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A framework to quantify the differences between multi-modal travel demand: A case study on Brisbane network using Bluetooth and smartcard data

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Abstract

Understanding the differences in multi-modal travel demand can help transport planners to improve the sustainability of a transport system. Thus, this study aims to develop a multi-step methodological framework to identify gaps in demand between different modes and apply on a realistic large-scale network. The framework includes three methods. Method 1 is carried at a coarser level of spatial resolution, while method 2 and 3 are carried at one level finer resolution than that of method 1. The proposed framework is demonstrated using car and transit OD matrices developed from observed Bluetooth and smart card data, respectively for the Brisbane City Council region. The gaps in transit service usage are estimated between different sections of the network by identifying OD pairs that have low transit usage but high car demand. The findings from this study show that there are significant number of OD pairs that might require further investigation in order to improve overall transit patronage for Brisbane city. For instance, Method-1 showed that SA4 (coarser level) OD pair of Brisbane North- Brisbane East needed the most attention for transit improvement, and method-2 further identifies the SA2 (finer level) zones within Brisbane North- Brisbane East (for example, Eagle Farm – Pinkenba) that needed to be further investigated. Although the techniques are only applied to car and transit matrices, the proposed methods are generic in nature, and therefore can be applied to compare other modal combinations.

1 Introduction

Integrated and effective infrastructure management is necessary to meet the growing demand for transport of emerging urban cities. Understanding the transport needs of communities is one of the most important responsibilities of any local government. Especially, the differences in free and constrained demands from multi-modes can help transport planners to improve the sustainability of a transport system. Examples of such free and constrained systems in a multi-modal combination include car (free) and transit (constrained) or for freight truck (free) and rail (constrained) etc. This study develops a generalised framework to understand the demand patterns of one mode in comparison with the other mode and applies the methodology to a specific combination of car and transit demand.

The observed transit demand (say from a smart card) is heavily biased towards its supply and does not capture the true travel demand. This is because, the goals and objectives of public transport are different from other modes of transport as it must cater diverse clients (the public), in many aspects like mobility, travel opportunities and transit service performance (Messenger and Ewing, 1996). Transit demand is also constrained by the transit network coverage within any geographical and temporal boundaries. On the other hand, better connectivity of road network coverage does not cease the car-users and availability of their seam-less trip information (say from Bluetooth) over larger spatial coverage provide an alternative way of understanding true travel demand patterns. Inferring knowledge from car travel patterns might provide many deeper insights into transit level of service than focusing on observed transit demand only. This can be achieved by comparing transit OD matrices with car OD matrices.

In transport modelling the travel demand for any mode are represented by origin-destination (OD) matrices. Comparison of OD matrices need appropriate statistical measures because they are high dimensional data points. Especially, the structure of an OD matrix represents the travel demand distribution.

1. In method-1, Pearson Correlation coefficient used in this study is used to compare the structures of two OD matrices (car and transit) and to compare OD flows of individual OD pairs between car and transit we used another measure – demand ratio. These two measures help transport planners to prioritise OD pairs based on the transit improvement at a higher-zonal level and has strategic importance.
2. In method-2 we compared OD matrices based on trip generations which also refer to the structural properties of OD matrices (Antoniou et al., 2016). The trip generations rank the zones and helps planners to identify the hot spot zones. The lower-level OD pairs that needs immediate attention can be identified from the operational point of view.

Very limited studies such as Naveh and Kim (2018) focused on comparing multi-modal OD matrices such as car OD from Bluetooth and transit OD from smartcard data. However, the idea of identifying the opportunities in the constrained modes from the demand patterns of free modes has not been discussed before. Thus, the proposed methodological framework helps to understand the transit travel demand from the real data.

The objective of this study is to develop a methodological framework to compare and analyse OD matrices for both car and transit users, in order to provide valuable insights into the travel patterns.

This study has significant practical applications in transport planning and management. For example, areas having low or no usage of transit can be identified and compared with car OD demand. This can help transit planners, after further investigation, to take necessary steps for improving the transit patronage. It can be inferred that this analysis would not only identify the gap between transit and car usage but also provide an insight to opportunities identification, for instance, congestion pricing, ride sharing, Mobility as a Service (Maas), etc. The analysis is performed at a macro-level scale and the application of the same is demonstrated with a case study on the big network of Brisbane city, Australia.

2 Methodology

2.1 The idea of *free* and *constrained* travel demands

The concept of *free* demand arises from the notion that car users are free to take any path they like and can reach any part of the city with the vast road network coverage. Providing ownership of a car, a person can travel without any spatial and temporal constraint (Steg, 2007) except restricted areas. Since Bluetooth scanners capture a portion of car trips (Bhaskar and Chung, 2013), the observed Bluetooth demand represents *free* travel demand.

On the other hand, *constrained* travel demand is the result of commuting patterns that are constrained with respect to the spatial and temporal availability, accessibility, affordability and route options of transit service. Thus, the observed travel demand from smart card data is used to represent *constrained* travel demand.

Understanding the differences between *free* and *constrained* travel patterns helps in identifying the zones that might need further investigation in terms of meeting transport demands of any medium or large city. There could be multiple factors that impact the supply of transport infrastructure in order to meet the demand requirements. However, before plunging into detailed investigations, a quick analysis can help transport analysts to identify OD pairs or zones that might possibly have potential demand for public transit. A superficial identification of these gaps is possible by comparing observed car and transit travel demands at a larger spatial scale.

2.2 Proposed methodological framework

The study proposes a methodological framework that includes three empirical techniques/methods applied at different spatial resolution that can help transport analysts for inceptive comparison of travel demand patterns of both transit and car users.

It is to be noted that this study is primarily about the development of methodological framework which compares multi-modal networks, such as car and transit systems, and truck and train network for freight. However, the developed methodology is applied to compare car and transit system by employing Bluetooth and smartcard data as input data for car and transit OD estimation, respectively. For details on Bluetooth data, refer to (Bhaskar and Chung, 2013), and (Tavassoli et al., 2016) for smartcard data.

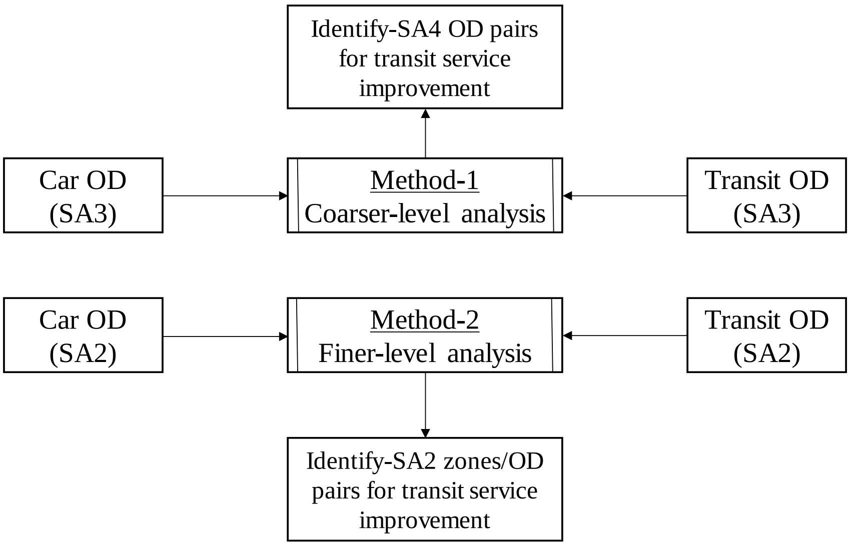
Method-1 consists of the comparison of observed Bluetooth and smart card travel patterns performed at a coarser geographic scale as shown in Figure 1. The OD pairs at one level finer spatial resolution are grouped based on their geographical integrity i.e. refers to the same coarser spatial OD pair. Pearson Correlation coefficient used is used in this study to compare the structures of two OD matrices (car and transit) and to compare OD flows of individual OD pairs between car and transit, the study adopted another measure – demand ratio. Although it is a macroscopic technique, it helps to quantify the differences in travel patterns between both OD matrices.

Method-2 includes the comparison based on different density levels of zonal trip productions and attractions at further finer spatial (second level spatial resolution) zones (Figure 1). This method classifies OD pairs based on the combinations of high, medium and low-density levels. Method-2 also helps in identifying the origin and destination hotspots of car and transit users.

Last but not the least is method-3 that helps to visually identify differences in OD distribution between both modes by representing through heat maps. This method helps in further validating the results from method-2 and is flexible in the sense that any spatial resolution OD can be analyzed. The finer OD matrices will give more insights into the travel patterns and vice versa.

The study demonstrates the application of all three methods with a case study application on the real network of Brisbane city, Australia.

Figure 1: Input datasets and output of the proposed methodological framework



Three methods proposed in this study can be applied individually to assess a city's PT and car usage patterns and identify the zones of transit improvement need. Nevertheless, all the proposed methods can be used to supplement the findings of the study. The authors are of the point of view that using all three methods will give further confidence to the analysts and planners.

3 Conclusion

The study develops a methodological framework to gain insights into the travel patterns by comparing two different modal systems i.e. constrained and free systems. The study chooses car and transit as the modal combinations and applies the methodology to compare and analyse OD matrices developed from Bluetooth and smartcard data from the BCC region. The observed smart card demand is biased towards the supply of transit service and does not represent the true transit demand. Thus, the smart card itself cannot help in identifying the zones that might need provision/improvement in transit service. To this end, the proposed methodological framework assists transport planners with quick empirical but macroscopic techniques in order to identify zones/regions within the city that might require more attention from a transit service perspective.

Applications of this study are vast in the context of transit improvement, the city's transit sustainability, etc. This study can serve as an inceptive study for congestion pricing, MaaS, and deployment of DRU. Consequently, an extension of this study would be to identify appropriate zones for implementation of above-mentioned transport related applications and quantify its impact on overall travel patterns and transport sustainability of a city.

The findings from this study serve as a prerequisite and lead to the ultimate research objective of identifying spatial PT gap in an urban area. More specifically, the framework developed in this study for comparing two modes of transport, i.e., car and public transport, for identifying spatial PT gap could be further extended to other broader transportation modes such as comparing freight transportation modes including ship versus air and truck versus rail.

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