University Transportation Research Center - Region 2

Final Report

Empowering Individuals to Make Environmentally Sustainable and Healthy Transportation Choices in Mega-Cities through a Smartphone App

Performing Organization: City University of New York

April 2015

Sponsor:
University Transportation Research Center - Region 2

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The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis.

The UTRC was established in order to support research, education and the transfer of technology in the field of transportation. The theme of the Center is "Planning and Managing Regional Transportation Systems in a Changing World." Presently, under the direction of Dr. Camille Kamga, the UTRC represents USDOT Region II, including New York, New Jersey, Puerto Rico and the U.S. Virgin Islands. Functioning as a consortium of twelve major Universities throughout the region, UTRC is located at the CUNY Institute for Transportation Systems at The City College of New York, the lead institution of the consortium. The Center, through its consortium, an Agency-Industry Council and its Director and Staff, supports research, education, and technology transfer under its theme. UTRC's three main goals are:

Research

The research program objectives are (1) to develop a theme based transportation research program that is responsive to the needs of regional transportation organizations and stakeholders, and (2) to conduct that program in cooperation with the partners. The program includes both studies that are identified with research partners of projects targeted to the theme, and targeted, short-term projects. The program develops competitive proposals, which are evaluated to insure the mostresponsive UTRC team conducts the work. The research program is responsive to the UTRC theme: "Planning and Managing Regional Transportation Systems in a Changing World." The complex transportation system of transit and infrastructure, and the rapidly changing environment impacts the nation's largest city and metropolitan area. The New York/New Jersey Metropolitan has over 19 million people, 600,000 businesses and 9 million workers. The Region's intermodal and multimodal systems must serve all customers and stakeholders within the region and globally.Under the current grant, the new research projects and the ongoing research projects concentrate the program efforts on the categories of Transportation Systems Performance and Information Infrastructure to provide needed services to the New Jersey Department of Transportation, New York City Department of Transportation, New York Metropolitan Transportation Council , New York State Department of Transportation, and the New York State Energy and Research Development Authorityand others, all while enhancing the center's theme.

Education and Workforce Development

The modern professional must combine the technical skills of engineering and planning with knowledge of economics, environmental science, management, finance, and law as well as negotiation skills, psychology and sociology. And, she/he must be computer literate, wired to the web, and knowledgeable about advances in information technology. UTRC's education and training efforts provide a multidisciplinary program of course work and experiential learning to train students and provide advanced training or retraining of practitioners to plan and manage regional transportation systems. UTRC must meet the need to educate the undergraduate and graduate student with a foundation of transportation fundamentals that allows for solving complex problems in a world much more dynamic than even a decade ago. Simultaneously, the demand for continuing education is growing – either because of professional license requirements or because the workplace demands it – and provides the opportunity to combine State of Practice education with tailored ways of delivering content.

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UTRC's Technology Transfer Program goes beyond what might be considered "traditional" technology transfer activities. Its main objectives are (1) to increase the awareness and level of information concerning transportation issues facing Region 2; (2) to improve the knowledge base and approach to problem solving of the region's transportation workforce, from those operating the systems to those at the most senior level of managing the system; and by doing so, to improve the overall professional capability of the transportation workforce; (3) to stimulate discussion and debate concerning the integration of new technologies into our culture, our work and our transportation systems; (4) to provide the more traditional but extremely important job of disseminating research and project reports, studies, analysis and use of tools to the education, research and practicing community both nationally and internationally; and (5) to provide unbiased information and testimony to decision-makers concerning regional transportation issues consistent with the UTRC theme.

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16. Abstract

A paradox of industrialized society is the overreliance on unsustainable fossil fuel energy for transportation and insufficient use of sustainable bodily energy for more physically active modes of transport. Different modes of transportation require varying levels of physical activity, with cars being the most sedentary, followed by public transportation, and active transportation (walking and biking). Preference (individual and societal) for sedentary travel modes such as car driving over available physically active travel modes has contributed to air pollution and the epidemic of obesity. Low-carbon transport systems have the potential to improve the health of citizens and to mitigate climate change simultaneously. Among the potential solutions for low-carbon transport systems, innovations in technology and demand reduction have received much attention, with less consideration toward behavioral options that are also critical to a decarbonized transport sector.

Currently, behavioral change options are rarely considered in the decision-making process of transportation projects because their efficacy is largely unknown. An example of behavioral option for decarbonizing transport is a non-price-based policy to trigger individual behavioral change using "nudges", defined as any aspect of a choice set that alters behavior without foreclosing alternatives or significantly changing economic incentives. The intervention should be easy and cheap to implement; for example, a nudge could disclose information. Evidence has emerged that the American public has a knowledge perception bias for energy consumption and efficiency that tend to underestimates carbon emission of day-to-day activities. This study investigates whether insufficient and inaccurate perceptions of carbon emission and bodily energy expenditure in day-to-day travel may be barriers for adopting more physically active and environmentally sustainable travel modes.

We conducted a randomized controlled trial to assess impacts of a behavioral nudge intervention consisted of a new smartphone app onTrac. The app was developed to report personalized knowledge of carbon emission and calories burned associated with user specified travel modes, with walking and bicycling automatically detected through accelerometer. Undergraduate students of Queens College, City University of New York were recruited to participate in baseline surveys (N=85) designed to evaluate factors that may influence their travel mode preferences and behavior. Although both car and public transit commuters are found to be pro-environment, they are significantly different in that public transit commuters displayed less affection towards driving and were more comfortable using public transit (attitude factors), were more encouraged by their families to use public transit and had more friends who use public transit (norm factors). Transit commuters also had less situational constraints such as owning an automobile for work and managing their schedule than car commuters. Repeat surveys following a three week trial of the onTrac app found significant increases in self-reported consideration for the environmental impact of transportation choice among students who used the app (N=24), compared to the control group (N=26) who did not. Significantly more favorable attitudes towards carpooling post-trial were noted only among the car drivers (N=12) in the app group. Further studies, with larger sample sizes and an improved app that can detect all travel modes automatically using the smartphone's built in sensors are warranted to explore how this elevated environmental cognition may interact with attitude and situational factors, perhaps moderated by perceived control, to influence actual travel choice behavior.

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EXECUTIVE SUMMARY

A paradox of industrialized society is the overreliance on unsustainable fossil fuel energy for transportation and insufficient use of sustainable bodily energy for more physically active modes of transport. Different modes of transportation require varying levels of physical activity, with cars being the most sedentary, followed by public transportation, and active transportation (walking and biking). Preference (individual and societal) for sedentary travel modes such as car driving over available physically active travel modes has contributed to air pollution and the epidemic of obesity. Low-carbon transport systems have the potential to improve the health of citizens and to mitigate climate change simultaneously. Among the potential solutions for low-carbon transport systems, innovations in technology and demand reduction have received much attention, with less consideration toward behavioral options that are also critical to a decarbonized transport sector.

Currently, behavioral change options are rarely considered in the decision-making process of transportation projects because their efficacy is largely unknown. An example of behavioral option for decarbonizing transport is a non-price-based policy to trigger individual behavioral change using “nudges”, defined as any aspect of a choice set that alters behavior without foreclosing alternatives or significantly changing economic incentives. The intervention should be easy and cheap to implement; for example, a nudge could disclose information. Evidence has emerged that the American public has a knowledge perception bias for energy consumption and efficiency that tend to underestimates carbon emission of day-to-day activities. This study investigates whether insufficient and inaccurate perceptions of carbon emission and bodily energy expenditure in day-to-day travel may be barriers for adopting more physically active and environmentally sustainable travel modes.

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INTRODUCTION

Research Problem and Background

A paradox of industrialized society is the overreliance on unsustainable fossil fuel energy for transportation and insufficient use of sustainable bodily energy for more physically active modes of transport. Preference for sedentary travel modes such as car driving over physically active travel modes such as walking, biking and public transit when appropriate has contributed to air pollution and the epidemic of obesity. The outer boroughs of NYC, including Queens, are the most disadvantaged with longer commuting times than even some suburbs (Renn, 2012). Residents of outer boroughs are at higher risk of switching to car driving, resulting in higher CO_2 emissions and most probably lowering their physical activity associated with more active travel modes.

The recent global exponential growth in transport is fossil fuel driven and unsustainable (Banister et al., 2011). Because the per capita emissions from transport are nearly 6 tons-CO_2/yr in North America as of 2008, compared to < 1 tons-CO_2/yr in Latin America and China (Banister et al., 2011), much ought to be done to reduce or to stabilize carbon emissions from the transport sector in North America. Several solutions for low-carbon transport systems have been proposed, including behavioral options, demand reduction, and innovation in technologies (Banister et al., 2011). Different modes of transportation require varying levels of physical activity, with cars being the most sedentary, followed by public transportation, and active transportation (walking and biking). It has been shown that using public transportation can result in an excess bodily energy expenditure of 100 kcal/day among New Yorkers compared to car driving (Morabia et al., 2009b). At a mass level this is a substantial difference which may impact the trends of obesity (Morabia and Costanza, 2010). Both our overconsumption of fossil fuel energy and our insufficient use of sustainable bodily energy have deleterious effects. A greater use of active transportation modes, including public transit, would be beneficial for both the individual and society (Zheng, 2008).

Contributing to pro-environmental behavior barriers is the public's well-known knowledge perception bias for energy consumption and efficiency that tends to underestimate the carbon emissions of day-to-day activities. Public perceptions of energy consumption for a variety of household, transportation, and recycling activities are off-mark based on an online survey of 505 participants recruited from seven US metropolitan areas including New York on February 11, 2009 (Attari et al., 2010). Overall, participants underestimated energy use and savings by a factor of 2.8 on average, with smaller overestimates for low-energy activities and larger underestimates for high-energy activities. For example, the energy saved by reducing one's highway speed from 70 to 60 miles per hour on a 60-mile trip was overestimated to be about 30 kWh when the actual energy saving is smaller, at about 10 kWh. Furthermore, when asked for the most effective strategy to conserve energy, most participants mentioned curtailment (e.g., turning off lights, driving less) rather than efficiency improvements (e.g., installing more efficient light bulbs and appliances). Attari et al. (2010) concludes that well-designed efforts to improve the public's understanding of energy use and savings could pay large dividends. An MTA subway rider is about seven times more carbon-efficient than a single driver in a car (MTA, 2011), but it is not known whether commuters are aware of the magnitude of this energy saving and whether knowing so would affect an individual's decision to continue to use public transit or not. Similarly, commuters may not be aware of the fact that by using transit, there can be extra bodily energy expenditures (MacDonald et al., 2010) sufficient to prevent obesity (Morabia and Costanza, 2004).

Only recently have researchers begun to demonstrate the necessity and cost-effectiveness of implementing behavioral change interventions to improve energy efficiency (Allcott and Mullainathan, 2010). Historically, most research and development efforts were devoted for more energy efficient technologies. Energy efficiency, however, depends on both technologies and the choices of the user. Public transportation is a case in the point. In most American cities; even those with advanced transit systems, transit usage is minimal (Taylor et al., 2009). Although there are multiple explanations for this and more evidence is needed, we suspect that some barriers may be behavioral. In the New York region, transit plays a larger role in household trip-making activities. In 2010, nearly 40% of all transit commuters in the United States were in the New York metropolitan area, continuing an increasing trend from 37% to 38% from 1990 to 2000 (Renn, 2012). Allcott and Mullainathan (2010) argue that a rigorous process should be used to develop basic behavioral science into large-scale business and policy innovations, similar to using research to develop "hard science" into useful technological solutions. It is thus of interest to establish the credibility of such behavior based interventions for transport sector application by subjecting them to the tests of rigorous measurements to demonstrate both their energy savings and cost-effectiveness.

A key (non-price-based) policy for decarbonizing transport and making it healthier is to trigger individual behavioral change among car buyers or drivers using nudges (Thaler and Sunstein, 2008), although this does not exclude collective responses to improve energy efficiency. Improved understanding based on the Theory of Planned Behavior (Ajzen, 1991) supports the notion that a wide range of behavior interventions, succinctly known as "nudges" can help to shift behavior toward cost-effective options, although little has been done to test the efficacy of such interventions in shifting individual behavior toward energy-efficient options. A nudge is defined as any aspect of a choice set that alters behavior without foreclosing alternatives or significantly changing economic incentives (Thaler and Sunstein, 2008). The intervention should be easy and cheap to implement; for example, a nudge could disclose information. Currently, behavioral change policies are rarely considered in the decision-making process of transportation projects because their efficacy is largely unknown. Infrastructural modifications or policy changes can provide incentives to reduce driving in favor of alternative transport, yet strategies targeting psychological attitudes and perception may be a more promising and less expensive option (Gardner and Abraham, 2008).

Psychological influences on transportation choice are increasingly recognized in the travel behavior literature (Buys and Miller, 2011), and along with demographic factors, mode-specific factors such as access and comfort, trip characteristics such as distance and time, characteristics of the urban built environment, and policies against car usage, are variables used in the study of transportation mode choice (Zhou, 2012). Investigations of travel behaviors of university students have provided evidence for the importance of psychological factors for mode choices, especially pro-environmental modes (Collins and Chambers, 2005; Klöckner and Friedrichsmeier, 2011). Klöckner and Friedrichsmeier (2011) employed a two-level model approach to car use in a student group including both person-specific variables (e.g. intention, attitudes, habit, norms) and situation-specific variables (e.g. availability, trip duration, travel day, weather, trip purpose) to find that a large proportion of the variance in car use is located at the person level, suggesting the importance of psychological predictors on travel mode choice, yet likewise that the importance of situational factors cannot be ignored. A study of 205 university students in Melbourne, Australia found that situational factors surrounding transport choice, such as access, cost, and time, interact with psychological factors such as egoistic and social beliefs to, along with transport-related environmental beliefs on personal control and the environmental threat of cars, jointly influence pro-environmental commuter behavior (Collins and Chambers, 2005). The Theory of Planned Behavior (TPB) (Ajzen, 1991) has been found useful in predicting pro-environmental behavior in the field of transportation because it also includes a range of such non-psychological situational constraints that make performing any behavior more difficult (Heath and Gifford, 2002). Situational factors aside, a systematic review of 25 years of literature on the psychological correlates of car use found that intention, car use habit, and perceived behavioral control over non-car use had the largest effects on behavior. Yet the analysis identified a general lack of evidence on the effects of pro-environmental cognitions on behavior or intention, concluding that more research is needed to clarify this relationship between environmental beliefs on attitudes and intentions (Gardner and Abraham, 2008).

Research Objective and Plan

This study seeks to clarify the relationship between psychological factors such as environmental beliefs and the pro-environmental travel mode behavior among young adults. Because the situational and psychological factors for using various travel modes common in the New York City Metropolitan area have never been evaluated, this study represents a first step forward and is thus focused on probing the perception and knowledge of carbon dioxide emissions from various travel modes among the study population of Queens College students. Specifically, the study seeks to ascertain whether improved personalized knowledge of carbon avoidance and bodily energy expenditure during commuting, delivered to the study subjects through a mobile phone app, can strengthen the intention to use public transit, to walk and to bicycle. The carbon avoidance is defined as the amount of carbon dioxide emission avoided for each passenger mile traveled using a pro-environment travel mode such as public transit vs. driving solo in a car.

A survey questionnaire based on TPB was administered among students to assess their knowledge of carbon dioxide emissions and health benefits associated with various travel modes and the factors and attitudes that can be barriers for adopting more physically active and environmentally sustainable travel modes at baseline. A trial was conducted to assess the impacts of a behavioral nudge, an iPhone app named onTrac developed specifically for this study, on the perception of commute-related energy use and expenditure. The smartphone app has the ability to report back to the user on carbon avoidance and calories burned associated with each trip segment and travel mode. Calories burned were estimated using the metabolic equivalent associated with each travel mode and the time spent traveling in each mode. Queens College student participants were randomly allocated to one of two groups: using onTrac, and control. Knowledge about energy use and expenditure, preferences and intentions for travel modes were again measured at endline through the same questionnaire.

METHODOLOGY

Study Population

Queens College (QC) is one of the senior colleges of the City University of New York (CUNY). In 2012 the College enrolled 16,187 undergraduate (57.6% female, 1,449 freshmen) and 3,913 graduate students (72.7% female). QC employs 1,266 full time staff including 606 faculty and 1,316 part time staff including 858 adjunct faculty in 2011. Located in south Flushing and without a subway stop within an easy walk (< 20 min.), it is reached by several bus lines. To reach QC via public transit involves a bus transfer for subway/rail riders: from Main Street, Flushing via Q25, Q34 or Q17, from 71st and Continental Avenue, Forest Hills via Q64, and from Jamaica Station via Q25 or Q34. Four other buses (Q20A/B, Q44, Q88 and QM4) have stops nearby. Students have commuted to campus using cars (43%), bus only (25%), subway and bus (25%), and walking/bicycling (6%) based on our annual QCUTE (Queens College Ultimate Transportation Evaluation) online survey conducted in the spring semesters between 2008 and 2014 (Morabia and Zheng, 2009). Public transit has the longest median time of commuting (bus: 55 minutes, subway/bus: 75 minutes). QCUTE surveys have also found that a majority of students, faculty and staff commute from Queens (Table 1). Since the inception of the QCUTE survey in 2008, there has been a small increase in the percentage of people who car pool, up to 13% in 2013. Analysis of QCUTE data has found that per capita emissions from commuting to and from Queens College is about 1.7 tons-CO_2/yr (Zheng, unpublished). The annual carbon footprint of 20,000 people commuting from the metropolitan NYC area to the Queens College campus is approximately 33,000 tons of carbon dioxide.

Survey Instrument Development and Pre-Testing

The survey instrument (Appendix A) collected information on the student's status at Queens College and the time and travel mode of their commute to campus on that day. The survey instrument was developed with assistance from undergraduate Environmental Science and Environmental Studies students enrolled in the senior capstone course Environmental Problem Solving in the Fall semesters of 2012 and 2013. During the first half of the course, students studied selected papers in theory of planned behavior (TPB), energy use behavior, health protective behavior, technology use behavior, travel mode survey methods, and travel mode choice. In the second half of the course, the students worked in groups to design a TPB based survey instrument exploring factors for or against a transportation mode, to pilot test the instrument, to present the findings and to write a report. The transportation mode investigated by the students included car pool, public transit, bus, non-fossil-fuel mode, fuel efficient car in comparison to driving a car. The final survey instrument contains statements (Appendix A) that broadly represent many of the constructs included in common health behavior theories such as the Theory of Planned Behavior. It was again pre-tested on Queens College undergraduate students enrolled in an introductory level course in February and October 2013. It also explored knowledge about energy use and expenditure, attitudes towards various transportation modes, and intention for behavioral changes through a series of statements with a 1-6 Likert scale response for agreement, ranging from "Strongly Disagree" through "Strongly Agree." The range of questions was purposely very broad in order to cover a range of beliefs and to better understand the starting point knowledge and attitudes of this student population.

Smartphone app: Intervention Tool

An iPhone app, onTrac, was developed to report carbon emissions associated with user specified transportation mode for car, bus, train, subway, with walking and bicycling automatically detected through built-in sensors (GPS and accelerometer) on the iPhone. The onTrac version 1.0.6 records GPS data once every second to a "track" file, containing latitude, longitude, altitude, speed, for a trip the user starts and stops. onTrac detects walking/bicycling mode through two criteria: 1) threshold speed that user can specify but the default for walking is < 10 mile/hr and for biking is < 20 miles/hr; 2) magnitude of acceleration measured by accelerometer: based on the acceleration data recorded once per 0.5 seconds, if the standard deviation of the last 20 samples (10 seconds) is > 0.25 for 40 consecutive samples (20 seconds), the mode is then walking/biking. The distance traveled is calculated based on latitude and longitude data. Saved tracks on user's phone are uploaded to a remote cloud server for storage and analysis. OnTrac also reports calories burned.

The users can view the following statistics of carbon footprint: carbon emission, carbon avoidance, equivalent gasoline usage. They are estimated by the app as follows:

kg CO_2 emitted = $E \times d$
kg CO_2 avoided = $(Ecar - E) \times d$
Ratio = (kg CO_2 emitted) / $(Ecar \times d)$
Equivalent gasoline usage = (kg CO_2 emitted) / (kg CO_2 per L gas)

Where:
Ecar = kg CO_2 / meter for an avg. American car is set as default. User can customize.
E = kg CO_2 / meter in a certain mode of transport. MTA values used as default (MTA, 2011)
d = meters traveled in a certain mode of transport determined by onTrac app algorithm.

The users can view the following statistics of calories burnt based on the metabolic equivalent (MET) associated with different travel mode and for different speed (Ainsworth et al., 2000; Morabia et al., 2009a). For multi modal trip, the app output the sum of all the segments using appropriate MET and time traveled in each mode.

Calories burned = MET * weight (kg) * time (h)

Where:
Weight (kg) is entered by the user into the app.
Travel time (h) is estimated by the app for each travel mode.

Evaluation of Impact: A Randomized Controlled Trial

Queens College students were recruited through emails to the Queens College Ultimate Transportation Evaluation (QCUTE) survey listserv, flyers posted in public areas, in-person recruiting, and peer recruiting, and were offered a $15 incentive to be received after completion of the trial. One hundred twenty-one students agreed to participate and were randomly assigned to either receive the onTrac app or serve as the control group based on the order of which they contacted the researcher is an odd or even number. However, only 85 students, 42 in the app group and 43 in the control group, actually completed the baseline survey to participate in the trial. The period of the trial lasted 3-4 weeks, after which participants completed the repeat final survey to conclude their participation. Only 50 students, 24 in the app group and 26 in the control group, completed the final survey, thus drop-out was a challenge, although it seems to have affected the two trial groups similarly. The trial took place during the difficult time period between spring and summer break that included final exams so student drop-out was probably more or less random. The survey questionnaire administered at two time points to both app and control groups is used to assess the impact of use of the onTrac smartphone app. The study design and survey instrument were approved for use by the City University of New York IRB.

Data Analysis

The survey item responses were on a Likert scale of 1 to 6. SPSS 22 was used for descriptive analyses, spearman correlations, and logistic regressions to compare survey item responses to actual travel mode behavior (public transit vs. car driving).

RESULTS

<u>Population Baseline</u>

This particular survey instrument afforded the opportunity to gauge a baseline of environmental awareness and attitudes towards various travel modes among the student population of Queens College. 85 students recruited on campus completed this survey at the start of the trial in April 2014, however, an additional 109 student volunteers in environmental science courses completed a similar version during pre-testing at two earlier time points, February 2013 and October 2013. Despite the differences in recruitment of student participants the differences between the responses at each time point were not significant, adding support for the findings of the trial baseline, but also allowing for all 194 responses to be combined in the subsequent analysis in order to increase descriptive power. Undergraduate students comprised 97% of the 194 survey respondents, 67% were female, and the median age was 21 years old. Average reported commute time to campus on the day of the survey was 47 minutes, with 44% of respondents commuting by car and the rest using a combination of public transportation and walking. This student sample is slightly more female than the general undergraduate population at Queens College, but otherwise is representative (Table 1).

Table 1: Characteristics of Survey Participants Compared to Queens College Student Population

	Trial (n=85)	Classes (n=109)	Queens College
Female	72%	62%	57%[1]
Median age	21	21	21[1]
Median commute time	45 minutes	40 minutes	50 minutes[2]
Commute that day – Car	35%	51%	42%[2]
Commute that day – PT	65%	49%	53%[2]
Queens residents[4]	68%	75%	68%[3]
Nassau/Suffolk[4]	24%	20%	24%[3]

[1]Queens College 2012-2013 Factbook, undergraduate full-time students (N=16,187)
[2]QCUTE 2014 (N=1,160)
[3]Analysis of home addresses of Queens College students enrolled in 2013-2014 academic year by Andrew Beveridge, Department of Sociology. A total of 17,687 addresses are within the tristate area and analyzed, out of 19,088 student records because some entries have addresses that are out of the tristate area or cannot be found.
[4]74% of Queens residents and 17% of Nassau residents commute by public transportation

By looking at the mean agreement scores to the series of statements in the questionnaire (Appendix A) we can identify items of strong agreement or disagreement within this student population, and consistency across surveyed student groups regardless of their regular transportation choice. The items with strong consistency are organized by common themes below in Table 2. For example, within this student population there was general agreement with statements indicating general environmental knowledge and awareness of the environmental and health benefits of using public transportation. Similarly there was agreement with statements that indicate the intention or desire for pro-environmental behavior. Other statements with strong agreement emphasize the factors that influence commuting preferences, such as convenience, cost, accessibility, comfort, and friends' behavior. The statements with strong disagreement were expressions of personally relevant knowledge, such as knowing the carbon emissions or calories burned from their daily commute or how a public bike share program works. Willingness to make an effort for energy efficiency or believing that any effort can make a difference was neutral in this population.

Table 2: Survey items with similar mean response scores by car or public transit commuters on scale of agreement from 1 = Strongly Disagree to 6 = Strongly Agree among trial-recruited students at baseline and class-recruited students during questionnaire pre-testing phases

Survey Items	Trial (n=85)		Class (n=109)	
General Knowledge/Awareness (≥4, Agree)	**Mean**	**SD**	**Mean**	**SD**
Greenhouse gas emissions are contributing to global warming	4.95	1.23	5.22	1.01
People who take public transportation usually have lower	4.45	1.13	4.62	1.08

greenhouse gas emission levels than people who drive				
Walking, bicycling, or using public transportation can lower my greenhouse gas emissions, compared to driving everywhere	5.17	0.93	5.27	0.94
Walking, bicycling, or using public transportation lets me burn more calories than driving everywhere	5.46	0.68	5.36	1.04
Carpooling can be as good for the environment as taking public transit	4.31	1.12	4.52	1.03
Pro-environmental Intentions (≥4, Agree)				
I have thought about the environmental impact of my transportation choices*	4.12	1.60		
The fact that walking, bicycling, etc. will reduce carbon dioxide emissions is a good incentive for me to use them	4.45	1.28	4.64	1.12
If cost were not an issue, I would prefer to drive a hybrid or electric car instead of a normal car*	5.02	1.36		
The issue of greenhouse gas emissions is severe enough to warrant individual initiatives such as carpooling	4.39	1.28	4.41	0.92
Carpooling would make me feel more environmentally responsible than driving alone	4.17	1.45	4.28	1.10
If I lived within 2 miles of Queens College, I would ride a bicycle, walk, etc. to commute	4.58	1.53	4.77	1.45
Influences on Commute (Attitude, Situational, Norm) (≥4, Agree)				
I primarily base my commuting choices on convenience*	5.00	1.21		
Cost is a factor in my choice of transportation to Queens College	5.02	1.19	4.67	1.43
Most areas I go in NYC are accessible through public transit	4.92	1.09	5.25	0.90
I am able to walk to the train/bus stop in my area	5.20	1.23	4.93	1.17
Public transit is more cost-effective than driving	4.45	1.53	4.39	1.40
I am more comfortable taking personal transport than public transit	4.37	1.40	4.37	1.33
The majority of my friends take public transit	4.35	1.5	4.08	1.45
Personally-Relevant Knowledge (≤3, Disagree)				
I know the amount of calories I burn from my daily commute	2.29	1.49	2.42	1.36
I know the amount of carbon emissions produced by my daily commute	1.95	1.21	2.48	1.45
I know how a public bike share program works	2.06	1.30	2.11	1.38
I know of the Queens College Carpooling Program	1.72	1.23	1.84	1.07
I know enough people to carpool with	2.43	1.57	2.59	1.41
Motivation for Change (3-4, Neutral)				
I am prepared to spend more money to be more energy efficient	3.25	1.41	3.10	1.41
Occasionally changing my mode of transportation would not change my greenhouse gas emissions significantly*	3.48	1.24		

*Item included in final survey instrument for the trial (n=85) but not in the class pre-test of the instrument (n=109), SD=Standard Deviation

Although the set of statements above demonstrate generally consistent agreement and disagreement among this student population, other survey items show significantly different (p<.05) mean levels of agreement between survey respondents depending on what type of transportation they use regularly for commuting, public transit (n=109) or car (n=85) (Table 3). These differences are limited to statements reflecting attitudes, norms, or situational justifications for or against the different travel modes. There were no significant differences between the groups on agreement with general knowledge statements or expressions of pro-environmental intention listed above in Table 2. Logistic regression identifies the strongest statistically significant (p<.05) predictors of car use as agreement with "In general, I love driving," "It is necessary for me to own a vehicle for work/school," and "I am more comfortable taking personal transport than public transit." The strongest significant predictors of public transit use are agreement with the statements "Most areas I go in NYC are accessible through public transit" and "Cost is a factor in my choice of transportation to Queens College." A model including these 5 factors predicts car use correctly for 78% of respondents.

Table 3: Significantly different responses to survey items among car or public transit commuters and association with public transit use among trial-recruited students at baseline

Statement	**Mean (SD) All n=194**	**Mean Transit Users n=109**	**Mean Car Users n=85**	**ρ_s Correlation with Transit Use**
Situational Justifications				
It is necessary for me to own a vehicle for work/school	3.35 (1.8)	2.81	4.45	-0.47**
I cannot rely on public transit or carpooling because of my schedule	3.01 (1.5)	2.89	4.20	-0.42**
Regardless of the weather I can still take public transit	4.15 (1.3)	3.41	4.60	0.39**
Cost is a factor in my choice of transportation to Queens College	5.02 (1.2)	5.15	4.41	0.28**
I am able to walk to the train/bus stop in my area	5.20 (1.2)	5.39	4.61	0.27**
I am more likely to be late if I take public transit	3.99 (1.4)	3.87	4.49	-0.22**
Most areas I go in NYC are accessible through public transit	4.92 (1.1)	5.28	4.88	0.15*
I know enough people to carpool with	2.43 (1.6)	2.16	2.99	-0.26**
Attitude Statements				
In general, I love driving	3.69 (1.6)	2.95	4.51	-0.44**
I am more comfortable taking personal transport than public transit	4.37 (1.4)	3.92	4.92	0.38**

Public transit is more convenient to take than personal transport	2.80 (1.5)	3.32	2.30	0.34**
Public transit is more cost-effective than driving	4.45 (1.5)	4.80	3.90	0.27**
In general, I enjoy taking public transit	2.93 (1.5)	3.25	2.60	0.22**
I think carpooling is a safe means of transportation	4.23 (1.3)	4.11	4.57	-0.20**
Norm Statements				
My family encourages me to use public transit to commute	3.64 (1.4)	4.33	2.82	0.38**
The majority of my friends take public transit	4.35 (1.5)	4.65	3.61	0.34**
Carpooling is common in my neighborhood	2.38 (1.5)	2.41	2.93	-0.16*

**p<.01, *p<.05, Spearman correlation coefficient (ρ_s) between survey statements and public transit use. *Survey statements in italic font represent factors associated with car use*. Survey statements in plain font represent factors associated with public transit use.

Trial Impact

To assess the impact of app use during the trial period, only the 50 students who have completed both a baseline survey and the repeat final survey were included in the analysis for pre-trial and post-trial comparison. There were no significant differences between the app group (n=24) and the control group (n=26) at baseline, and the drop-out from both groups appears to be random (Table 4). The 50 students were 76% female, with a median age of 21 and a median commute time of 45 minutes. Only 38% commuted by car on the day of the final survey.

Table 4: Trial participants completing baseline and final surveys

	Trial Baseline (n=85)	Trial Final (n=50)
Female	72%	76%
Median age	21	21
Median commute time	45 minutes	45 minutes
Commute that day – Car	35%	38%
Commute that day – PT	65%	62%
Queens residents	68%	68%
Nassau/Suffolk	24%	24%

There were some technical difficulties in getting the app installed and useable on all the participants' smartphones. Only 7 of the 24 app group students reported using the app at least 3 times per week during the trial, however, as sample size was a limitation for the analysis the entire app group was treated as if they received the same intervention, and there was not scope to explore the variability in impact by the "dose" of the intervention received. The final survey suggests there may be a larger effect on more frequent users; 6 of the 7 students reporting using the app at least 3 times per week were able to accurately estimate the CO2 emissions from their commute to Queens College that day. Treating all students assigned to the app group as if they received the same intervention may obscure some of the differences that could be noted if more frequent use were ensured.

Comparing pre-trial and post-trial responses, there were only two survey statements for which there was a statistically significant ($p<.05$) difference in change of agreement between the app group and the control group. App users showed increased mean agreement with the statements "I have thought about the environmental impact of my transportation choices" (+0.79) and "I know the amount of carbon emissions produced by my daily commute" (+1.29).

Discussion and Limitations

Impact on Environmental Knowledge Post Trial. The trial demonstrated an impact on environmental cognition, especially among the frequent app users. Sample size was a limitation to this trial due to drop-out so that the final analysis included only 50 students between the app intervention and the control groups, and app-use among the intervention group is uneven. However, even with the small app group there are suggestions that there may have been a differential impact of app use on the users based on their preferred transportation mode. Car users in the app group showed significant increases in favorability towards carpooling viewing it as more convenient and more environmentally responsible after the trial. Public transit users in the app group showed significant increases in awareness of their friends' use and the health benefits of using public transit. In both cases use of the app seems to have increased awareness and attitudes toward the benefits of the individual's already preferred transport choice. With a larger sample size these effect differences could be explored further.

Although the trial was limited to Queens College students, but there were no residential restrictions to participation. Access to public transit is different for the 24% of trial participants residing in Long Island with farther commutes (Table 1). For example, 12 of the 50 trial participants reside in Nassau County, which is not part of New York City, and only 2 (17%) report using public transportation for commute to Queens College, while 75% of the NYC students report using public transportation. Randomizing group assignment in this trial ensured that these differences did not bias evaluation of the impact of the app use, but repeating the trial among students with similar access to public transportation options could help to clarify the strongest influences on public transit use by limiting the variability in situational constraints.

It is worth noting that the intention of this study was to evaluate the effect of using a smartphone app on perceptions of energy use because the app is unlikely to change the situational factors or many of the attitude factors that influence the students' commuting behavior. For the more modest goal of the trial, i.e., to assess whether improved knowledge on carbon emissions can strengthen intentions to use more environmentally-friendly and healthy transportation choices, there are indications to suggest it succeeded with limitations discussed above. In addition, there is the well-known gap between environmental knowledge and pro-environmental behavior as discussed below.

Public Transit Commuters and Car Drivers both have Pro-Environment Attitude. Similar to previous research into the influence of transportation mode choice, this study identified both psychological (attitude and norm) and situational (access, cost, purpose) as predictors of mode choice for commute among young adults (Collins and Chambers, 2005; Heath and Gifford, 2002). Additionally, both public transit and car commuters demonstrated high degree of self-reported environmental awareness and pro-environment attitude. During the survey instrument development phase, students residing in Queens borough (N=111) were recruited to allow comparison between bus only and car commuters. The access to bus (situational factor) is less variable among Queens borough residents than students coming from all five boroughs and nearby suburbs (Table 1). Yet a similar mix of significant psychological and situational factors was found to influence actual travel mode. However, only in this sample of Queens borough residents, bus users displayed a slightly higher level of agreement than car drivers that protecting the environment is important to them and that they have the intention to reduce their carbon footprint. Much like the adult commuters in an Australian study who in general were in agreement that greenhouse gas emissions are a serious threat, the public transit users saw the threat being more serious than the solo car drivers did, and were more inclined to support policy aimed at emission reduction (Golob and Hensher, 1998). Together, the literature and our results suggest that the beliefs and attitudes of students besides self-reported environmental awareness are more important drivers of their regular commuting behavior. It is well known that individuals' proenvironmental action is complex and influenced by their beliefs mediating values in three separate domains – social, egoistic, and biospheric (Stern et al., 1993), not just environmental awareness. It is conceivable that an individual's belief that their actions can benefit the environment may moderate the influence of their environmental beliefs on their pro-environmental behavior (Collins and Chambers, 2005). Further research could look into the efficacy of this smartphone app intervention as a tool to increase perceived control over energy-use and benefits from transportation choice rather than just an increase in understanding on the impact of choice.

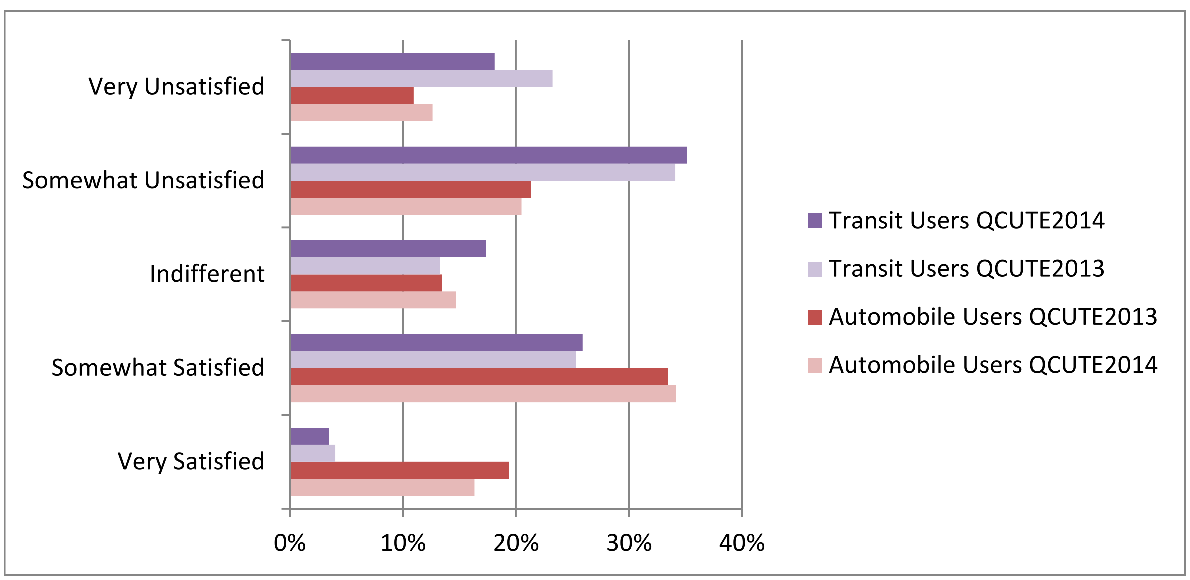

Figure 1: Degree of Satisfaction of Commuting Mode Among Car and Public Transit Users Found During QCUTE 2013 and QCUTE 2014

We also observed in QCUTE6 conducted in 2013 and QCUTE7 conducted in 2014 that the preference rates for commuting modes are consistent regardless of whether students currently commute by car or public transit: ~50% of the students preferred to drive a car, ~34% the students preferred public transportation. This is consistent with to what extent the students are satisfied with their current mode of commuting: 55% of transit users are somewhat unsatisfied and very unsatisfied, while 33% of car drivers are somewhat unsatisfied and very unsatisfied (Fig. 1). Taken positively, the results imply that if conditions were right, about one third of the current drivers could switch to their preferred mode of public transit. On the other hand, it also means that about half of the current public transit users are at risk of switching to their preferred mode of driving.

Opportunities for Behavioral Intervention. Our results provide insight into what might need to be done in order to prevent public transit users from switching to car driving, and to encourage car drivers to use public transit instead. Changing behavior is difficult and would likely require a comprehensive intervention at the multiple levels of influence identified in these surveys and by the literature in order to show impact. There are several attitude, norm and situational factors that are in favor of and against PT or car use (Table 3). Behavioral based intervention to influence these factors in a way that promote PT use can start with those that show the strongest positive and negative correlation with PT use. In terms of attitudinal intervention, whereas it may not be easy to instill a love of PT due to the prevalent American culture of love for an automobile, it may be possible to have advertising campaign to have some skeptics to become more comfortable taking PT (Table 3). In terms of norm intervention, family and friends are influential in PT choice (Table 3). This suggests that creative use of social media tool may be explored to promote PT use among young adults. Finally, the situational factors (juggling work and school, schedule, and weather) emerged as the most significant factors influencing PT use. These are difficult to overcome. The only ones that are possible to address include cost and improved service of PT (Table 3).

Conclusions

Analysis of baseline survey data collected from Queens College students in 2013 and 2014 suggests that travel behavior is more strongly influenced by attitudes and situational factors than by knowledge of environmental and health benefits, although personally relevant knowledge on carbon emissions and calories burned by travel was very low overall. The trial, in which participants had 3 weeks to use a smartphone app which delivered real-time user-specific data on calories burned and carbon emissions by travel mode and trip segment, demonstrated that this personally relevant knowledge can be improved – "I know the amount of carbon emissions produced by my daily commute," and that this can increase environmental cognition, "I have thought about the environmental impact of my transportation choices." Further study is needed to explore how this elevated environmental cognition may interact with attitude and situational factors, perhaps moderated by perceived control, to influence actual travel choice behavior.

APPENDIX A

SURVEY INSTRUMENT

Instructions: Please complete the survey questions below. Choose the answer that is the closest fit to what you think or do. There are no right or wrong answers.
Please tell us about yourself:

Age	________
Gender	M F Other
School status	o Freshman o Sophomore o Junior o Senior o Graduate – Masters o Graduate – Doctorate o Post Doctorate o Other (please specify) ________________
Home Address	
How did you commute to the College this past week? (check all that apply)	o Car o Subway o Bus o Motorcycle o Ferry o Bicycle o Walking o Other (please specify) ________________
How long did it take you to commute from your home to campus today using which transportation mode?	______ Hours ______ Minutes o Car o Subway o Bus o Motorcycle o Ferry o Bicycle o Walking o Other (please specify) ________________

Do you know the carbon dioxide emissions produced by your commute to school today?	o Yes o No Please estimate your emissions: ________________ lbs CO_2
Do you own or have access to a car for your commute to school?	o Yes o No

Your preferences and opinions:
For each statement below, please circle one number indicating your level of agreement.

	Strongly Disagree	**Disagree**	**Slightly Disagree**	**Slightly Agree**	**Agree**	**Strongly Agree**
I primarily base my commuting choices on convenience	1	2	3	4	5	6
Cost is a factor in my choice of transportation to Queens College	1	2	3	4	5	6
Public transit is more cost-effective than driving	1	2	3	4	5	6
In general, I love driving	1	2	3	4	5	6
In general, I enjoy taking public transit	1	2	3	4	5	6
I am happy if I get to walk during my commute, even though it adds to my commute time	1	2	3	4	5	6
Public transit is more convenient to take than personal transport	1	2	3	4	5	6
Most areas I go in NYC are accessible through public transit	1	2	3	4	5	6
I am more comfortable taking personal transport than public transit	1	2	3	4	5	6
I am more likely to be late if I take public transit	1	2	3	4	5	6
Regardless of the weather I can still take public transport	1	2	3	4	5	6
If I lived within 2 miles of Queens College, I would ride a bicycle, walk, or rollerblade, etc. to commute	1	2	3	4	5	6

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
I cannot rely on public transit or carpooling because of my schedule	1	2	3	4	5	6
I think carpooling is a safe means of transportation	1	2	3	4	5	6
Carpooling is convenient	1	2	3	4	5	6
The majority of my friends take public transit	1	2	3	4	5	6
Carpooling is common in my neighborhood	1	2	3	4	5	6
I know enough people to carpool with	1	2	3	4	5	6
I plan to carpool in the future	1	2	3	4	5	6
I am more likely to take the bus transfer from the nearby subway stations than to walk here	1	2	3	4	5	6
The majority of my family exercises (walk, bike, run, gym, etc.) at least twice a week	1	2	3	4	5	6
My family encourages me to use public transit to commute	1	2	3	4	5	6
I do not have any negative feelings toward public transit	1	2	3	4	5	6
It is necessary for me to own a vehicle for work/school	1	2	3	4	5	6
The opinions of my peers influence which mode of transportation I take	1	2	3	4	5	6
I am more likely to gain weight if I use a car to commute to Queens College instead of using public transit	1	2	3	4	5	6
I exercise (walk, bike, run, gym, etc.) at least twice a week	1	2	3	4	5	6
I am able to walk to the train/bus stop in my area	1	2	3	4	5	6
I know the amount of calories I	1	2	3	4	5	6

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
burn from my daily commute						
I know of the Queens College Carpooling Program	1	2	3	4	5	6
I know how a public bike share program works	1	2	3	4	5	6
If cost were not an issue, I would prefer to drive a hybrid or electric car instead of a normal car	1	2	3	4	5	6
I have thought about the environmental impact of my transportation choices	1	2	3	4	5	6
I know the amount of carbon emissions produced by my daily commute	1	2	3	4	5	6
Greenhouse gas emissions are contributing to global warming	1	2	3	4	5	6
Most people believe the environment is affected by fossil fuel consumption	1	2	3	4	5	6
People who take public transportation usually have lower greenhouse gas emission levels than people who drive	1	2	3	4	5	6
Carpooling can be as good for the environment as taking public transit	1	2	3	4	5	6
Carpooling would make me feel more environmentally responsible than driving alone	1	2	3	4	5	6
I am prepared to spend more money to be more energy efficient	1	2	3	4	5	6
Individuals older than 20 years should engage in at least 150 minutes of physical activity per week	1	2	3	4	5	6
Occasionally changing my mode of transportation would not change	1	2	3	4	5	6

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
my greenhouse gas emissions significantly						
Walking, bicycling, or using public transportation can lower my greenhouse gas emissions, compared to driving everywhere	1	2	3	4	5	6
Walking, bicycling, or using public transportation lets me burn more calories than driving everywhere	1	2	3	4	5	6
The issue of greenhouse gas emissions is severe enough to warrant individual initiatives such as carpooling	1	2	3	4	5	6
I would only carpool if I were the driver	1	2	3	4	5	6
I am able to walk to the train/bus stop in my area	1	2	3	4	5	6
It is tiresome to use a non-fossil fuel mode of transportation (walking, bicycling, roller-blading, etc.) to get to campus	1	2	3	4	5	6
The fact that walking, bicycling, roller-blading, etc. will reduce carbon dioxide emissions is a good incentive for me to use them.	1	2	3	4	5	6
I would be more inclined to carpool if there were a campus parking discount for those who carpooled.	1	2	3	4	5	6

Your use of the transport app:

What kind of smartphone do you use most often?	o iPhone o Android
How often did you use the app while commuting?	o >5 days per week o 3-5 days per week o 1-2 days per week o Less than once per week o Never

How easy was the app to use?	o Very easy o Easy o Neither easy nor difficult o Difficult o Very difficult
Would you continue to use this app on your own?	o Yes o No o Maybe
Which aspects of the app were most useful? (check all that apply)	o Distance/time traveled measurements o Mapping features o Calorie counts o Emissions information o None of it o Other (please specify) ____ _
Has using this app changed the way you think about your commute? Please explain.	____ ____ ____ ____ ____ ____
What changes to the app would make it more useful to you when making transportation decisions?	____ ____ ____ ____ ____ ____

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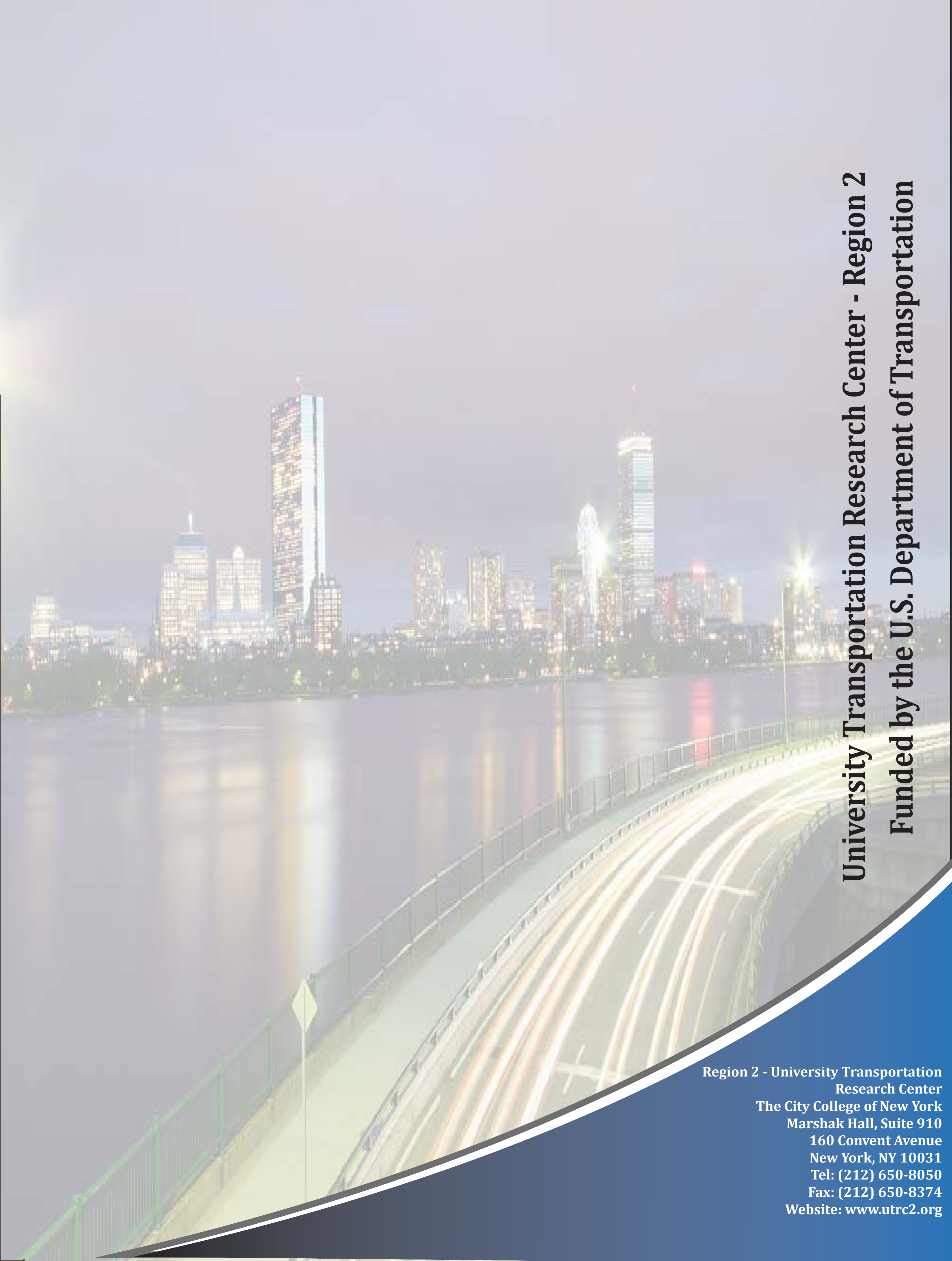

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