Assessing Transit Accessibility Unreliability and Social Equity Impact with Space-time Prisms

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Uncertainties in public transit systems’ travel time have been a major obstacle to make transit more accessible and reliable for commuters. Due to delays caused by traffic and road conditions, the actual accessibility derived from real-time data can be very different from the one promised by the schedule. However, very few prior accessibility studies addressed this discrepancy explicitly with time geography methods. In this paper, we use a well-established time geography method, space-time prism (STP), to measure the *accessibility reliability*. Accessibility reliability is defined as the difference between STP derived from retrospective real-time data and STP derived from schedule data. The methods will use two mobility datasets of large volumes: General Transit Feed Specification (GTFS) real-time data, which produce retrospective real-time STP, and GTFS schedule data, which produce scheduled STP. We will also investigate the reliability measure’s connections to social equity factors, such as different social, demographic, and economic factors. The paper will conduct a case study in the Central Ohio Transit Authority (COTA) bus system, a public transit agency in Columbus Ohio. The analysis will focus on the spatial and temporal patterns of the reliability measure from 2018 – 2021 across the city of Columbus, especially the changes before and during the COVID-19 pandemic. This can provide insights about possible impacts of the pandemic on the reliability of the transit accessibility in different communities. All the analyses and results will be visualized in a public web-based platform. This paper provides a scalable time-geography approach to gauge the reliability of transit accessibility with very large datasets; some results can also reveal new empirical patterns of transit accessibility’s impact on social equity.

1. Introduction

As transit planning’s focus shifting from mobility to accessibility (Banister, 2008), accessibility becomes a crucial determinant to promote transit policies and foster transit use. Accessibility measures the ease of reaching destinations: a transit system with higher accessibility can have better usability and user experience for transit users; therefore, authorities aim to increase accessibility as one of their priorities. As public schedule dataset like General Transit Feed Specification (GTFS) becomes more available, researchers and transit planners start to calculate accessibility with static scheduled data. Standard data formats introduce a convenient way to access the transit system’s network information, including stops as nodes, trips as links, and scheduled travel time as travel cost. This has greatly helped us understand the accessibility of transit system.

However, accessibility of transit systems is highly dynamic and time-dependent due to traffic condition and delay that the actual performance can be very different from the schedule (Park, Mount, Liu, Xiao, & Miller, 2020). Many prior studies have examined the possible problems of using scheduled data for modelling and benchmarking (Bills & Carrel, 2021; Wessel, Allen, & Farber, 2017; Wessel & Farber, 2019): actual accessibility can have significant deviations from the accessibility calculated from schedule data. There are several factors that contribute to this deviation: first, road conditions and congestions can slow the vehicles down and human operators can leave the stops earlier than the scheduled time. Second, only travel time at timepoint stops is explicitly defined in the official timetables of many transit systems; travel time at non-timepoint stops is derived from interpolation, which is not strictly followed in practice.

This paper introduces a time geography approach based on space-time prism (STP) to understand *accessibility reliability*, retrospective accessibility’s deviation from scheduled accessibility. This measure represents the difference between the actual physical accessible space and the expected accessible space calculated from schedule data during the same time budget; the aggregated version of this measure can also show consistency and quality of the transit service, which is vital for administrative and planning purposes. We use GTFS schedule and GTFS real-time data, then produce retrospective real-time STP and scheduled STP, and finally derive the difference between the two STPs. The origin-level deviation measure has been reported to be non-uniform (Wessel & Farber, 2019) and non-random (Wessel et al., 2017); however, few studies examined its connections to social equity factors, such as different social, demographic, and economic factors. This paper fills in this blank by using geostatistics model to investigate the potential correlations.

We conduct a case study in the Central Ohio Transit Authority (COTA) bus system, a public transit agency in Columbus Ohio. The analysis focus on the spatial and temporal patterns in different levels from 2018 – 2021 across Columbus, especially during the COVID-19 pandemic. This paper provides a scalable time geography approach to measure the reliability of transit accessibility with very large datasets and investigate its implications on social equity.

1. Background
2. Time-independent network based on static data
3. Time-dependent network based on static data. unreliability research
4. Time-dependent network based on dynamic data
5. Method

We introduce the method to calculate the accessibility unreliability in this section. We first introduce the two main transit datasets we use in this paper. Then, we demonstrate the time-dependent Dijkstra algorithm to calculate the two versions of space-time prisms. Last, we propose the data source and geostatistic model to investigate the connection between accessibility reliability and other social and demographic factors.

* 1. Data source

The main data source of this paper will be general transit feed specification (GTFS) data, which can be moreover categorized into GTFS static and GTFS real-time data. GTFS static is the de facto

Space-time prism is a well-established time geography method to measure accessibility in public transit systems (Miller, 1991; Wu & Miller, 2001).