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研究課題名（和文）Complex Transit Fare Structures: Modelling and Potential Impacts

研究課題名（英文）Complex Transit Fare Structures: Modelling and Potential Impacts

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研究成果の概要（和文）：本研究の成果は以下の三点である。一つは、欧州都市交通機関との共同研究を通じて、公共交通運賃構造の変化が都市間に与える影響を調査し、最適で複雑な価格設定を目指す都市と価格の単純化を目指す都市との間に対立が生じることで、「公平な」運賃を決定することの難しさを示したことである。二つ目は、運賃体系を考慮した交通量配分手法を構築したことである。この手法は、運行間隔に基づいて運賃構造をモデル化できるものであり、既存の経路検索方法を改善することが可能となる。三つ目は、連続近似を用いることで、運賃制度がサービス水準に与える影響を示し、運賃を引き上げることで社会的便益が増加するとは限らないことを明らかにした。

研究成果の概要（英文）：The research achieved three main results: Firstly, through collaboration with European Metropolitan Transport Authorities we conducted a survey among large cities showing trends in public transport fare structure changes that are triggered by electronic ticketing and smart phone based ticketing. A conflict between aiming for "optimal, complex pricing" and aiming for simplicity arises. We further showed the difficulty in determining "fair fares". Secondly, an approach to transit assignment that is capable of considering a range of fare structures, in particular non-additive fares, has been established. The approach advances existing path search methods by being the first that is able to model such fares within frequency-based assignment. Thirdly, using continuous approximation, the research illustrates how fares can improve the service quality but that from a social welfare perspective there is usually not much benefit in raising fares.

研究分野：Transport Planning

キーワード：Public Transport　Fares　Assignment　Transport Policy　Network Design

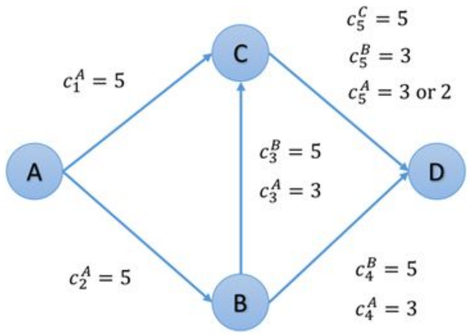
１．研究開始当初の背景

The fare systems of different public transport operators vary significantly not only in the amount of charge per distance but also in the complexity of the fare structure. Whereas in some cities flat fare structures are applied, other cities use zonal, distance or even route-based fares. Currently a number of cities are aiming to change their fare structures but are hindered by adequate demand forecasting tools. In particular there appear to be have been no approaches in commercial software that can model distance-degressive fares where the marginal fare per distance is decreasing the longer the journey. This policy trend and lack of approaches to consider "non-additivity" motivated this research.

２．研究の目的

Following from this background, this research firstly aimed to develop a transit assignment approach that is capable of filling the above described gap. The following scenario describes the problem in more detail.
We consider a link cost structure that can be described with a vector where the first entry denotes the fixed cost for entering the network. The second entry describes the cost for traversing the first link, the third the cost for traversing the 2nd link and so on. The last vector entry describes the cost for traversing link n-1 as well as all subsequent links. E.g. $F = (10,5,3,2)$ denotes a cost structure where the traveler has to pay a base charge of 10 units, a cost of 5 units for the first link, a cost of 3 units for the second link and a cost of 2 units for all subsequent links. Consider below where D is the destination.

The figure illustrates that the classic optimal strategy approach where optimal destination specific "hyperpath trees" cannot be used as



the costs for Links 3, 4 and 5 depend on the "past", i.e. how many links have been traversed before. Furthermore, even for a single origin-destination specific hyperpath, different costs for the same link might be required as is the case for Link 5 from C to D for travelers from A. Travelers on path {A,C,D} will be charged 3 units on the link (C,D) whereas travelers on path {A,B,C,D} will be charged 2 units on the same link.

Besides the modelling work, we aimed to gain more insights into what future fare structures in cities will look like. For this we conducted a qualitative survey with a range of public transport operators in large metropolitan cities.

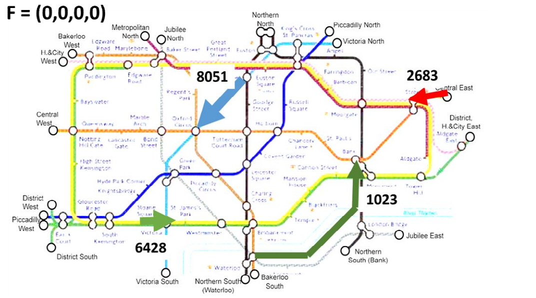
３．研究の方法

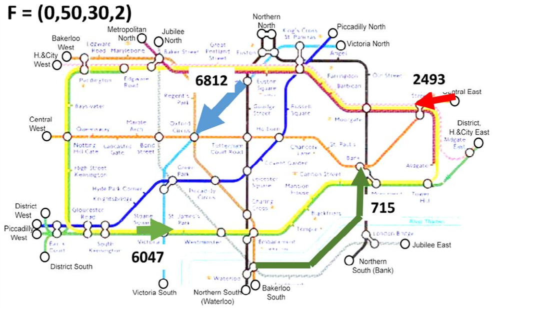
For the route choice problem we develop a mathematical description of the problem considering the "travel history" of a travel until reaching a node. With this we can obtain the expected costs of specific links and with that we aim to obtain the optimal hyperpaths. We develop a 2-stage solution algorithm in which we first distinguish origin-destination pairs for which we can guarantee that the fare does not alter the optimal paths. For the remaining O-D pairs we then develop approaches based on the concept of "critical nodes" that minimize the need for hyperpath enumeration. For details on the developed algorithm we refer the interested reader to our publications.

Regarding the qualitative survey among cities we conducted a survey with the support of EMTA (European Metropolitan Transport Authorities) as especially among European cities a range of fare structures are currently being explored.

４．研究成果

For the modelling part we could demonstrate that our approach is feasible of obtaining the optimal hyperpath with non-additive fare structures in reasonable computational time. Furthermore, we illustrated how the resulting hyperpaths are changing depending on the fare structure as in below two figures where we use London's metro network as example. The results illustrate how appropriate fare structures could help shifting demand away from crowded links and therefore can be considered also a demand management tool.





Regarding the survey analysis among transport operators we clarified a number of key trends such as the emergence of larger fare zones aiming to integrate wider regions. Furthermore, whereas there is one group of cities aiming to implement more complex fare structures, there is another group that is aiming for simplifying the fare structure. The following figure showing key words that appeared in the discussion with the cities illustrate the conflict well. Roughly we can distinguish two groups of cities. We found that the theme “fair fares” is used by both groups of cities to justify very different, indeed contrary, developments. Some cities and operators consider it as fair to charge according to distance and consumption, whereas for another group of cities it is fairer to not do so out of equity considerations and to support those with lower incomes living at the edge of cities who would have to pay more with distance-based fare structures.

５．主な発表論文等

（研究代表者、研究分担者及び連携研究者には下線）

〔雑誌論文〕（計　6　件）

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④ Fonzone, A., Schmöcker, J.-D. and Viti, F. (2016). New Services, new travelers and new models? Directions to pioneer public transport models in the era of big data. Journal of Intelligent Transportation Systems, 20(4), 311-315.

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〔学会発表〕（計　4　件）

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〔図書〕（計　1　件）

① Kurauchi, F. and Schmöcker, J.-D. (2016). Public Transport Planning with Smart Card Data. CRC Press (Taylor and Francis Group), 261 pages.

〔産業財産権〕

○出願状況（計　0　件）

○取得状況（計　0　件）

〔その他〕
ホームページ等

Report for European Metropolitan transport Authorities, titled "Determining Fare Structures: Evidence and Recommendations from a Qualitative Survey Among Transport Authorities." Available from: http://www.emta.com/spip.php?article693

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