Impact of Unplanned Service Disruption on Urban Transit Systems

1 INTRODUCTION

With advances in automated fare collection (AFC) and automated vehicle location (AVL) data, system-wide effects of transit network incidents can be investigated. In this study, we propose data-driven analysis frameworks from both supply and demand aspects to create a better understanding of incidents’ impacts. The analysis includes quantifying network redundancy, analyzing passenger flows, and modeling individual choices. The framework is applied to two rail disruption cases from the Chicago Transit Authority (CTA) system.

2 STUDY DESIGN

CTA Case Study Areas

Main Analysis Framework

- **Supply Analysis**: We propose an incident-based network redundancy index to analyze the network’s ability to provide alternative services under a specific rail disruption. The impacts on the operation are analyzed through headway changes.
- **Demand Analysis**: We calculate the demand changes of different rail lines, rail stations, bus routes, and bus stops to better understand the passenger flow redistribution under incidents. Individual behavior is analyzed using a binary logit model based on inferred passengers’ mode choices and socio-demographics using AFC data.

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\text{Redundancy Equation: } R = \frac{\sum_{i} \sum_{j} A_{i,j} \cdot p_{i,j} \cdot A_{j}}{\sum_{i} \sum_{j} p_{i,j} \cdot A_{i,j} \cdot A_{j}}
\]

where:
- \( A_{i,j} \) = trip demand from point \( i \) to point \( j \)
- \( p_{i,j} \) = probability of choosing route \( i-j \)
- \( A_{i,j} \) = capacity of route \( i-j \)

3 RESULTS

Supply Analysis
- **Redundancy Index**: The Blue Line and Brown Line cases, scored 9.3% and 74.7% capacity to transport passengers during the incident, respectively.
- **Headway Analysis**: Blue Line

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\text{As the incident proceeded, inbound delays rose, while outbound delays remained relatively constant. Unaffected Blue Line headways were typical.}
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Demand Analysis
- **Passenger Flow: Blue Line Incident**
- **Passenger Flow: Brown Line Incident**

4 DISCUSSION

Major findings
- Results show that service frequencies were reduced on incident lines (by around 30%–70%). Nearby lines are also slightly affected. Passengers showed different behavioral responses in the two incident scenarios. In the low redundancy case, most of the passengers chose to use nearby buses to move, either to their destinations or to the nearby rail lines. In the high redundancy case, most of the passengers transferred directly to nearby lines.
- Passengers did not always act rationally, especially when redundancy was low. Some alternative routes, which were less crowded, were not chosen. A lack of understanding of the bus network or transit network in general may be the cause.
- A passenger’s socioeconomic status, along with the role CTA played in their everyday life, affected their retention rate to using the service post-incident. Higher-income riders were hypothesized to be able to change their mode of transport, whereas pass holders and reduced fare passengers understood the system better and/or relied on the system primarily.

Policy implications
- Data like this can be utilized by agencies to better understand how passengers move, both rationally and irrationally. This allows agencies to better prepare and execute system fixes during service disruptions. It also allows agencies to make long term plans and service changes, allowing for greater resiliency in the future.

5 CONCLUSION

- Using AFC and AVL data, a comprehensive analysis can be conducted for the impact of incident on urban rail systems from both demand and supply perspectives.
- Transit agencies can apply similar techniques to better understand how their dynamic networks operate in the face of both known and unknown variables, allowing for better transit planning.

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