

Dan Cretella
53 Kings Highway
Long Valley, New Jersey 07853

March 11th, 2020

Jack Molenaar,
Senior Director
Rutgers University Department of Transportation
55 Paul Robeson Boulevard
New Brunswick, New Jersey 08901

Re: Improving the Service of the Rutgers Bus System

Dear Mr. Molenaar,

Rutgers University-New Brunswick is an institution that serves nearly 40,000 people every academic year. Each one of these students relies on the university to enable them to succeed in their academic careers, and for many, the bus system is an integral part of that success. However, the bus system is in need of systemic improvements so that it can better serve the community at Rutgers. Like many other bus systems, the Rutgers bus system faces the issue of bus bunching. This phenomenon occurs when two busses on the same line arrive at a stop simultaneously, causing major service disruption. Many students at the university take classes on more than one of Rutgers' five campuses every day and therefore rely on quick and efficient service to get them where they need to go.

The project I am proposing should be of great interest to you, as it will improve student life at the university and bolster Rutgers' reputation as an institution dedicated to innovative and revolutionary ideas and actions. The Rutgers University Department of Transportation already has the means and the resources to make the necessary improvements to the bus system without changing the number of buses in the fleet. I would like you to keep this opportunity in mind as you read through my proposal in more detail.

Given that the last two waves of freshman students Rutgers have welcomed are the largest classes in the university's history, we should expect increased use of the bus system. Many first- and second-year students live on campus without a mode of personal transportation and will therefore need to use the bus system to travel between campuses. In order to keep up with the growing demand for quality service from the bus system, changes in operations will be necessary. I hope you can see the positive impact my proposal plan will have on Rutgers' student body and reputation. Please feel free to call me at (908) 399-8436 or email me at dte82@scarletmail.rutgers.edu with any questions, comments, or concerns. Thank you for your time.

Sincerely,

Dan Cretella

Improving the Service of the Rutgers Bus System

Submitted by:

Dan Cretella
53 Kings Highway
Long Valley, NJ 07853

If found, please return to above address

Submitted to:

Jack Molenaar,
Senior Director
Rutgers University Department of Transportation
55 Paul Robeson Boulevard
New Brunswick, New Jersey 08901

Submitted on:

May 4, 2020

Prepared for

Writing for Business and the Professions
01:355:303
Professor Francesco Pascuzzi
Project Proposal

Abstract

The research of this proposal asserts that the efficiency of a bus system can be improved by making changes to the way the system operates. Research suggests that by abandoning the use of a rigid schedule and implementing adaptive control tactics, bus bunching can be alleviated, and the system can function as intended. Using strategies of dynamic holding, bus to bus communication, and GPS technology, the goal is to reduce occurrences of bus bunching within the Rutgers bus system and provide quality service with consistent arrival times. It is important to consider using these tactics to improve the bus system. The proposal includes extensive research on the bus bunching issue and independently collected data from active Rutgers students on their experiences with the bus system. By employing these low-cost, low-risk strategies, the Rutgers bus system can be improved, thus improving student life and the university's reputation.

Table of Contents

Abstract.....i

Table of Contents.....ii

Table of Figures.....iii

Executive Summary.....iv

Introduction.....1

Literature Review.....3

Plan.....4

Budget.....5

Discussion.....5

References.....7

Table of Figures

Figure 1: Percent of Students Who Think the Bus System Needs Improvement.....	1
Figure 2: Student Issues with the Bus System.....	2
Figure 3: Rider Use by Line.....	2

Executive Summary

Bus bunching, the problem the Rutgers bus system faces, is an issue that plagues public transportation systems around the world. Even in New Jersey, the NJ Transit bus system has fallen victim to bus bunching (nj.com). The article by Larry Higgs records an account from a rider who says multiple busses on the same line will arrive at once, causing the wait for the next bus to double in length.

iii

Bus bunching occurs when busses deviate from their intended arrival time and ride too close to each other. This can be caused by a variety of factors, including slowed traffic, increased passenger loads, driver error, or mechanical failure. This causes two busses to arrive at the same stop in rapid succession, or even simultaneously, creating longer wait times between arrivals for passengers and causing certain busses to carry an inefficiently low number of riders.

Traditionally, bus systems have operated on a schedule-based schema that is ultimately made null by collapsing headways between busses (Bartholdi). A system that relies on spacing buses using a predetermined headway time is ineffective due to the positive feedback loop created by inconsistent dwell times and passenger loads (Morriea-Matias). Extended loading times due to a large number of passengers cause the bus to fall behind schedule. When the next bus arrives, and there are fewer passengers, it is able to run ahead of schedule. This pattern continues until the busses are arriving at the same stop simultaneously, as shown in an interactive simulation created by Lewis Lehe of Setosa and UC Berkeley's Department of Transportation Engineering.

A survey conducted among active Rutgers students found that the bulk of participants have faced inconveniences when using the bus system that are symptoms of bus bunching. One hundred percent of students surveyed think the bus system needs to be improved. The same number of participants reported experiencing a bus arriving late and being unable to get on a bus due to overcrowding. Studies have found that these problems directly relate to bus bunching.

While this issue seems impossible to mitigate due to the external nature of the causes of the problem, a number of peer-reviewed studies have found multiple ways to alleviate bus bunching.

These studies have been conducted on existing bus systems in Georgia, Chicago, and Dublin and simulations based on mathematical data.

A study conducted at the Georgia Institute of Technology found that when a bus system abandons a schedule of arrivals and departures and tells drivers to focus on efficient driving, bus bunching is almost entirely avoided. This study found that headway times between busses become self-regulated by traffic patterns that run in concurrence with the route. When one driver is affected by an external factor that slows all traffic, other busses will be slowed too. After these disruptions, the buses will tend, spontaneously, to re-space themselves at equal intervals.

In another simulation-based experiment, researchers determined that an adaptive control system like mentioned above is the best strategy for combatting bus bunching. It was found that for a control scheme like this to be successful, drivers will need to maintain regular communication with one another to regulate headway times. By communicating, drivers can agree upon a target travel speed, report disturbances in the flow of traffic, and coordinate holds at control points to regulate headway times. Researchers explain that a rigid schedule offers little opportunity to adapt to a collapse in headway times and that an adaptive control scheme is much more effective.

Another study conducted on the busiest bus route in Dublin found that strategies of dynamic holding at control points, like in the study mentioned above, have successfully prevented bus bunching. The primary goal of dynamic holding is to regulate passenger loads between buses. When one bus arrives at a large crowd of passengers, loading and unloading times become longer, keeping the bus at the stop for more time than intended. This phenomenon allows the following bus to catch up to the one in front of it, causing the headway to collapse. This pattern will continue until both busses arrive at the same stop simultaneously. Dynamically holding the rear bus at a stop while the front bus moves along will regulate headway times and allow for the service of more passengers.

The final study used to form the plan to combat bus bunching at Rutgers found that the use of GPS technology can help mitigate the problem. This study found that the use of an android app that tracks live positions of busses can be used to reduce rider wait times. This technology can also be used by dispatchers to monitor the proximity of one bus to another. If a dispatcher notices a bus is riding too close to another bus, shortening the headway time, they can instruct that driver to hold a control point until the headway time has stabilized to the target time.

The plan to improve the bus system at Rutgers employs all of the strategies that these studies found to be successful. By abandoning a rigid schedule of arrival times and employing tactics of driver-to-driver communication, dynamic holding at control points, and remote GPS tracking, the transportation department can limit instances of bus bunching and provide better service to riders. This plan does not require any new technology or changes to the existing bus fleet to be successful. Each Rutgers bus is already equipped with radios capable of communicating with other busses and the dispatch station and already uses the TransLoc system to provide estimated arrival times to passengers through the app. If it would please the department, research specific to the Rutgers bus system can be conducted to strengthen this plan at a cost between \$40,000 and \$90,000.

With the use of these strategies to combat bus bunching within the Rutgers bus system, the university and department of transportation can greatly improve the service of the bus system and therefore improve student life at Rutgers.

Introduction

The problem that the Rutgers bus system faces is in no way uncommon. Bus bunching has plagued public transportation systems all over the world. Even in New Jersey, the NJ Transit bus system has fallen victim to bus bunching (nj.com). The article by Larry Higgs records an account from a rider who says multiple busses on the same line will arrive at once, causing the wait for the next bus to double in length.

v

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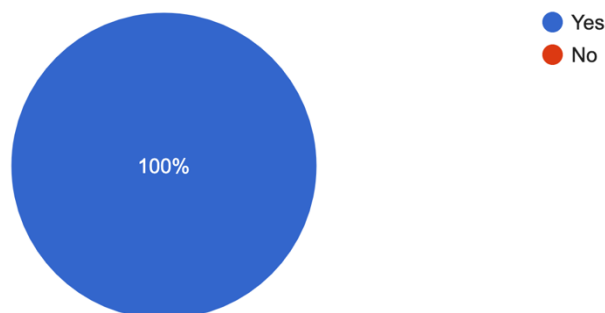
I conducted a survey of Rutgers students actively enrolled in the university. The survey was composed of a variety of multiple choice and short answer questions about their experiences with the Rutgers bus system and how often they traveled to specific campuses. According to this

survey, 75% of students surveyed reported they had experienced the same phenomena, and 100% reported having experienced a bus being late.

Figure 1: Percent of Students Who Think the Bus System Needs Improvement

Do you think the bus system needs improvement?

4 responses

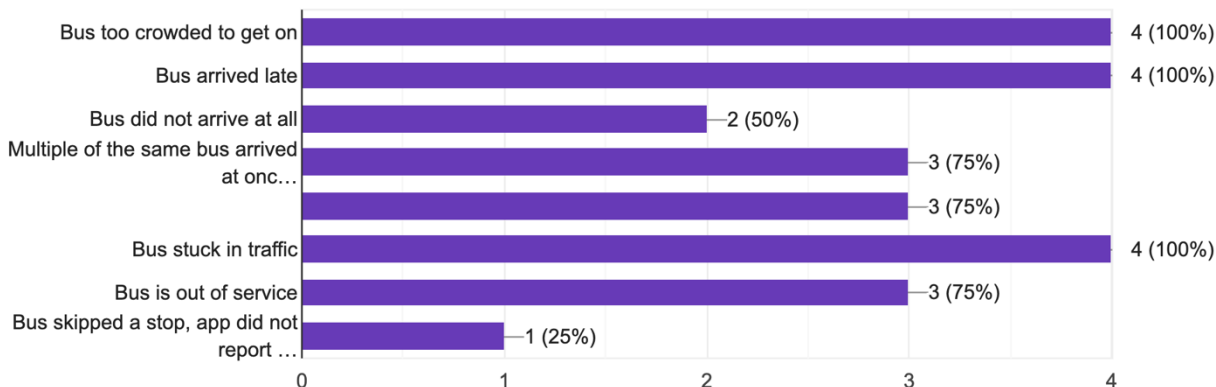


Complaints from students weren't limited to lateness. The survey I conducted posed a question where respondents could choose up to eight scenarios they had experienced with regard to the service of the bus system.

Figure 2: Student Issues with the Bus System

Have you ever encountered any of the following issues with the Rutgers bus system?

4 responses



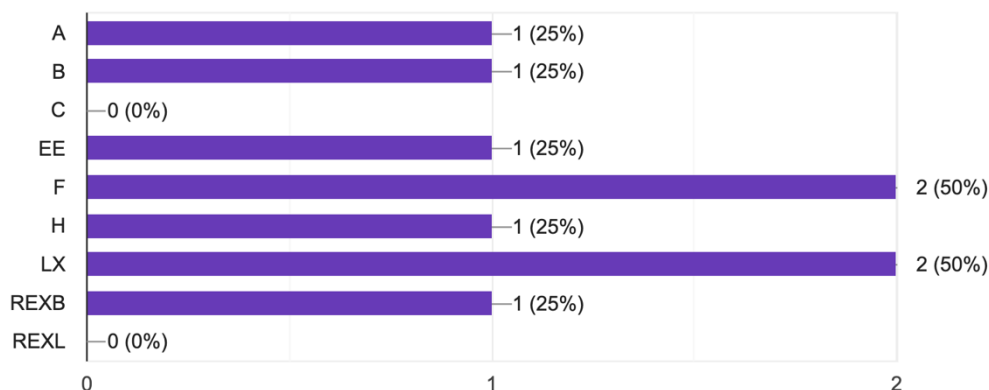
The conducted survey also found that the average student at Rutgers relies heavily on the bus system. Since Rutgers is divided into five campuses students are required to travel around town to attend their classes, sometimes between multiple campuses a day. Responses on how often a participant used the bus system ranged from two times a day, to three days a week, and some said

they use it every day. The survey also found that there is a relatively even distribution of use among the system's different lines.

Figure 3: Rider Use by Line

Which bus do you take most frequently?

4 responses



According to the Rutgers 2030 Physical Master Plan, the Rutgers bus system sees about 10 million riders annually, all of who need to get to class, work, or wherever else on time. In concurrence with the data mentioned above, we can determine that at least 5 million trips through the Rutgers bus system each year will face an issue causing riders inconvenience. It is also true that in the last two academic years, Rutgers has welcomed the two largest freshman classes in the university's history. In order to set these new students up for success and to anticipate added strain on the bus system, changes need to be made.

Literature Review

Rutgers must deal with the bus bunching issue using concepts proven to alleviate the issue in other bus systems. I have gathered peer-reviewed studies from credible institutions that have researched the problem and proposed solutions with their findings. By using a variety of information and tactics outlined in the following studies, Rutgers will be able to improve the service of the bus system.

Past Studies: A self-coordinating bus route to resist bus bunching

This 2011 study was performed on the most active bus line at the Georgia Institute of technology by John J. Bartholdi III and Donald D. Eisenstein. In this experiment, the bus drivers were instructed to ignore adherence to a schedule altogether and focus on moving with the flow of traffic instead. This tactic enables drivers to focus on driving as safely and efficiently as their circumstances will allow. In interviews with drivers following the experiment, it was reported

that drivers favored abandoning a schedule and felt the tactic enabled them to do a better job. This study found that when attempting to determine target headways, there are too many external variables that affect the spacing between buses. Bartholdi found that headway times between busses become self-regulated by traffic patterns that run in concurrence with the route. When one driver is affected by an external factor that slows all traffic, other busses will be slowed too. After these disruptions, the buses will tend, spontaneously, to re-space themselves at equal intervals (Bartholdi). This was proved true when researchers abruptly removed one bus from the route, leaving only two vehicles. Under a schedule, this headway would be expected to grow, but the flexible system was able to realign headway times in 17 minutes (Bartholdi).

Past Studies: Reducing bunching with bus-to-bus cooperation

In this simulation experiment, Daganzo and Pilachowski find, in concurrence with the previous study, that a schedule-based control scheme is ineffective in preventing bus bunching. Rather, this study suggests that an adaptive control scheme will yield regular headway times with increased efficiency regarding passenger loads and travel times. In order for this scheme to be effective, drivers must communicate with each other so that they can adjust travel speeds and holding times to regulate spacing between adjacent busses. Daganzo explains that “the control approach can systematically account for the uncertainties due to traffic and demand”, meaning that an adaptive control system is more resilient than one based on a rigid schedule. In concurrence with adjusting travel speeds, Daganzo suggests that buses should be held at discrete control points for brief periods of time in response to inconsistent headway times. While this may be a slight inconvenience to current passengers, slightly extending dwell times allows passengers to catch the most current bus, equalizing passenger loads between busses and, in turn, regulating dwell times. The results from the simulations tested found that cooperative control succeeds in preventing bus bunching.

Past Studies: A predictive-control framework to address bus bunching

This experiment provides a control framework based on data collected from a busy bus route in Dublin. The aim of this research was to understand how dynamic holding could alleviate bus bunching and reduce headway deviation (Andres). The primary goal of dynamic holding is to regulate passenger loads between buses. When one bus arrives at a large crowd of passengers, loading and unloading times become longer, keeping the bus at the stop for more time than intended. This phenomenon allows the following bus to catch up to the one in front of it, causing the headway to collapse. This pattern will continue until both busses arrive at the same stop simultaneously. The first bus will be overly crowded, and the second bus will be significantly less full. By employing strategies of dynamic holding, the rear bus can dwell at the stop for a longer amount of time. This will help create more consistent headway times between the busses and allow passengers to get on a bus with plenty of space. While longer dwell-times are inconvenient to passengers, dynamic holding has been found to be much less frustrating to passengers than alternate solutions like stop skipping and can create 40% more slack, improving route speeds (Andres).

Past Studies: A thrifty approach to the bus bunching problem

This piece of academic research proposes that the use of GPS tracking can alleviate wait times for passengers by providing them with accurate bus locations. Through the use of an android app, riders can plan their arrival to a specific stop in accord with the bus's projected arrival. This study demonstrates that the technology in question can be used to keep real-time tabs on each bus on a specific route. While this technology is designed for use by the passenger, it could also be used by those managing the bus system. Looking back at the previous study mentioned, it is important for drivers to maintain spacing through a self-regulated system. The technology proposed in this system uses GPS locations and Google traffic data to track buses (Archanaa). With this data available, management has the potential to communicate with drivers and inform them of their proximity to the bus in front of or behind them. This technology already exists at Rutgers through the TransLoc service. While this service is intended for use by the rider, it could also be used by dispatchers, making the service more cost-effective.

Plan

The following section provides the details of a plan based on my analysis of the research described above. This plan considers all academic literature used for reference and data collected from current students of Rutgers University. I am currently in the process of collecting a greater sum of data from students who use the bus system in their daily lives.

The first part of the plan is to abandon any use of a rigid schedule of arrivals and departures. Studies had found that when drivers focused on flowing with traffic and getting from stop to stop as efficiently as they could, headway times were more consistent, and no bunching occurred. In addition, not having to create a schedule of arrivals will put less strain on First Transit management, allowing them to shift efforts to prepare drivers for a change in the system of operations. Previous studies have shown that after abandoning a schedule, drivers felt they were able to transport riders in a faster and safer manner.

The second part of the plan is to utilize existing technology to communicate between buses. Each bus in the Rutgers fleet is equipped with a radio capable of communicating with other buses and the first transit dispatch center. Drivers can use these radios to maintain space between busses by agreeing on a target speed, communicating interruptions with traffic patterns, and announcing when they will be taking mandated breaks. This method will allow other busses along the same route to plan accordingly and reduce the time it takes to adjust the spread of the busses.

The third part of the plan will be to utilize existing GPS technology to track buses from a remote location. Each bus in the Rutgers fleet is equipped with a GPS tracking device. Dispatchers can use this location technology to see where busses are in respect to one another and instruct specific drivers to slow down or speed up to maintain consistent space between busses.

The fourth part of the plan is to employ tactics of dynamic holding when buses begin to bunch. In the event, that headway times between busses begin to collapse, and busses on the same line arrive at a stop simultaneously, one bus will wait behind. This will allow the emptier bus to load more passengers on and reduce the passenger load for the next bus. The time spent dwelling to

create space between busses will also provide drivers with a short break from work, enabling them to pay more attention while they drive their route.

The best time to implement these changes will be after the academic year comes to an end and the system shifts to its summer schedule. Waiting until the summer to enact this plan will cause minimal disruption to the community the system serves and will give drivers and other department of transportation staff time to adjust to the changes before the next academic year.

Budget

This plan will not be difficult to bring to fruition and will not require the department of transportation to purchase new hardware or software or make changes to the number of buses in the fleet. If it would please the department, research specific to the way the issue affects Rutgers could be conducted at a cost between \$40,000 and \$90,000. Aside from the cost of research, the department would not need to spend any money outside of the existing budget dedicated to employee salaries, vehicle maintenance, and the cost of the current TransLoc system.

Discussion

The problem with Rutgers University's bus system has been plaguing students for years and has ingrained itself in the reputation of the university as a whole. This plan aims to improve the university bus system, thus improving the lives of the students and faculty who rely on it to succeed.

My plan consists of four clearly defined actions; (1) Abandoning the use of a rigid schedule of arrivals and departures, (2) utilizing existing technology to communicate between busses and with dispatchers, (3) utilizing existing GPS technology to track busses from the dispatch center, and (4) exercising tactics of dynamic holding in the case of a collapse in headway times. This plan will not only increase the efficiency of the Rutgers bus system by mitigating bus bunching but also improve the lives of the many students who rely on it. The bus bunching issue at Rutgers can be mitigated by making these operational changes, and with the help of the Rutgers University Department of Transportation, this proposal can become a reality.

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Rutgers University Physical Master Plan Volume 1: New Brunswick

The Planning Context pp. 74