Urban public transport fare design dimensions Post Covid and in a Sharing Society with a focus on Japan

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Introduction: Public transport fare structure dimensions

Determining fares is a complex issue involving a range of stakeholders, including operators, travellers and often government. A core problem with any fare changes is that there is uncertainty as to how a population will react to a fare change. People might choose different modes if the price becomes unattractive or adapt their travel behaviour and travel to different destinations, at different times or at different routes. This make it difficult to find the "optimal" fare. What defines optimality is furthermore a question in itself. If operators can freely decide the fare, revenue optimisation is likely the primary objective. However, even for this simple objective, different answers might be given. For example, different assessment of future risks and different planning horizons can lead to different optimal fares. Revenue maximisation over a short time horizon might not be optimal in the long run. People often require time to adapt so that, for example, a short-term fare increase, might create a revenue surplus but in the longer run could lead to a loss. If public interests are involved defining optimality is even more difficult. Additional objectives such as spatial and temporal coverage of a wide range of travel needs of the population might need to be considered and lead to (multi-objective) social welfare maximisation problems.

Fares are "multi-dimensional" which furthermore makes finding optimal ones difficult. This multi-dimensionality is the main topic of this chapter. I suggest that seven fare dimensions can be distinguished as shown in Table 1. An operator can adjust the fare in any one or multiple of these dimensions simultaneously to optimize, or at least improve, the fare structure with respect to prior defined objectives.

Table 1. Fare structure dimensions

Fare dimension		Description/ Decision variable	Examples
Primary dimensions for each trip	Spatial differentiation	Distance travelled, “protected” zones	Flat fares, zonal pricing, different types of distance depending prices
	Temporal distinctions	Time-of-day, season, booking time	Peak hour pricing, surcharges for festive periods,
	Service quality distinctions	Surcharges for on-board privileges	1st vs 2nd class ticket, Onboard Wi-Fi charges, Seat reservation charges or discounts, delay compensation
Secondary dimensions: Modification of the “primary dimension” fares.	Integration	Fare discounts for usage of multiple services (of the same operator)	Free bus-to-bus transfers, Bus-to-train transfer discounts
	Loyalty rewards	Discounts for regular usage	Passes, price capping, point systems
	User group distinctions	Discounts based on sociodemographics	Freedom passes, student tickets etc.
	Booking process	Fare variation depending on booking process and time	Early booking discounts, paperless ticket discount

The spatial and temporal dimensions are probably the most often commonly considered ones as they determine the fare change depending on how far and when the journey is taking place. Flat fares are the simplest structure where the fare is independent of time and distance travelled but almost arbitrarily complex fare structure can be found in different places around the world. Furthermore, pricing according to the “travel class” and additional services is common for longer distance journeys though less so for urban travel. Also, a part of service quality are potential delay compensations. Some public transport operators promise travellers partial or even full refunds if the service has been delayed by too long.

Besides this, there are, however, additional “secondary” dimensions that can modify the fare: For one, multiple and regular usage, in particular of services of the same operator, is in most cases rewarded with discounts for subsequent trips. For example, multiple single trips that constitute a journey are often priced less than several trips during different times of the day that are each classified as a journey. Further, multiple usage of services across a day, week or month are in most cases rewarded with other discounts. Other time, space and service quality depending fare modifications are implemented for vertical and horizontal equity reasons. the spatial and temporal fare often vary depending on who travels. A typical example is that an older person might pay less for the same journey on the grounds that s/he is in more need of taking the journey by public transport and/or because it is assumed that s/he has less disposable income. Similarly, a person with a disability might not have to pay surcharges for a higher service quality such as a reserved seat.

To note is further that the set of feasible fare structures depends on the technology with which fares are collected. Paper tickets do not allow for a simple implementation of complex discounts depending on how many and how far a person has been travelling. Electronic ticketing such as smart card systems make such implementations much easier. It further enables an integration of the ticketing with other services. For example, joined pricing of travel and discounts of goods or for entrance fees to attractions.

Three causes triggering the need for fare structure changes

Public transport service providers need to react to the environment in which they are operating and adjusting fares is one of the tools. At least three technological and societal trends have been, and will be, a major trigger to consider fare structure changes along the above-mentioned dimensions.

Firstly, COVID is having a large impact on public transport and urban public transport demand is not likely to recover soon fully to pre-COVID levels. Even if lockdowns and other mobility restrictions will not return the effects of COVID will be apparent. For one, establishing trust in the services, in that there are no increased infection risks, is a major task. Furthermore, some passengers have walked away from public transport and have formed new habits. They might be now using "my car" or have discovered the attractiveness of active modes and hence are not likely to return (Eisenmann *et al.*, 2021). Many public transport operators have accumulated significant debts due to COVID and might need to recover these partially through fare increases. Along which of the seven fare design dimensions this will occur will be an important question. It will also depend on how organisational structures and business models of public transport operators will be changing which is closely related to the role of public transport within "Mobility as a Service" (MaaS) as this article will discuss.

A second trend, and connected to the later defined MaaS concept, is the rise of new forms of mobility. Ride-sourcing service such as DiDi, Uber or Grab have been, on the one hand, creating some demand for public transport by functioning as feeder services but, on the other hand, have taken away demand from mainstream, mass urban public transport such as buses and metro. Whether the net effect is positive or negative can be disputed and has been especially researched in the US with its large ride-sourcing market. 2018 studies suggest that the effect is insignificant (Malalgoda and Lim, 2018) or even positive for transit (Hall *et al.*, 2018). Instead a large report in 2020 suggests that there is evidence that especially in metropolitan areas the net effect for public transport is negative (Watkins *et al.*, 2020). The ability of ride-sourcing services to provide reasonably priced, seamless door-to-door services provides advantages that the "old" public transport cannot provide. The trend is likely to continue and become even stronger once the ride-sourcing services become autonomous and can then operate with even lower prices (Mo *et al.*, 2021; Iacobucci and Schmöcker, 2021). Besides such "cheap taxi" services, mobility in cities is under transformation due to e-scooters, shared bicycles and other "(e-)micro-mobility" or "little vehicles" as they are sometimes referred to. Here, mass transit can have some more hope that these services function more as feeder services than as replacement, but clearly for short distance trips some local bus or metro trips will also be replaced (Krizek and McGuckin, 2019). In other words, micro-mobility can function as collaborative first-last mileage (1LM) services as well as a competing mode for short trips. As to what element is larger will depend on a range of factors including urban geography, the transit network layout and the quality of the road network.

A third important overall trend is related to digitalization. Teleworking, online shopping, and better information about live crowding and attractiveness of specific places not necessarily mean people travel less, but that they travel to a broader range of different destinations. Working from home, for example, is likely to replace regular trips to a fixed destination with other trips such as shopping and recreational trips in the neighbourhood (Elder, 2020; Ravalet and Rérat, 2019). COVID certainly further sped up this trend and it will be interesting to observe what percentage of jobs has permanently shifted to teleworking. The article will discuss that this broader spatial and temporal distribution of trips will also have impact on the fare structures.

Taking these trends together, one might hence argue that the role of public transport is overall changing. The "mass" aspect in terms of many people travelling to the same destination on a regular basis is likely less needed. "Mass" is also possibly less desired to ensure some form of social distance on the services as well as at the activity places. To note is also that with the advent of autonomous driving it becomes cheaper to operate smaller, more frequent vehicles.

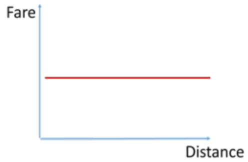
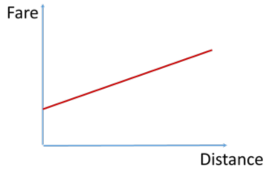
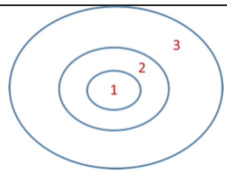
Nevertheless, some form of "large public transport vehicles", at least larger than taxis, will remain to be needed in the foreseeable future. Relying only on shared (autonomous) small vehicles is likely not sustainable as shown in simulations where large (autonomous) ride-sourcing fleets are added to a city's transportation system (e.g. Mo *et al.*, 2021). At least this is likely to be the case until all vehicles are autonomous, connected and run fully based on renewable energy sources. Until then transport service adjustments are certainly one aspect as to how operators can react to these challenges. The other tool are fare level and structure adjustments. The remainder of this chapter is a discussion as to how fares might change following the above defined seven dimensions. A relatively long discussion is devoted to the spatial fare discussion as it is one of the most prominent adjustments.

Spatial dimension: Fare flexibility

Table 2 shows the general types of distance-based fare structures and their main merits and demerits. Flat fares do not differentiate prices according to the distance dimension and are easiest to understand for customers as well as to implement for operators as tickets need to be checked only once, either when boarding or alighting. Flat fares might, however, be perceived as unfair, though the fairness discussion is complex. On the one side, distance-based fares are arguably fairer as passengers "pay for what they consume". On the other side, passengers are "punished" if they live further away from the main points of activities. Some people might choose longer access times for a trade-off with life quality enhancing larger properties that can often be found in the suburbs. For others, with low income, the residential location might, however, be less of a choice and they might be forced to travel long distance to work places.

Zonal fares might be seen as a compromise between flat and distance-depending fares. The introduction of zones allows one to distinguish prices for areas with certain land-use characteristics. Suburbs are often priced different than central business districts. The latter are often priced higher to avoid public transport congestion. Zones can also be used to encourage choices of residential locations not too far from commuting destinations but to reduce the aforementioned potential negative effects for poorer population groups. There are a range of zonal types as shown in Figure 1. Ring-radial types are common in areas dominated by one municipality whereas "areal zones" are more common in cases of wider regional fare structures. Ring-radial types might further have sectors to be able to differentiate fares according to length even if these are within a ring.

Table 2. Basic categorisation of spatial fare structures (adjusted and extended from Vuchic, 2005)

	Flat	Distance-based	Zonal
			
Merits	Simple for users	Fairness perception: Travellers pay according to "consumption"	Compromise between flat and distance-based ones
	Cheap to implement	Potential for Revenue maximisation	Ability to surcharge or discount certain areas
Demerits	Fare level increase has largest effect	Potentially difficult fare calculation (if route depending)	Inequitable costs for short, cross-zonal and long, within zone trips
	Lack of flexibility to adjust	Expensive to implement and control	

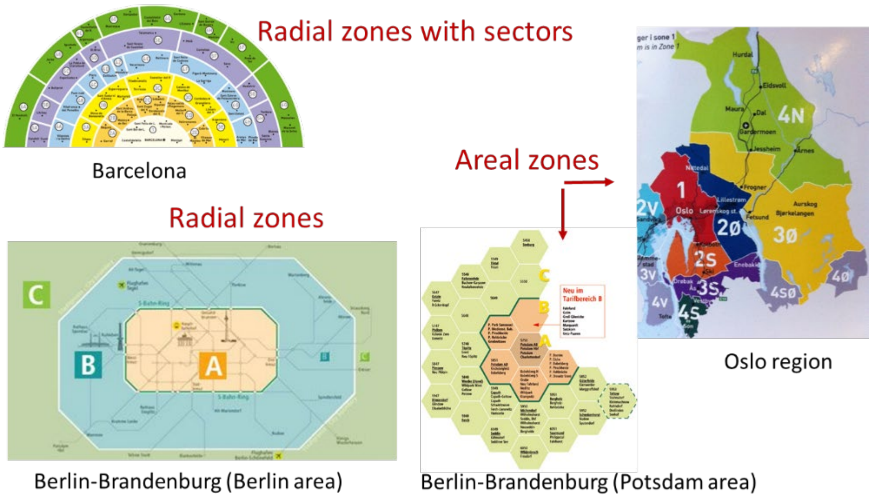


Figure 1. Examples of different types of zonal fare structures (Source: Schmöcker *et al.*, 2016)

There is an important difference for all these three fare types compared to ride-sourcing fares. The latter are not fixed and published and can be origin-destination specific without a predefined "distance-function". This allows ride-sourcing operators to offer fares that are attractive for a specific journey in comparison to all other modes (and other ride-sourcing competitors). In other words, the flexibility of the fare structure allows the ride-sourcing operators to get closer to (short-term) revenue optimal fares. Whereas users of ride-sourcing services appear to be willing to accept this uncertainty, it is generally less accepted for public transport prices. Previous research has shown that simplicity is a value in itself regarded highly by public transport passengers (Bonsall *et al.*, 2007; Bonsall *et al.*, 2009). Even though sensitivity to some price differentiation might have been reduced through cashless payment systems, this is likely to remain the case in particular for frequent travellers. A recent study tested different forms of complexity in the form of temporal and spatial aspects and confirmed that difficult to understand spatial fare structures are disliked and might lead some people to abandon public transport (SGS, 2020). Furthermore, the equity and transport accessibility discussion is also, at least until now, focused on public transport and less on shared mobility. Within the fairness discussion there are often expectations that specific origins or destinations should not be charged too differently or at least transparent, for such equality reasons (Batarce and Mulley, 2016).

This "simplicity expectation" is an important constraint for public transport operators and to remain attractive for various parts of cities calls for more flexible spatial (and temporal) fares instead of remaining only attractive for people that have close access to public transport or happen to have the origin and destination of their activities in the same zone.

Below Table 3 is taken from the study of Zhou (2021) and shows an example of an assignment based, roughly, on Kyoto data. The city is divided into 500m^2 zones and origin-destination demand is modelled based on data obtained from mobile spatial statistics of a major mobile phone service provider. Public transport travel times between all meshes are estimated based on average bus speeds assuming a uniformly distributed service coverage. Inhomogeneity in the public transport accessibility is added through the addition of the two metro lines serving Kyoto from north to south and west to east. Travel time between meshes served by the metro are then estimated by the faster metro speed. Passengers from other meshes have the choice between taking the bus or walking to a metro station and then taking the metro. To note is that the urban commuter train lines of JR, Hankyu and Keihan have not been modelled. In Kyoto and many other Japanese cities these lines do, however, play an important role and would reduce the spatial inequality in public transport provision illustrated in Figure 2. With less spatial inequality and better public transport provision also some of the exemplary effects shown in Table 3 would be reduced.

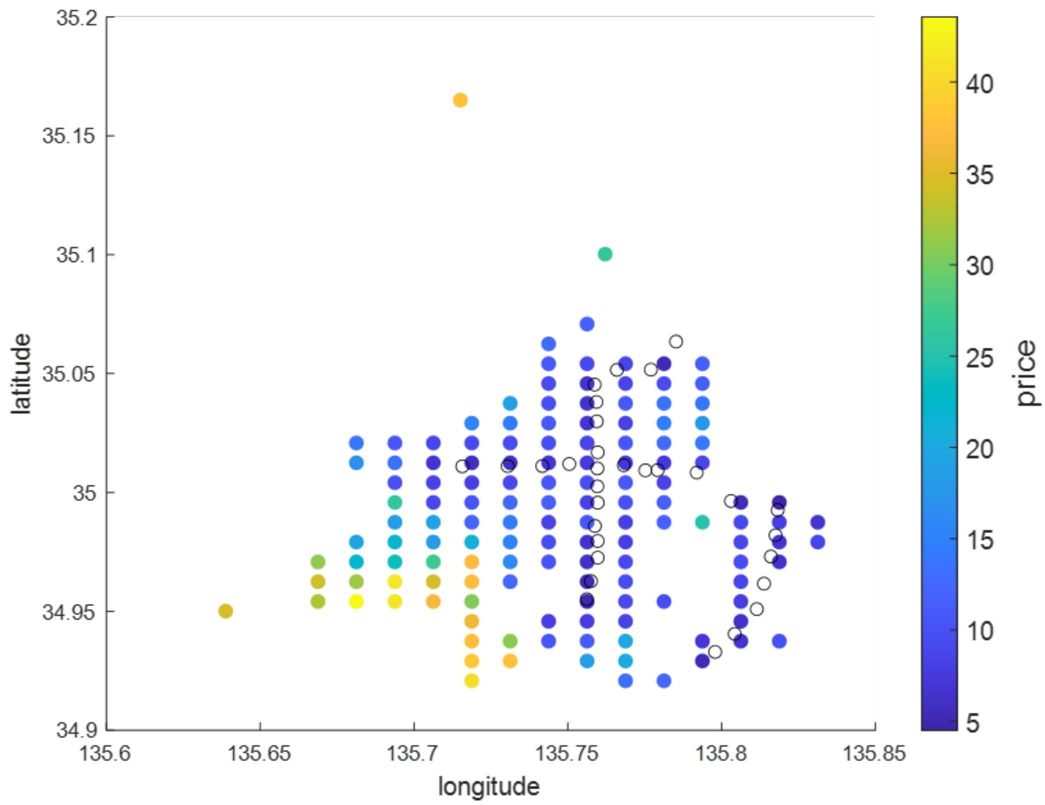


Figure 2. Illustration of modelled area. Each coloured dot represents one mesh area. Colours indicate generalised, mean public transport travel cost to travel to any other mesh. Empty dots represent metro lines (Figure adjusted from Zhou (2021)).

The model further assumes that autonomous ride-sourcing services have become ubiquitous and operate with a large fleet size. The operation, including relocation, of these vehicles is based on a simulation described further in Iaccobucci *et al.* (2019) and Iacobucci and Schmöcker (2021). In the study of Zhou (2021) the focus was on the pricing that might be chosen by a revenue-maximising ride-sourcing operator and its potential impact on public transport. The results are not meant to be a precise future scenario but to indicate limiting cases of tendencies to be expected.

Three scenarios are shown in the table. In the first case no ride-sourcing service is operated. In the second, the ride-sourcing operator is assumed to be limited to distance depending prices, whereas in the third scenario the revenue optimal price for each OD pair can be charged. In the unconstrained pricing case the ride-sourcing service in fact takes a lower modal share as it picks up only journeys that are attractive for the service. The operator sets the price of the journeys at a marginally lower price compared to taking public transport considering generalised cost for the OD pair including access/egress to the station. As a result, the total cost of the travellers is only marginally reduced compared to the scenario without ride-sourcing service. This example illustrates the likely effect if the pricing of one market player is constrained whereas the other player can charge the, for him, optimal prices. More flexible public transport pricing could not only lead to larger revenue for public transport but also to larger social welfare.

Table 3. Operator and passenger costs for a Kyoto mobility case study with a large autonomous car-sharing fleet (Model details are reported in Zhou, 2021)

Scenario	**Passengers**			**Car-sharing (CS) operator**			
	Total cost of PT ($)	Total cost of CS ($)	Total cost ($)	Revenue ($)	Relocation cost ($)	Profit ($)	Modal share
Without car-sharing	2,822,900	--	2,822,900	--			
Distance-specific pricing	425,540	1,004,952	1,430,492	904,460	66,783	837,677	88.65%
Dynamic pricing	1,453,900	1,282,100	2,736,000	1,204,400	50,060	1,154,340	47.05%

To note is further that the COVID and digitalization trends are likely to increase a dispersion in activities so that a public transport service that is only relevant for some, previously frequently travelled, origin-destination (OD) pairs will lose further customers so that the effects shown in Table 3 will be further emphasized.

In case of (OD independent) distance-based fares it has to be considered that current fare structures are usually not linear as indicated in Figure 1. Instead the fare increase per km is usually concave, i.e. marginal decreasing the longer the journey. This means that longer journeys are relatively more attractive to be made by public transport. If one further considers the fixed access and egress costs than this effect is even further pronounced. Marginal decreasing prices also appear to be a "natural" pricing strategy as operating costs are to a large degree fixed costs and distance depending costs are low. For ride-sourcing services this is only to a lesser degree the true.

A potential future strategy for public transport operators might hence be to strengthen this aspect to keep a competitive advantage to ride-sourcing trips for relatively long urban trips. Maadi and Schmöcker (2020) analyse this and suggest that marginal decreasing prices can lead to win-win situations for travellers and public transport operators. Focusing on the longer journeys might also be desired from an environmental point of view. Short journeys can be made increasingly with the aforementioned micromobility options. Furthermore, aiming to compete with micromobility through pricing strategies appears to be not feasible. Travelers are not likely to be very sensitive to the low fares for short distance trips and convenience aspects will outweigh the decision criteria in many cases.

The temporal dimension

The temporal dimension of fares appears to be relatively little utilised in Japan for urban public transport. Peak hour pricing for single journeys is nearly non-existent. Only small discounts are available for passes or multiple tickets that are limited to off-peak travel. For example, rail operators such as e.g. Hankyu, sell “11 for the price of 10” multiple tickets that can be used at any time during the day. If one limits oneself to travel off-peak hours only one can obtain “12 for the price of 10” tickets.

Compared to peak hour pricing in other countries the differences between such peak and off-peak prices are, however, relatively low. In Sydney, for example, off-peak fares are 30% cheaper than peak-hour fares. Sometimes stated reasons for the little usage of this fare dimension in Japan are that employers usually carry the transportation costs and that employees should not be penalized for having to be at the work place at a specific point in time. At the same time the congestion in Tokyo’s and other major cities public transportation network during peak hours remains a significant issue. The COVID crisis has given additional pressure for encouraging peak demand spreading. To some degree the changed activity patterns have supported spreading but pricing will be an additional tool.

More common in Japan are, for longer distance train travel, surcharges and limited validity of season tickets for festive seasons. The validity of multiple-ride Shinkansen tickets, for example, often excluded holiday periods around New Year, Obon or the “Golden Week”. The prices for single tickets is, however, remaining fixed in Japan even during these festive seasons. In many other countries, where ticket prices for long-distance trains depend on demand, travellers can end up paying significantly more for journeys during peak seasons.

The service quality dimension

The third primary dimension are fare differences according to service quality. The most obvious quality distinction for urban public transport is whether one travels standing or seating. Traditionally the seat itself is seldomly priced for urban public transport, whereas pricing for seat reservations is common for interurban travel. However, this is starting to change. In Tokyo, for example, on some commuter trains seat reservations can be made (The Mainichi, 2016).

Further, with COVID fears the dislike of passengers for traveling in crowded services increases and passengers are more willing to pay for a guaranteed seat and space to other customers (Shelat *et al.*, 2022). In how far this has increased demand for 1st class seats is, however, not yet clear from available studies. Chapter 5 of this book discusses the feasibility of commuter services being transformed into reservation only services. In general, lower passenger density means lower capacity but it can be argued that the effect might be reduced or even fully compensated by potentially higher speed due to faster boarding and alighting. If that is the case then also fare increases could be avoided.

Guaranteed seats with services such as free Wi-Fi might also be an attractive point for public transport compared to ride-sourcing. For example, laptop work seated on a train is more convenient than on the backseat of a shared vehicle. Furthermore, if the above assumption that new transport systems such as e-scooters and shared bicycles decrease the usage of public transport for short trips holds, then the remaining and, on average, increasingly longer public transport trips are also likely associated with the desire for more on-board service quality.

With respect to on-board quality improvements hence the overall trends seem to point all in the same direction: There is scope to re-gain customers with higher service quality and passengers are more likely to be willing to pay for it.

Finally, as noted in the introduction, delay compensation might also be considered to be a part of the service quality discussion. Operators such as Transport for London (TfL) offer customers travelling on the tube (but not on buses) a reimbursement of their ticket price if they experience more than 15min delay (TfL, 2021a). Precondition for this is that customers have registered there information with TfL which might not be the case for occasional travellers. The role of delay compensation might also become larger with more competition from other modes and wider service integration as will be discussed in the following.

The integration dimension

In the remainder the topic are the secondary fare structure dimension. These are dimensions as to how the spatial, temporal or service quality depending fare will differ according to user, booking and trip attributes. Firstly, I discuss the fare integration between services for a single journey. Within this context Mobility-as-a-Service (MaaS) has become a major keyword and describes an operational and pricing integration of several mobility services within a city with "the user at its center" (Hensher, 2020). The Japanese Ministry of Land, Infrastructure, Transport and Tourism distinguishes five different levels of MaaS (MLITT, 2018); ranging from no integration (Level 0) to integration of information provision (Level 1), integration of payment for single trips (Level 2) to provide ticket bundles across modes (Level 3) and co-operation with public authorities to guide transport policy (Level 4). To note is that actual implementations on a wider scale above Level 2 are so far limited.

MaaS concepts are expected to increase in the future and modify the role of current public transport operators. Mulley and Nelson (2020) discuss four forms of MaaS illustrated in Figure

3 and refer to these as “walled gardens”, “public MaaS”, “regulated utility MaaS” and “Mesh-y MaaS”. A main point of their discussion is the implications for public transport finances. The main difference between these four forms is the existence, ownership and regulatory power of the (financially attractive) platform that handles trip requests, their booking, payment and assignment to modes. Whereas in “walled gardens” and “regulated utility MaaS” the public transport operator would remain in competition with other modes, in the “public MaaS” concept the public transport operator becomes the integrator of the services. Mesh-y MaaS is characterised by the absence of a regulator so that users, different operators, payment systems and trip booking organisations can all interact freely with each other.

In public MaaS the user interface with the booking and ticketing facilities for trips with various modes including, possibly, bicycle sharing, ride-sourcing and conventional public transport is regulated and fed with information by the public transport operator who has contracts with the bicycle sharing and ride-sourcing companies. If the public transport operator turns into such a “MaaS operator” then this might have large implications for the primary fare dimensions.

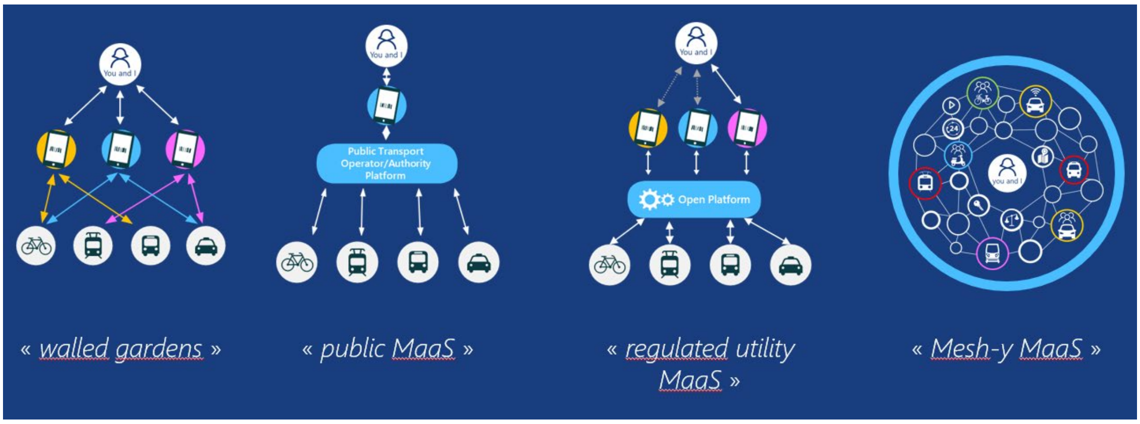


Figure 3. MaaS organisational forms. Figure taken from Mulley and Nelson (2020).

In that case, since the MaaS operator would have a stake in all modes, one can define and calculate optimal fares as those that generate a maximum revenue across all modes. For single journeys, discounts might be given to those who combine public transport services with micromobility for the 1LM. Encouraging such services to be used as feeder services could open up new markets for the longer distance public transport services where users currently use their own car.

In the following I limit the discussion to the case that one or several traditional mass public transport operators are “on their own”, i.e. the objective of fare policy concerns the mass public transport service provider only. Furthermore, in Japanese cities, despite MaaS being a buzzword, MaaS implementations beyond Level 2 appear to still require some time. The current situation is that transfers to different operators - and often even transfers among lines of the same operator – are associated with surcharges or even the need to buy a new ticket. Clearly integrated prices are required to improve the competitive advantage compared to other modes. From an international perspective, the Japanese fare *technology* integration is world-leading whereas the fare *structure* integration is not.

Within the context of infectious diseases such as COVID, from a public health perspective, however, a contradicting objective should be discussed. Transfers might want to be discouraged as it creates a new mix of travellers. If travelling on the same service can also bring the traveller to the destination, but with a longer travel time, that option might have to be encouraged. In Japan, this is particularly relevant for interchanges between local and express services. If the origin and the destination are served by local services but not an express service, then often an interchange from a local to an express and back to a local service can save a (small amount) of travel time. If the travellers can be encouraged to stay on the local service this might be desirable from a public health perspective as well as possibly from a congestion perspective since express services tend to be more crowded. Hence, though in general integration is desirable, there might be some drawbacks as well. One might conclude that the integration policy is depending partially on how the virus spreads. If the spreading probability is highly depending on the time spend in the vehicles and less related to density, in the above example, instead a fare policy that encourages usage of express trains and strictly minimizes the total travel time of all travellers would be desirable.

The loyalty dimension

"Loyalty" in this discussion is used to describe the repeated usage of public transport. In contrast to the integration dimension here multiple usage not for the same journey but over a day, week or longer periods is meant. Clearly there is again overlap to the MaaS discussion in that "ticket bundles" also refer to multiple journeys. Mulley and Nelson (2020) discuss that the type of MaaS implementation will have implications for the way public transport is subsidised. This in turn will have implications for the price of single tickets and ticket bundles. If ticket bundles are sold by an independent platform it will be difficult to reward public transport usage. If instead the public transport operator sells multimodal ticket bundles (public MaaS, Level 3), still discounts for frequent usage of public transport are easier to implement. Even "complex", artificial intelligence based sustainable, behavioural change encouraging pricing schemes are thinkable. For example, if a repeated usage of ride-sourcing for a particular trip is observed, a discount might be provided to this user for undertaking this trip next time by public transport. As in the previous section, my focus is, however, on repeated usage of mass transit services only. It is suggested that various types of loyalty schemes could be used to (re-)attract customers.

"Passes" that provide unlimited travel for fixed price and "multiple journey tickets" are the classic way to discount regular usage. Considering COVID and digitalization impacts, an important issue is the consideration of the increased risk for investing in a ticket given uncertainty as to how much travel might actually be needed or permitted over the validity period of the pass. Customers might hesitate to buy longer term passes as they cannot foresee their travel conditions too far ahead. Even COVID taken aside, increasing teleworking might make it more difficult for customers to estimate whether it is worth it to purchase a pass.

Therefore, one way to counter this might be for the operator to take some share of the risk. Electronic ticketing has made "price capping" feasible and in some cities around the world this has been implemented. In London, for example, price capping is applied for customers without longer time period passes. Such customers can use their pay-as-you-go smartcard without concern as to which ticket is best for them to use. Instead customers will be stopped charging if the sum of their ticket prices has been exceeding the price of a pass. The concept has been initially introduced for the set of journeys across a day (daily capping) and subsequently been expanded to all journeys across a week (weekly capping) (TfL, 2021b).

In Japan a similar idea has been introduced with the "My-Style ticket". Where normal passes are limited to specific routes, this ticket allows flexibility as to route choice. More importantly, in the context of the COVID discussion is that the ticket is also an "insurance". If the person has not used the service much during the month, the person will only be charged the amount that s/he actually travelled and be reimbursed (see Osaka Metro, 2021). The scheme can hence be called a "backward capping" scheme in contrast to the London style "forward capping". In the Osaka case the backward capping does include some surcharge for the user, i.e. the user has to pay for the insurance. Figure 4 illustrates the two capping concepts. The argument as to when a such an insurance surcharge is appropriate might be mainly based on the time-period of the pass. In the Osaka case it is a monthly ticket so that the risk incurred for the operator is substantial. To note is that forward capping could also include an insurance fee.

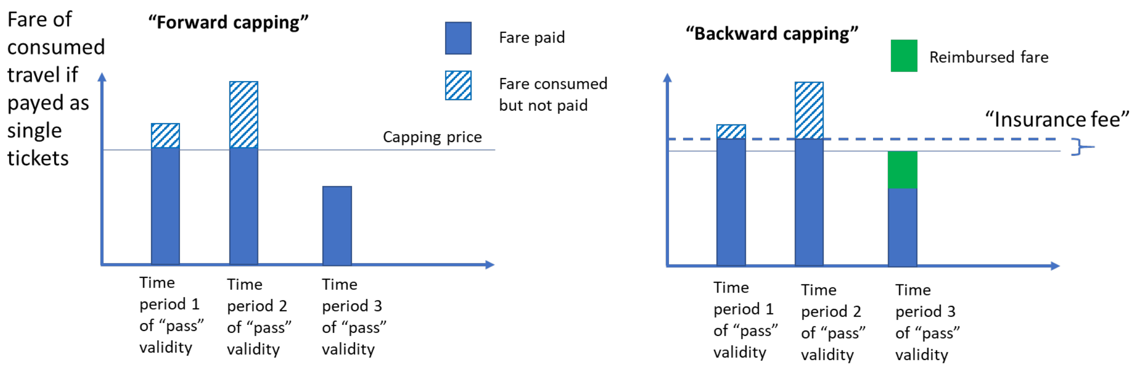


Figure 4. Illustration of London style forward and Osaka style backward capping with insurance fee

With unpredictability of travel needs (or even permissions to travel) such capping schemes are likely to gain in popularity. Reasonable monthly passes and capping are further a potential tool to counter the competition from new transport forms. As ride-sourcing is likely to remain more expensive than mass public transport, travellers might be more willing to commit on a public transport pass than on a more expensive pass for unlimited ride-sourcing trips such as promised in some MaaS concepts. Hence finding appropriate prices for passes appears to be an important issue for sustaining public transport demand.

Finally, in this subsection the potential for loyalty points for travel and other activities must be noted. Mileage schemes and other rewards schemes are common for airlines as well as for retail. In retail, nowadays these are not only limited to expensive items but are also common for frequent small purchases comparable to prices paid for public transport. In Japan, for example, all major convenience store chains have their loyalty cards. The main reason why such loyalty schemes are introduced is to fend of competition by aiming to "bind customers" to this chain. Applied to public transport, however, this competition is often missing or less severe. Either because there is only a single operator offering a service, or, the competition is not perceived as repeated decisions. Take the transport between Kyoto and Osaka as an example. Here there is a competition between Hankyu, Keihan and JR. Commuters from Kyoto tend to make once a rational decision based on their perceived utility as to which route to take and then stick to it. This means that additional "points" are not likely to influence their decision. Occasional travellers on the other side, are likely to inform themselves about the best route and since their travel is not frequent are also not a market for loyalty points.

Though point schemes for a public transport operator might hence be only of limited use to address competition with other operators, the situation could be different if the goal is to persuade travellers to use public transport instead of their car and/or to attract them to use public transport in combination with other activities. Here in particular Japanese public transport operators with their wide range of other businesses could have an advantage compared to many operators abroad. A good example is the Shizutetsu co-operation. The company's core business is the bus operation in Shizuoka City but besides that, Shizutetsu owns a number of other businesses including a shopping mall and several supermarkets across the city. Shizutetsu made a number of trials to offer discounts for shopping activities if the traveller has also been using a Shizutetsu public transport service to access the supermarket or mall.

In Nakamura *et al.* (2016) a stated preference survey was conducted with respondents from Shizuoka to assess the sensitivity of travellers to such loyalty points. Users were promised discounts for shopping in a Shizutetsu store if they would have used a Shizutetsu bus service on the same day. Different rewards such as a lottery with a chance to win a large price and small certain rewards where compared. Furthermore, current Shizutetsu transport and/or shopping users where included. The overall conclusion from all scenarios was that with limited, reasonable loyalty schemes some public transport users could be attracted to go more shopping in the company's stores. Furthermore, some, though fewer current shoppers who do not use public transport were attracted to also start using public transport. In general, it is suggested that "urban mileage cards" have some, limited, potential to attract customers to public transport.

The user group dimension

In contrast to previous dimensions here users receive spatial, temporal and/or service quality related discounts not conditional on any previous usage but as a result of certain socio-demographic characteristics. In Japan, as in many countries, discounts for persons with various disabilities or special needs, students or older people are common. Student discounts are mostly in the form of reduced prices for monthly passes. In most countries older people can obtain discounted or even free travel passes. The passes mostly have a long temporal validity and are also often not restricted to certain routes.

In Japan these passes are commonly referred to as "Silverpass" and are widely available in many cities. The conditions to obtain a Silverpass as well as the rules associated with this pass though vary across Japan. Whereas in some cases the pass can be obtained for free, in other cases a fee is required. In some cases incentives are given in the form that giving up ones driving licence qualifies one to obtain a Silverpass with unlimited local public transport usage for free.

Considering the three triggers for change discussed in this chapter as well as general sociodemographic trends, different influences are expected. For Silverpasses, on the one hand, changing sociodemographics with an increasingly aging population might also mean that conditions for obtaining the passes have to be revised and tightened in order for operators to keep their farebox revenues. On the other hand, the demand for Silverpasses might be reduced due to COVID and new transport forms. Firstly, especially for older people, ride-sourcing and increasingly autonomous vehicles might make non-public transport options more attractive and reduce the desire for obtaining a Silverpass. Secondly, the fear of COVID is likely to have a longer lasting effect on the fear of using public transport especially among the more vulnerable aged population.

For younger people, such as students, similar to above discussion and to arguments made in Section "Loyalty rewards", the increasing amount of educational activities being conducted online may reduce the need to obtain passes. To note is also that from a public health perspective there might be some pressure to not incentivize frequent travel of those vulnerable to infections or for population groups for whom the effect of an infection might be significant. In other words, it could be considered that the monthly passes should be made less attractive for population groups with higher risks. Overall, I suggest that the conflict to reduce the price for certain sociodemographic groups but to raise the fair out of operational necessities might further increase.

I conclude this section with a note that MaaS implementations will also have an impact for this dimension. MaaS implementations, possibly particularly "mesh-y-MaaS" will allow to price ticket bundles differently for certain population groups. If the booking-app is independent of the operator then it might be profit enhancing to make more user group distinctions than currently.

The booking process dimension

Finally, fares can vary according to when and how a ticket has been purchased. For long distance rail and especially air travel this is often clearly one of the most important aspects that determines the fare. Such early pricing concepts are, however, rarely employed in urban contexts. It is not only a data management and reservation system problem but also because users value flexibility and do not want to be forced to make short distance travel decisions early. Nevertheless, for demand management purposes, especially with COVID, early booking allows the operator to manage the demand better. Further, as discussed in the previous chapter, the omnipresence of smart phones makes fast but mandatory reservations services feasible which could also encourage incentives for early bookings or (small) penalties for the on-the-spot changes to reservations.

One implementation might further be to combine early booking and peak-hour pricing for regular travellers. That is, there is only a limited contingent of monthly passes between two zones or on a certain line for a certain price available. If this limit is exceeded, the next batch of tickets would be sold at a higher price, or, if users want the original price, they need to buy a pass for a different time period. Also here, with electronic ticketing the introduction of such concepts is not difficult.

Conclusions

This chapter proposed that fare structures can be divided into seven dimensions. Applied to Japan, public transport fares have long been simple in some of the above seven dimensions and complex in others. As a brief summary: On the one hand, spatial fare structures are often difficult to understand for users in Japan with flat zone tariffs applied to some part of the journey and distance-based pricing with a range of exceptions in other parts. A main reason for this has been the competition among several operators. On the other hand, the fares have little time dependency in terms of time-of-day or seasonality. Service quality differentiations, as in reserving for seats, are starting to be introduced also for urban travel. Integration of fares in Japan between operators is still behind common practice in many countries, partly again because of the multitude of operators. It was discussed that loyalty schemes could be much more utilized considering the wide range of additional businesses that public transport operators in Japan are involved in.

Overall there is a conflict between simplicity and complexity. Simplicity is a value in itself as travellers do not have to pre-plan or calculate what the best fare is. Operators might avoid complex fare structures that promise to create higher revenue for the longer-term benefit of customer satisfaction. A good example is Stockholm where the fare structure has been changed multiple times but eventually returned to a flat fare for large parts of the system.

Figure 5 is taken from Schmöcker *et al.* (2016) and illustrates the conflict. In their study operators from Europe and Northern America where asked what type of changes in the fare structure they are hoping to make in the future and with which kind of objectives. The operators mentioned several structural changes to the fares according to the dimensions discussed in this chapter. In particular harmonisation of the spatial fare structure including the peripheries around the metropolitan areas was a big topic. Other operators also mentioned changes to peak hour prices and changes in terms of discounts for specific sociodemographic groups. The figure plots a word cloud of the objectives for such changes. Simplification in itself is an objective for many and was mentioned as a value by half the operators. The other half want to make use of advanced ticketing technology and diversify their ticket range. Interestingly, *fairness* was mentioned by both groups. Whereas some perceive simple fares as fairer, others perceive it fairer to charge according to needs and service usage. An argument for spatially simple fares is, as noted in the introduction, that those who need to travel long distances because they cannot afford accommodation in the city centre should not be additionally burdened by higher transportation fees.

Figure 5. Keywords mentioned regarding future fare strategies by public transport operators. Size of words indicates frequency of mentioning (Source: Schmöcker *et al.*, 2016)

Part of simplicity is also transparency and predictability of prices. Ride-sourcing operators such as Uber, for example, have received numerous complaints for OD and time dependent prices (RideGuru, 2018; New York Times, 2021). Sudden surcharges for e.g. airport journeys when other modes experienced disruptions or in times of high demand after festivities have been experienced. This clearly led to frustration among many travellers.

The discussion highlighted, however, that at the same time ride-sharing can take advantage of inflexible public transport fares. Due to operation on fixed lines, spatial inequalities in service quality are a characteristic of mass public transportation systems. As argued, ride-sourcing operators can hence maximise their revenue and reduce public transport demand by attracting passengers that have higher generalised cost for the public transport option. To avoid overly complex spatial pricing, but to secure a certain market share, possibly these effects can be reduced by utilising the other six fare structure dimensions.

It was emphasised that COVID and digitalization amplify these challenges due to the mass public transport unfriendly trend towards further activity dispersion. This might reduce the need for diverse time-of-day pricing but, at the same time, creates the need for new fare products that reduce the risk of buying, for example, long term passes. The chapter also proposed that pricing for high quality public transport services can be considered as an opportunity for public transport. Overall, clearly, the seven dimensions should be utilised to maintain and improve the attractiveness of future urban public transport.

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