cities, there are cities undergoing changes. Bertaud calls them “composite” cities and gives the following definition: “The “composite model” is the most common type of urban spatial structure. It contains a dominant centre but a large number of jobs are also located in the suburbs. In this type of cities most trips from the suburbs to the CBD will be made by mass transit while trips from suburb to suburb will use individual cars, motorcycles, collective taxis or minibuses.

The “composite model” is in fact an intermediary stage in the progressive transformation of a monocentric city into a polycentric one. As a city population grows and the built-up area expands, the city centre becomes more congested and progressively loses its main attraction. The original raison d'être of the CBD was based on its easy accessibility by all the workers and the easy communication within the centre itself because of its spatial concentration.” (Bertaud et al.,2009).

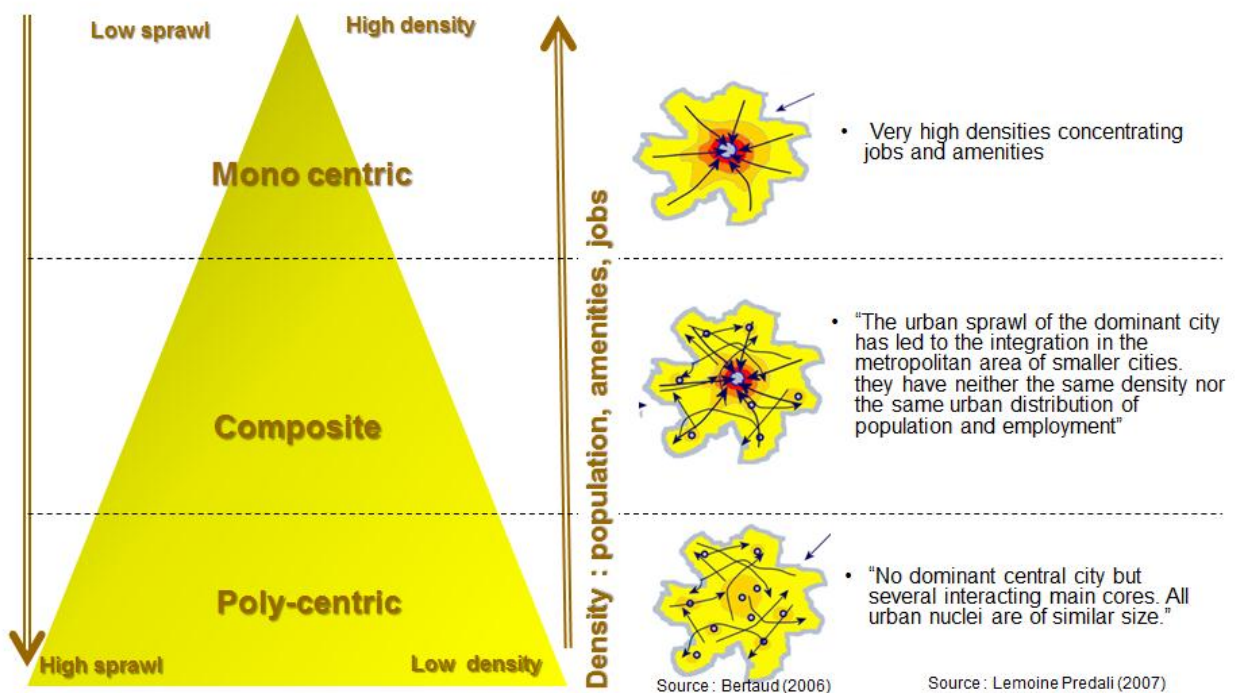


Figure 1 – The three major types of urban organisation and their influence on trip generation.

In composite cities, characteristics of monocentric and polycentric cities are mixed:

- Fewer trips from central to peripheral area.
- New trips from suburb to suburb.
- Long distance trips (depending of area size) for workers commuting.
- Urbanization along urban corridors.

Urban network should change from radial scheme to dispersed schemes. Otherwise car use might be considered as the only alternative to public transport when network infrastructure doesn't follow commuting patterns changes.

(Bertaud, 2004) gives the following summary of evolution of the forms:

“No city is ever 100% monocentric, and it is seldom 100% polycentric (i.e., with no discernible “downtown”). Some cities are dominantly monocentric, others are dominantly polycentric and many are in between. Some circumstances tend to accelerate the mutation toward polycentricism—a

historical business centre with a low level of amenities, high private-car ownership, cheap land, flat topography, grid street design—and others tend to retard it—a historical centre with a high level of amenities, rail-based public transport, radial primary road network, and difficult topography preventing communication between suburbs."

In this context, the shape of the public transport network implemented must be considered. It reflects needs of mobility at one given time of the development of the city.

## I-B FROM URBAN PLANNING TO TRANSPORTATION NETWORK

Several studies explain the challenge of deploying a public transport network in the different forms of cities to respond to the demand of the different commuting patterns. Several network strategies have been described: radial network (Thompson, 1977), (Dodson and al, 2011), corresponds to mono centric cities, dispersed network strategy (Thompson, 1977) is more common in composite cities, and radial network strategy can be found in polycentric cities with specific grid (Newman and Kenworthy, 1999). Routes and nodes described respond to some of the needs of the passengers depending on the structure of the cities. But as cities change forms quickly as well as passenger commuting patterns, public transport infrastructure have difficulties in responding to new demands... The phenomenon of dispersion in the metropolitan area leads to new schemes of mobility. “Individual behaviour reshapes urban form in the long terms (Du and Wang, 2011).

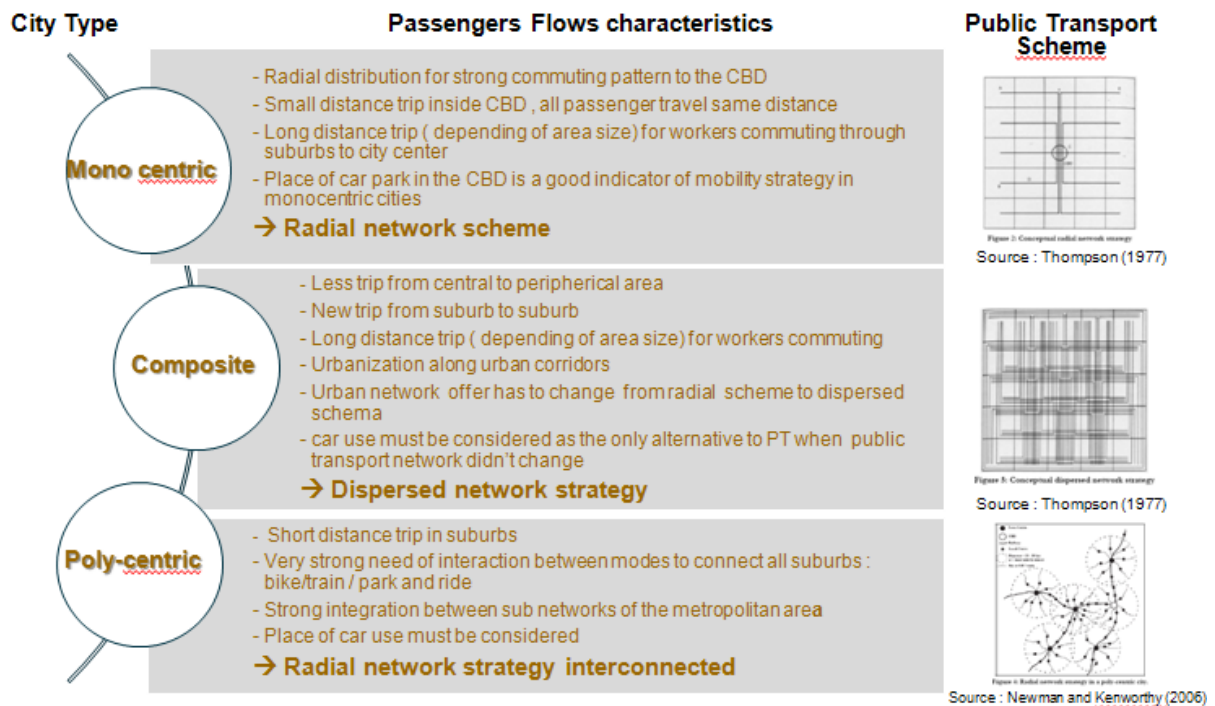


Figure 2 – Correspondence between city morphology and public transport network structure

Public transport networks tend to reflect the morphology of the cities that evolves from one type to another, for example from mono-centric shape to poly-nuclear or polycentric shape. Public transport structures need to adapt. Nevertheless, as infrastructure costs are high, discrepancies appear. More agile systems such as smartcards can allow seamless use of all modes. The result is a better use of the network. Urban forms of the city and the public transport network shape characteristics have a strong impact on cost structure of the

network. Radial systems in monocentric cities are operated by high capacity rail systems as in Tokyo or high speed bus (Seoul). Do fare structures reflect the reality of costs?

## **II – CHARACTERISTICS OF “DISTANCE-BASED” FARE SYSTEMS**

Can fare grids be a response to customer’s need of mobility and influence public transport use at the same time? Fare policy and fare grid reflect organization of the network. But, whereas public transport network infrastructure is not flexible and need investments, fare grid can introduce flexibility to give a better orientation of use of the network. Fare can be an incentive to use a mode, a route.

### **II-A THE MAIN CHALLENGES FOR A TRANSPORT PRICING POLICY**

EMTA (European Metropolitan Transport Authorities) study on electronic ticketing in public transport gave the following definition of public transport pricing policy (Mezghani, 2008): “The greatest challenge for a pricing policy is to determine a tariff structure that reconciles the user’s need for an affordable public service with the commercial interests of the operators, while at the same time pursuing the authority’s social and spatial objectives “.

*Pricing strategy must reconcile targets of the 3 actors of the public transport:*

For public authorities, fare should simultaneously increase public transport modal share, attract passengers, set low prices and simple tariffs, balance prices and limit exclusion, increase multi-modality and inter-modality, minimize public subsidies or financial compensation clearing and share revenues.

As far as the operator is concerned, fare strategy should cover costs and maximize profit, build an attractive public transport system (image & loyalty card), ease control routes, reduce fraud, simplify revenue collection.

For the passenger, main expectations are minimizing transport cost, facilitating use of PT, multi-modal use and equity.

Pricing policy on the other hand has to take into account two main dimensions: spatial and social organization is an input: extensive routes and highly density networks are not priced the same way. Price should be fair for long distance commuter especially when low revenue customers live far from central business district where they work... A second dimension is the demographic profile of the users of the network: are they mainly students, workers, or senior citizen? (Fatisson, 2012)

*Price policy is built on three pillars*

Mezghani explains in EMTA study (Mezghani, 2008) that “journey-based” price discrimination reflects characteristics of the trips. As it is directly linked to the spatial dimension, it is suggested to be called “distance-based” fare strategy in this paper.

Zonal concentric fare, cell zones fare, flat fare and kilometric fare belong to "distance-based" strategy. The second pillar of price strategy described by Mezghani is “passenger based” price discrimination and concessional fare. These fares are linked to demographic segmentation.

The third pillar, that is not very often studied, will be called “use-based” price discrimination. Mezghani calls it “ticket-based” strategy, due to strategy based on the way trips are sold. He considers all tickets in the same category no matter if these tickets are sold: considering time use (off peak ticket / night ticket), trip use (unlimited, season, multi journey tickets), mode use



(multi-mode, multi operator) or payment use (value ticket, pay-as-you-go). With the notion of “use based strategy”, four criteria of use can be introduced: time, trip, mode and mean of payment.

(Fearnley, 2003) describes what would be “inventive pricing”. Innovation described by Ferney is time differentiation (off peak fare), membership fees, surcharge on high standard (airport fare), rebate and pre-sold ticket.

To increase fare box as (Fearnley, 2003) explained, there is not much to expect from “passenger- based” price discrimination as it is mostly linked to social policy. Flexible fare systems can be the solution to maintain modal share and service levels. Flexible fare system is a notion very close to “use-based” price discrimination: for example giving possibility to use a public transport service and pay afterwards at the end of the month can be very convenient for those who do not want to care about tickets and season tickets. Flexible fare means that it will be charged different price for the same route (for example different prices for different kind of services: air con bus, express or standard bus).

In fact “inventive pricing” of Ferney is also a mix of “ticket-based” strategy and “use-based” strategy. Fearnley’s inventive pricing belongs to “use-based” price discrimination. As fare management is always improving, these strategies of differentiation are getting more and more common. Their impact on fare box revenue has to be studied and part 3 suggests a method to evaluate the capability of public transport authorities to implement “use-based” price discrimination.

## II-B “DISTANCE-BASED” FARE GRID DESIGN DEPENDS ON MOBILITY PATTERNS

“Distance-based” pricing is the most common used grid and reflects PT’s network orientation. Fare strategy must take into account public transport network forms to respond to commuting patterns. This idea has been developed by (Lemoine and Predali,2007) who made a correspondence between the morphology of the city and the distance based grid. They consider six case studies belonging either to composite (called polycentric by the authors) or multipolar models: Chicago, Los Angeles, London, Montreal, Munich and Berlin. “Pricing structure is related to the urban region structures and is seen as an answer to mobility needs: most polycentric areas have concentric zone structures, multipolar areas apply cells pricing”.

The following table gives a definition of all “distance-based” strategies from flat fare to distance based fare and gives the impact of the grid on the spatial use of the network.

	Definition	Spatial organization	Social location equity	Cost
<b>Flat fare</b>	All passengers are charged the same	Systems that fits well when all passengers travel approximately same distance	Will be equitable if high revenue passengers live near the center and poorer farther out ... price per km > for those who can afford	Correspond to medium cost Depend of structure of traffic
<b>Concentric Zonal fare</b>	Flat fare within each zone so distance for orbital trips is not considered ; price determined according number of zones crossed	Fits large territories with different centers	Not equitable for passenger travelling short distances across 2 zones. “ long trip within the same zone cost less than shorter trips that cross zone boundaries	
<b>Cells zonal fare</b>	Price of radial and orbital trips: transport perimeter is cut out in polygonal zones of similar size and price depends on the number of crossed zones	Fit large territories with radial and orbital trips	Very accurate cells will provide equity.	High collection cost without E-technology
<b>kilometric fare</b>	Price per km is applied, each route is divided in fare stages. Fares are charged according to the number of sections or stages travelled	Different operating cost or different demand in each section	Is equitable if the fare scale is very accurate . But if low income are located far from the center , this system is less equitable than flat fare	High collection cost without E-technology

Figure 3 – “Distance based “strategies, definitions (Mezghani, 2008)

Do public transport authorities implement these strategies systematically on their territories?  
Is there a link between implemented fare strategies and characteristics of the city: urban sprawl, need for motorized trip in the peripheral area?

### **III- ASSESSING “DISTANCE-BASED” AND “USE-BASED” FARE GRIDS**

This part proposes a methodology to see if the fare strategies of ten cities are reflective of their urban development. As previously said, price discrimination can be described through three components: “distance-based” score, “use-based” score and “passenger-based” score. A focus will be made on “distance-based” score and “use-based” score as “passenger-based” score has already been studied by (Hodson, 2005). On one hand he considers discrimination on journey characteristics such as: time period for traveling, travelled distance and mode choice. On another hand he considers differentiation on the basis of tickets characteristics: availability of tickets at cheaper price than single for example.

#### **III A- METHODOLOGY AND DEFINITION OF THE STUDY**

Distance-based, use-based and passenger-based price discriminations are three approaches to qualify a fare system in a given city. Most of public transport authorities, except those using flat fare, are making a combination of fare related to these notions. Figure 5 associates metrics to each definition. Distance-based score and use-based score, only have been calculated for this paper.

These scores give an indication of how the cities use fare levers. Hodson’s scoring methods are applied. Hodson calculated a composite of indices of what he called “journey-based price discrimination, ticket-based discrimination and discounts for students and young people”.

In this paper, metrics are slightly different from Hodson’s ones, as some indicators and metrics are redefined and there is no calculation of a global score. The aim is to position each city one to another through their capability of using either use-based or distance-based strategies.

Distance-based score and use-based score have been calculated as the result of intermediate calculations of the following metrics. Each intermediate score (Figure 8) on each metrics is expressed as a proportion of the maximum score on that metrics for the 10 cities studied (Figure12). Then, for a given city, all intermediate values are summed. A weighting might be used: for example, first step on last step price/km metrics will be weighted by 25% in the final distance based score to avoid giving too much emphasis to tapering charges policy. Final score is calculated for the 10 cities and rescaled to run from 0 to 1 (Figure14).



From “distance-based” price discrimination to “use based” price discrimination  
(BOUTEILLER, Catherine; FAIVRE D’ARCIER, Bruno)

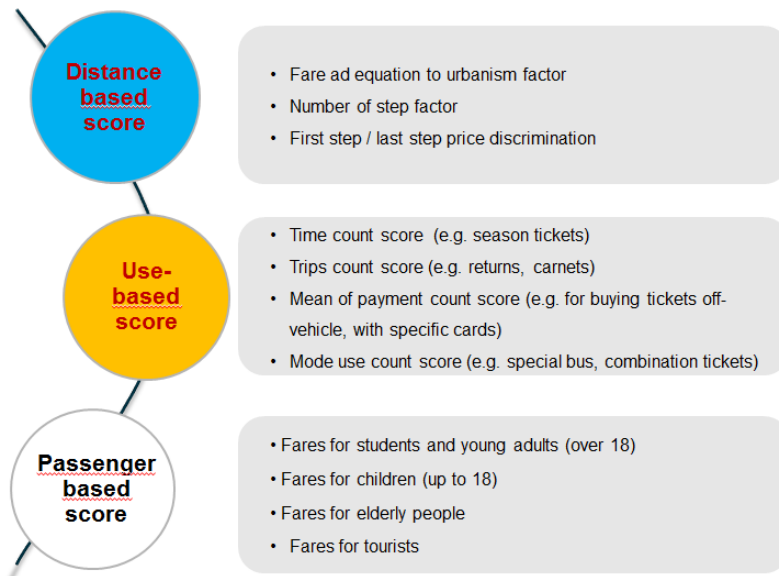


Figure 4 – Components of price discrimination

“Distance-based” price discrimination

It should reflect the adequacy of the fare to the length of the trip in a given network in relation to the city morphology: travelled distances are not the same in monocentric cities or polycentric cities: distance-based fare can be evaluated through a set of metrics related to:

- Distance based policy structure of fare: “number of step” factor is given by the construction of price /km delivered for each kilometer from 0 to 40 km.
- “First step / last step price discrimination”: fare per km is calculated for each kilometer from center to periphery. First step/last step price is a coefficient of degression but as it must be linked to the number of step factors, it will be counted only by 25% in the final sum.
- “Fare adequacy to urbanism” factor is a qualitative metrics witch result of the study of distance-based policy and urban form of the city (Figure.8).

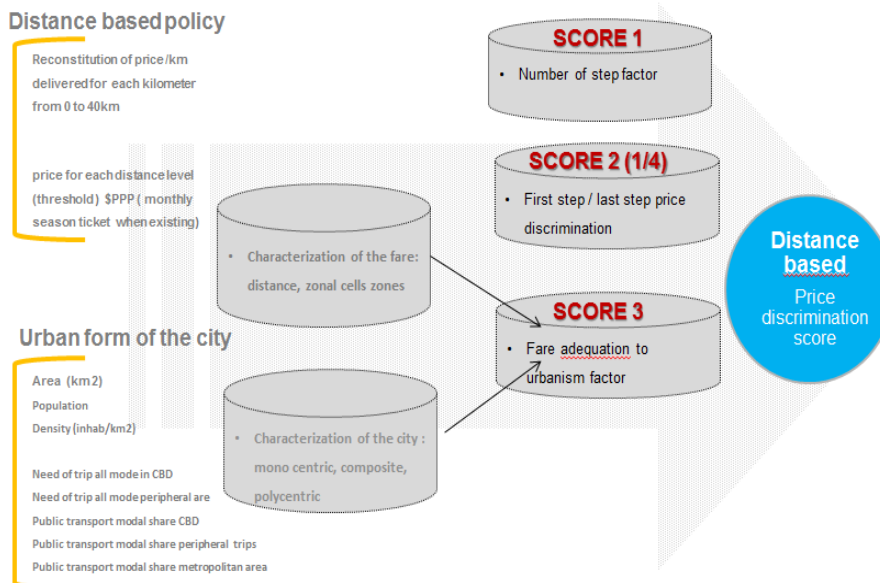


Figure 5 – Methodology of “distance based” fare scoring

### “Use-based” price discrimination

“Use-based” score is defined as a combination of 4 scores that have been evaluated through 4 criteria. The use of a public transport can vary with:

- Period of time use: ticket for a day, a week-end, several days, a month.
- Trips use: one trip, 10 trips, 14 trips ...
- Payment support use: pay a different price for ticket bought in a bus or charged on pay as you go card.
- Mode use: different price according to the mode: express bus, air conditioned bus, standard bus ...

To evaluate each of these criteria, Hodson already used two factors and two others have been added.

- “Ticket availability “is one of the factors proposed by Hodson to quantify each dimension of price discrimination: it is the number of differentiated tickets available. “Maximum discount” is the second one used by Hodson: it is the maximum price difference between a differentiated ticket and a ticket that is not differentiated, expressed as a proportion of the cost of the higher priced ticket.
- The two additional factors added are the “maximum raise factor which is the opposite calculation of the maximum discount and the “marketing complexity factor” which is a more qualitative factor for innovation: peak /off peak fare, pay as you go card...

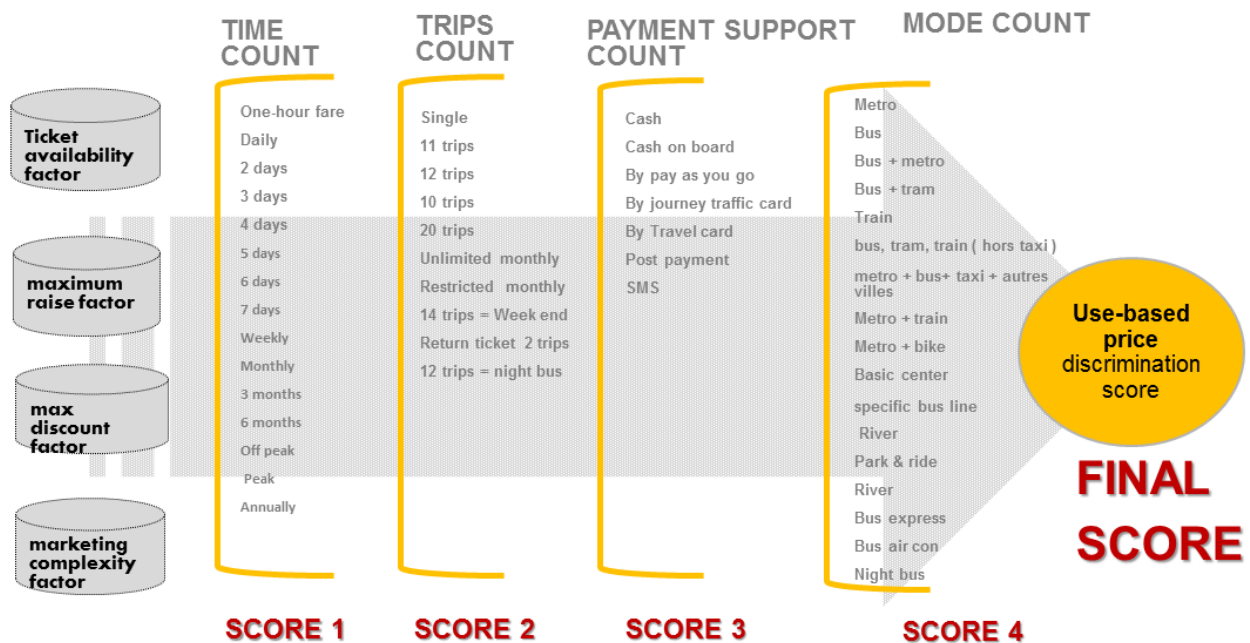


Figure 6 – Methodology of “use-based” scoring

### III B- “DISTANCE-BASED” PRICE DISCRIMINATION SCORE: CALCULATION AND RESULTS

#### Selection of the cities

Literature on urban planning gave many indications whether a city belongs to one category or another: monocentric, polycentric or composite morphologies. (Murayama et al., 2006) gave a complete approach of growth, city design, and sustainable development in several megacities around the world in particular London, Toronto, Seoul.

For Amsterdam, (the Ramstad Polynet study, 2005) gave precious indications on trip flow between cities around Amsterdam. For Madrid region, (Caceres and Sánchez, 2009) made an analysis of the changing commuting patterns and gave several maps of trip flows that were compared to public transport network.

Focus on flows between CBD and peripheral area determines the nature of trips needed. For Copenhagen, the synthesis on the Fingerplan made by (Ostergard, 2007) produced a few maps of polycentric scenario in Copenhagen region.

Main information on cities is summarized in the following table (Figure 7).

City	Urban structure	Urban sprawl	PT modal share Metro area motorised	Need motorized trip periph. area	Network adequacy to structure	Fare model (number of fare steps)	Adequacy of fare model to urban need
Tokyo	Mono centric	4	70% (2010)	49%	Yes radial	Kilometric (5)	4
Singapour	Monocentric	0	63% (2010)	-	Yes	Kilometric (39)	4
Seoul	Mono centric + peripheral tend composite	5	63% (2010)	58%	Yes but new need of trip in suburbs	kilometric 5km steps Flat fare 10km center (7)	4
Toronto	Composite	9	24%(2006)	?	Yes partially	Flat until 20km + kilometric 9 zones	3
Madrid	Monocentric + peripheral	3	50% (2007)	60%	Yes but still too monocentric	Flat fare 8km+ zone based (8)	3
Paris	Strong need in periphery few poles + dense in CBD	7	30% (2006)	71%	Not for suburbs / too radial Need "grand Paris"	Concentric zonal (4)	2
London	Strong need in periphery + dense in CBD	5	47% (2006)	84%	Not for long distance suburbs	Concentric zonal (9)	3
Berlin	Polycentric	34	12% (2006)	40%	Yes	Zonal (3) + Cells	4
Amsterdam Randstad	Polycentric	5	17% (2007)	50%	Yes Star network around cities	- Kilometric for cash 0,142/km - Cell zones for other (7)	4
Copenhag.	Poly centric with strong CBD	33	13% (2006)	30%	Not too radial	- Cell zones (9) - flat fare center	3

Figure 7 – Selection and characteristics of the cities

#### Several datas collected to determined “distance-based” final score

Monthly season ticket converted in \$PPP have been studied to determine few indicators. The price per trip and the price per km have been calculated. Monthly season ticket is supposed to be used 50 times. All fare grids proposed on web site were studied. Fare grids are sometimes flat, sometimes linked to a zone of a given number of km, or a cell comb. For example, Tokyo fare grid, as published on commercial website, gives the following indications: for 1 to 6 km fare charged is 160 yen, then 7 to 11 km , 190 yen ...etc...until 40 km. Five fare steps are necessary to reach 40 km. Price is calculated in \$PPP with trading economics’ data. It costs 0.25 \$PPP to make a trip until 11 km.

The adequacy of fare to urban need is the result of two factors: the fare structure: flat, zonal, kilometric; and the urban structure characterized by commuting patterns (Figure 8)

	Adequacy of fare to urban need	Steps	Last/first Price/km
Singapore	4	39	82%
Tokyo	4	5	72%
Paris	2	4	71%
Madrid	3	4	71%
Seoul	4	7	58%
Berlin	4	3	54%
London	3	9	53%
Amsterdam	4	8	22%
Copenhagen	3	9	20%
Toronto	3	9	10%

*Figure 8 – Main metrics obtained for calculation of “distance based” price discrimination score*

1. Monocentric cities have developed distance based-strategies with very accurate levels of price, reflecting the relative cost of mode or route. In Singapore, 39 levels of price are possible. In Tokyo as in Singapore, price per kilometre in the city centre is much higher than in suburbs: for example price /km in the CBD is 82% higher than price per km 40 km away.
2. Composite cities have a fare strategy that must fit needs of mobility in all areas: long distance commuters to historical CBD or short trips in suburbs. Composite cities have to face development of suburbs and new patterns from suburbs to suburbs without going through the city centre. Main challenge is that PT network is not always able to deliver good service: suburbs do not benefit from the same infrastructure that the one implemented in the city centre. People may go through the centre to reach another suburb. Composite cities have concentric zonal fare and very often, flat fare in the city centre.
3. Polycentric cities have another challenge: delivering services in all directions: trips can start anywhere in the area. Public transport use is very often multi modal. Fare strategy is cell zone fares; price is equal for a number of crossed cells wherever trip starts in the area. Price per km in the centre or 40 km away is nearly the same.

*Calculation of fare/km from city center to 40 km away.*

Levels of price per kilometre are always calculated to search if the pricing strategy is corresponding to an orientation of the use of the network in its geographical dimension:

1. Poly-centric cities deliver the same fare per km in all the area of the PTA. Price increases proportionally with distance covered through cells zones of equal distance. The target is clearly facilitating trips in all the polycentric area. Price per km is the same everywhere which means that the level of service delivered is the same wherever the journey starts in the network.

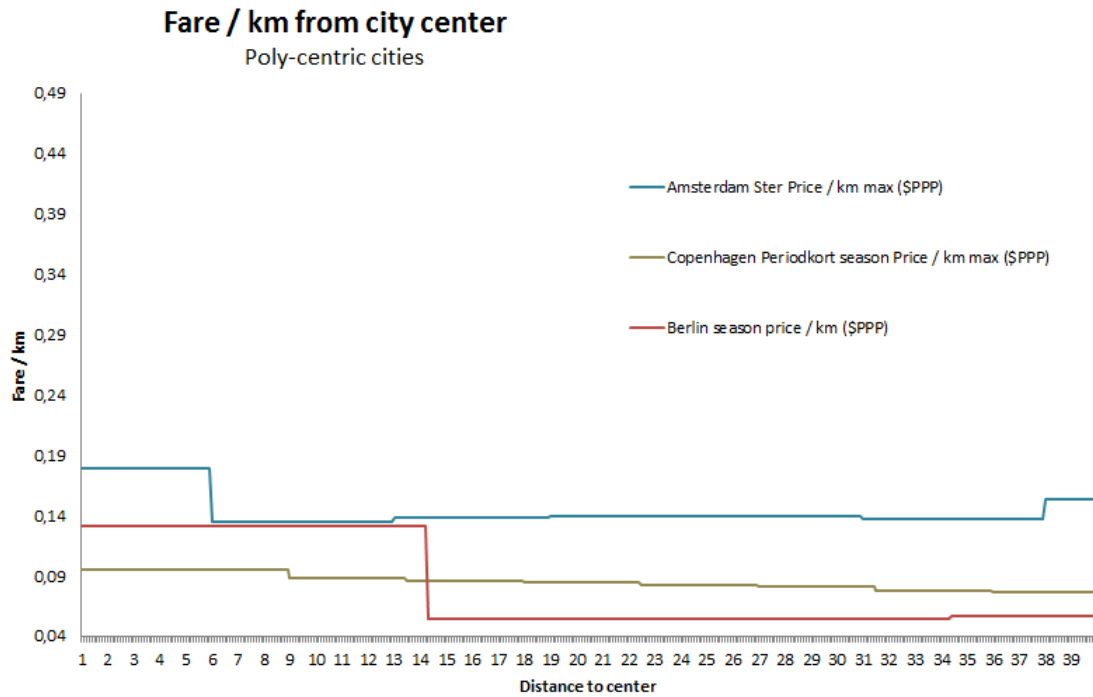


Figure 9 – Polycentric cities fare/km profile (1 to 40 km) - 2012 season ticket price

2. Mono-centric cities are kilometric based and make a real difference between price/km in the city center and in suburbs: degression is higher than in composite cities. The Seoul urban area used to be mono-centric and tends to a composite system. The fare is flat in the centre (Figure.10) until 10 km whereas in Singapore flat fare is limited to 4 km and for Tokyo, 6 km.

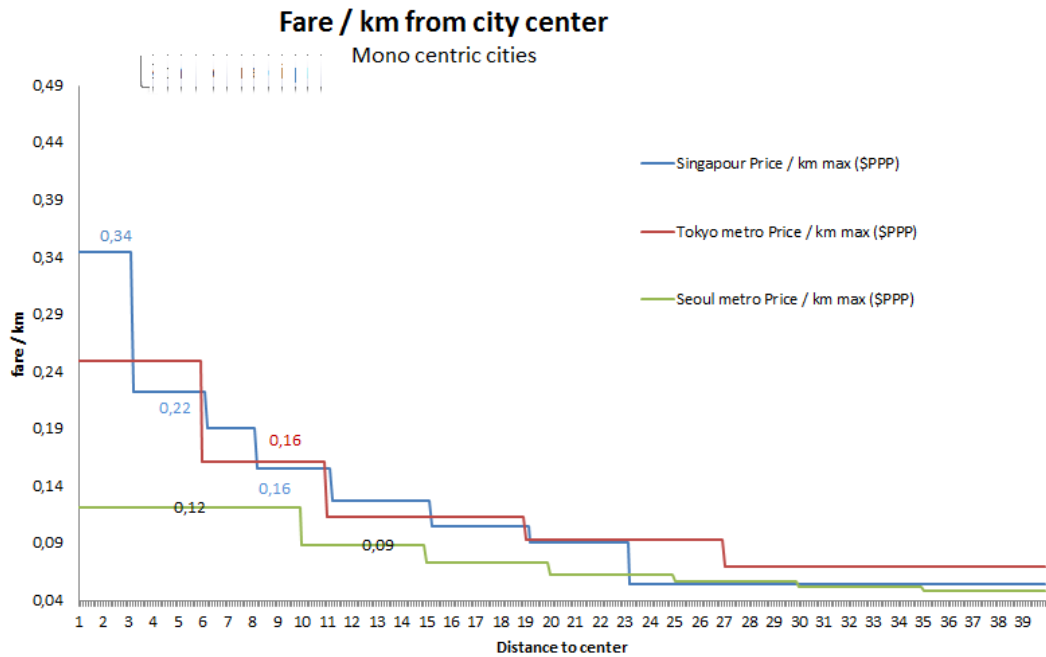


Figure 10 – Mono centric cities fare/km profile (1 to 40 km)

Figure

- Composite cities use flat fares in the centre and concentric zonal fares: the level of degression is less important not to penalize suburban inhabitants that do not benefit from the same level of services. Flat fare policy in the centre is very different from one city to another. Flat fare is usually a 10 km area. It can be more, as in Toronto where the Toronto Transport Authority uses flat fare until 20 km on its network, which is not the case on the Go network (11 km). Go network is not supposed to be used in CBD and price /km in CBD is prohibitive compared to TTA network.

**Fare / km from city center**

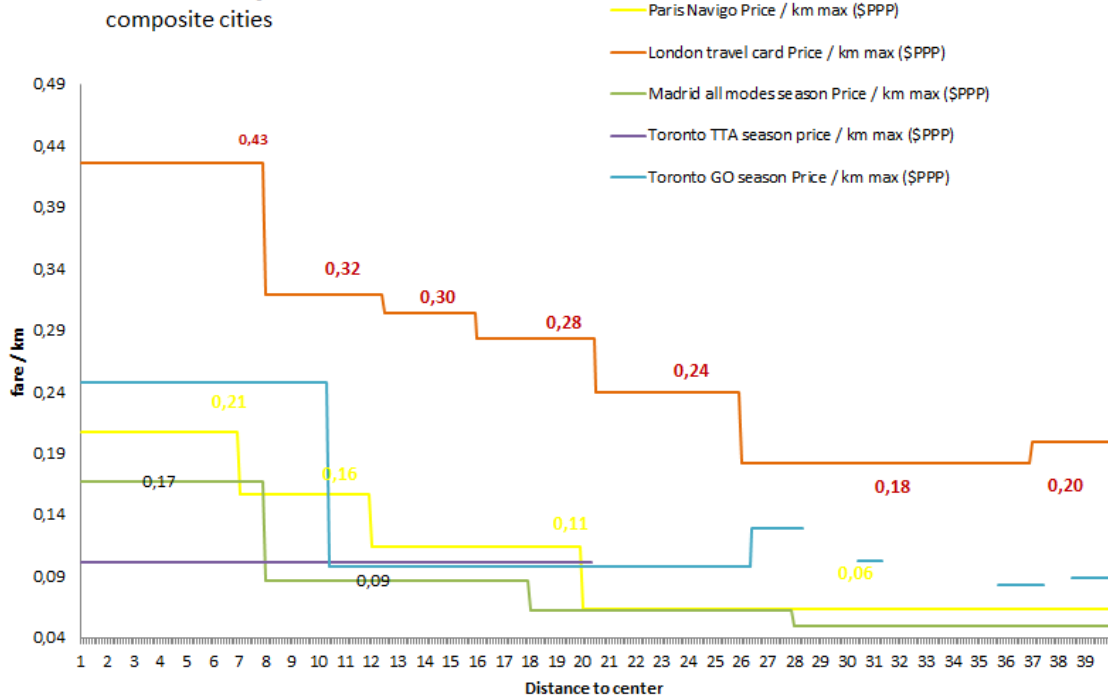


Figure 11 – Composite cities fare/km profile (1 to 40 km)

**Synthesis of distance based score**

Distance-based” score is the combination of 3 sub cores: fare adequacy to urbanism score, number of fare level (or fare step) factor, first step/last step price/km (Figure.12).

**distance-based score**

	fare adequacy to urbanism	number of step factor	Fist step / last step 40km price	distance based Final score
Singapour	1,0	1,00	1,00	1,00
Seoul	1,0	0,18	0,71	0,60
Tokyo	1,0	0,13	0,88	0,60
Amsterdam	1,0	0,18	0,27	0,55
Berlin	1,0	0,08	0,65	0,55
Madrid	0,8	0,21	0,87	0,52
Londres	0,8	0,23	0,65	0,51
Copenhagen	0,8	0,23	0,24	0,46
Toronto	0,8	0,23	0,14	0,45
Paris	0,5	0,10	0,87	0,36

Figure 12 –Calculation of the “distance based” price discrimination score

The three studied sub scores give an idea of the global adequacy of fare policies to: city morphology, level of detail of the fare strategy and level of price from city center to 40 km away.

1. Tokyo or Singapore have a maximum score for adequacy of fare to city morphology with distance based strategies but do not differentiate level of fares the same way (5 steps for Tokyo, 20 steps for Singapore between 1 and 40 km). Singapore fully uses distance based pricing with a high level of sophistication: 39 levels of prices, 80 % difference between CBD and 40 km area. Singapore has adapted very accurately its offer of service through integrated card fare depending on route distance. Mono-centric cities use kilometeric-based strategies. These cities are able to evaluate the cost of each route and the system of calculation reflects distances (mostly radial).
2. Amsterdam, Copenhagen and Berlin metro area have a real strategy to deliver the same price per km everywhere on the network (Figure.10). This strategy is linked to their polycentricism. Copenhagen and Amsterdam have a fare strategy that enhances peripheral patterns and full use of the network. These cities have low density of population. Their networks are not so dense in metropolitan areas and public transport modal shares in peripheral zones are not high. Strong fare integration is supposed to be a vector of development of public transport. Polycentric cities make low difference between price / km delivered in the CBD and 40 km away.
3. Madrid, London and Paris are composite cities, with radial networks that partially respond to the need of trips. Their fare strategy leads them to zonal fare with few levels but strong rebate between CBD and 40 km away. Seoul wants to develop PT between the city and new centres: Bundang, Ilsan, Pyeongchon, Sanbon, and Joongdong were planned around the city of Seoul. Seoul subway is interconnected with the other network and the railway, same for Madrid who added 2 zonal fares corresponding to areas of Castilla la Mancha.  
The level of efficiency with regards to urban need is medium in composite cities where radial networks do not match needs of suburbs-to-suburbs trips. Zonal Fare strategies are very different from one city to another: level of fares, number of steps, reductions to take into account distance to city center and density of the network. Concentric zonal fares should be very accurate to maintain equity.

How to conceal radial networks and geographic equity? In Paris, London, Singapore, high income households are located very close to CBD: a high level of fare in the city centre reflects this strategy. Nevertheless, fare grid systems do not appear to cope well with the type of city.

London still has a radial network, but city morphology is tending to a polycentric form. Is the zonal fare system still adapted compared to cell zones or distance based? Level of price is very high and is not a good signal for car users. Paris has a radial network but faces strong peripheral commuting patterns: public transport authority is reducing the number of zones and even mentions the possibility of a flat fare, which seems contradictory. Tokyo has long distance commuters but surprisingly low integration of routes (except on pay as you go cards) and no season ticket integrated.

Copenhagen has a polycentric fare structure but its network is still radial.

“Distance -based “price discrimination is the most common grid as it reflects mainly the urban form of the city with the limits enounced above.

### **III C- RESULTS OF THE STUDY OF “USE-BASED” PRICE DISCRIMINATION STRATEGIES**

*Synthesis of use-based score*



As described in chapter III-A, all fares are compared using the percentage of discount or rise compared to the price of a single ticket paid cash. A score also takes into account the marketing complexity and the number of fares offered in each category. Score is calculated from 0 to 1: score 1 is the maximum attributed to the city that reached the best sub score.

Use-based score can be split into 4 sub scores:

1. Time use: One-hour fare; daily, 2 days, 3 days, 4 days, 5 days, 6 days, 7 days, weekly, monthly, 3 months, 6 months, off peak, peak, annual
2. Trip use: single, sold by 2 tickets, 10 tickets, 11 tickets, unlimited pack.
3. Payment use: cash, cash on board, pay as you go, travel card, post payment
4. Mode use: metro, bus, bus and metro, train, cycle, ferries, express line, air con line, night bus line, combination of mode...

**use - based score**

	Time	Trip	Payment	Mode	use-based Final score
Toronto	0,37	0,44	0,54	0,40	0,44
Madrid	0,49	0,91	0,21	0,69	0,57
Copenhage	0,48	1,00	0,11	0,45	0,51
Berlin	0,83	0,70	0,48	0,58	0,65
Amsterdam	1,00	0,63	0,21	0,87	0,68
Singapour	1,00	0,75	0,64	0,68	0,77
Seoul	0,27	0,23	1,00	1,00	0,62
Paris	0,41	0,42	0,53	0,41	0,44
Londres	0,88	0,38	0,78	0,62	0,67
Tokyo	0,82	0,98	0,21	0,74	0,69

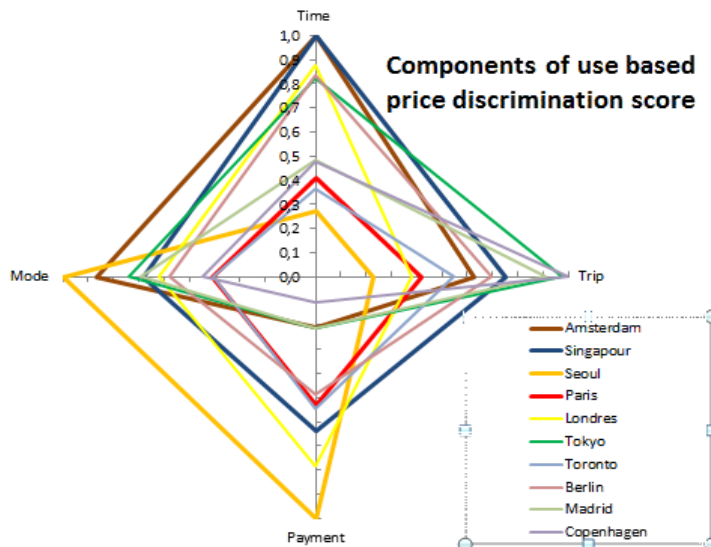


Figure 13 – Use based score and representation

Use-based score performance is determined by the capability of the network to make price discrimination on several choices: time, mode, trip and means of payment: Singapore uses all possibilities, as London. Seoul focuses its strategy on mode (bus) and payment, no season ticket or special offers related to time use or trip use. Amsterdam or Tokyo do not make any difference of price for use of personal card (payment score) which is not the strategy of London, Seoul or Singapore that are making discount for users of smartcards. Cities like Paris do not use these tools for differentiating prices.

#### *Time use*

Existing peak / off peak prices makes the difference for the marketing complexity factor, for time differentiation score: Singapore, Tokyo, London. Some cities do not promote time-based pass. There is no season ticket in Seoul. Tokyo, with its “all line metro pass”, has an expensive offer. Season tickets are very prohibitive in Singapore that has a very high level of raise factor for this offer. Amsterdam has its own strategy proposing a large offer of day-tickets.

#### *Trip use*

Trip use offers are very common in Tokyo. This strategy is not used in Seoul and very limited in other cities (10 trips tickets only). In Singapore or Tokyo, access to unlimited trips products is prohibitive with a very high level of fare.

#### *Payment use*

Developing smartcards tools does not mean systematically offering a discount for using them. London, Singapore, Toronto have incentives to use pay-as-you-go cards, whereas Amsterdam and Tokyo do not give any incentive for using them. Seoul offers several products with discounts or raise. Paris ticket “T +” paid on bus is more expensive and makes part of this payment use fare policy even if it is not very innovative

#### *Mode use*

These products are very linked to the capability of differencing modes and combination of mode products. Marketing differentiation is strong when it exists a demand for express lines, specific combination as metro+bus, park & ride strategies, air-con lines ... Seoul bus reengineering of the network is visible with a maximum raise factor on specific lines, the same for Singapore (air-con, express lines) ... Amsterdam has a strong park & ride policy. Madrid metro fare are different from a line to another

### **III D- RESULTS OF THE COMBINATION OF DISTANCE BASED PRICE DISCRIMINATION SCORE AND USE BASED PRICE DISCRIMINATION SCORE**

Use based and distance based strategies are complementary and their conjoint study gives a good glance of the PTA strategy to maximize revenue.

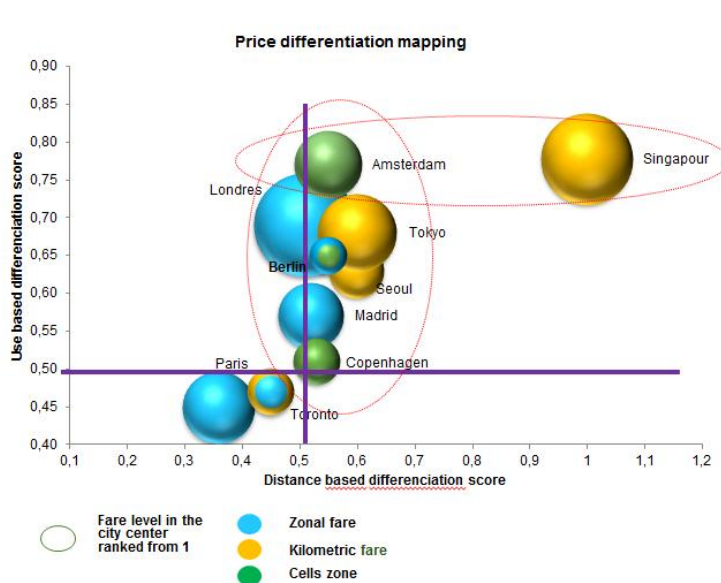


Figure 14 –Price discrimination mapping; combination of distance based and use based score

To explore price discrimination mapping (Figure 14), it is necessary to question a few assumptions.

- 1- Use based pricing strategy is not linked to distance based strategy as it could be assumed: There are 2 high levels of use based discrimination scores in two different systems of network pricing (kilometric for Singapore and cell zones for Amsterdam).
- 2- Is there a link between distance-based price strategy and city morphology? : It seems to be the case except for Paris: Paris’s low score, as far as distance based is concerned, is due to the inadequacy of its fare strategy to city morphology. Reducing number of zonal fare towards flat fares is the opposite of the strategies followed by cities facing expansion to multipolar activities.
- 3- Is there a link between high level of fare and high level of discrimination? Singapore, London or Tokyo have a high level of fare and high scores for distance or use based fares, but Seoul, Berlin or Amsterdam are very well positioned for price discrimination whereas price in their core centre is not high.
- 4- Is use-based strategy a factor of strong differentiation between cities? Innovation on services leads to price discrimination in several cities and it seems obvious that use based system is a motor of price discrimination: Seoul’s development of bus leads to innovative pricing on its network, London’s pay-as-you-go card allows several practices as peak/off peak prices, Berlin’s strategy to develop “short trip” with specific fares (40 % rebate) on a single fare, and on the opposite, Madrid raises the unit price if using public transport for more than 9 stops.

## CONCLUSION

This scoring analysis of the fare structure of PT networks on a limited sample of large cities in the world shows a great diversity of situations. This is partly due to local historical reasons, but it appears price differentiation is developing, in relation with new pricing technologies. It is hoped the combination of distance-based and use-based principles could better cope with the morphology of cities and the mobility needs of the population. It should also help to increase patronage and fare box revenue, even if such assumptions are not easy to assess.

Fare grids can be a tool to respond more accurately to the changing needs of the different urban schemes and to customers’ expectations : kilometric distance based, zonal fare, cells zonal fare correspond to different types of urban morphologies as mono-centric cities, composite cities or polycentric cities. But the study of fare grids enhances the complexity of combination of fare possibilities offered by fare management tools to implement “use-based” fare discrimination. In Asia, innovating aspect of fare grid is its capability to give a signal to customer expectations in matter of level of service and at the same time a tool to improve fare box ratio. We will go further by emitting the idea that fare grid is not only a lever to improve fare box but it has an effect on network usability and orientation of demand.

Use-based” grids are very complex and promote or restrict time, trip, mode, and payment uses of the network. These grids are used by some PTA as signals to orient demand toward a service or another: air-con bus, express line, pay-as-you-go card, short trips, park and ride...

Fare box can increase with fare grids that will combine the appropriate distance based policy (reflecting the urban structure) with the appropriate use based policy reflecting the structure of cost of the network and the willingness to pay of the travellers for specific services.

This first approach should be developed further, but this needs to have an access to more detailed data, such as the distribution of the fare box revenue according to the real consumption (trips per each fare). Price differentiation score should be then weighted with consumed quantities. Another improvement of the methodology would be to take into account the third type of differentiation, i.e. “Passenger-based” pricing, which is commonly used by PTAs for social reasons. Evolutions can be recently observed, with a progressive shift from individuals’ status (i.e., children, retired people, students,) to households’. Further developments of this study should also try to measure the elasticity of demand and the possible induction of patronage for a given price discrimination strategy chosen among “use-based” pricing possibilities.

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