International Research Training Model for Undergraduate Students: Investigating Public Transportation Commuting in Feira de Santana (Bahia), Brazil

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ABSTRACT

International Research Experiences are increasingly seen as important components of high impact undergraduate activities. An International Research focused on Transportation was developed utilizing the design and distribution of a Comprehensive Transportation Survey (CTS) in Feira de Santana, Bahia state (Brazil). In collaboration with the State University of Feira de Santana, the CTS was developed in Summer 2016 by a team of three program scholars. A team of ten students at State University of Feira de Santana was trained and engaged in conducting the surveys at seven bus terminals in Feira de Santana in Fall 2016 for initial data collection. A more extensive CTS for online deployment was also developed and was launched in Summer 2017. The results obtained can be utilized to address the increased ridership projected for Feira de Santana as the population is projected to increase to one million by the year 2040.

KEYWORDS

International Research, High Impact, Transportation, Feira de Santana, Brazil, Commuter Satisfaction

INTRODUCTION

The Open Doors report published by the Institute of International Education, the leading not-for-profit educational and cultural exchange organization in the United States has shown that over the last decade, a 58% increase in the number of US studying abroad and only a 12% increase in the number of minorities studying abroad in the same period. Similarly, over the same period, STEM majors going abroad showed an increase of 9%. All minority students and STEM students accounted for 28% and 25% respectively, in 2015/2016 [1]. The importance and benefits of STEM students having an international experience has been well documented [2,3]. Additionally, higher education is moving forward with embracing the concept of educating engineers as a global citizen [4,5].

The NYC-LSAMP (a National Science Foundation (NSF) funded initiative in operation at the City University of New York) committed to integrating international activities into program activities, and officially launched the activity in 2008 at the Annual Student Research Conference, with the theme of Explorations and Discovery. The continued collaborations (2008 to 2018) with 1) existing programs within the NSF and other federal agencies, 2) collaborations with a core of mentors/faculty who have international collaborations, 3) Study Abroad Offices, Departments, Institutes and Centers, and 4) other Louis Stokes Alliance programs across the US, have made International Research opportunities a reality for over 230 NYC Louis Stokes Alliance (NYC-LSAMP) Scholars. NYC-LSAMP Scholars in the last eleven years participated in research experiences in England, Sweden, Poland, Scotland, Spain, Italy, Germany, Austria, France, the Netherlands, Japan, China, Singapore, Australia, Vietnam, Sri Lanka, Honduras, Colombia, Costa Rica, Ecuador, Mexico, Brazil, Jamaica, Dominican Republic, St. Kitts, Ethiopia, Togo, Ghana, South Africa and Morocco [7,8].

In 2009, an approach was implemented in Cartagena (Colombia) to allow the NYC-LSAMP Scholars to integrate an International Experience into their undergraduate studies [9,10]. The main objective was to create authentic international research models that link culture/language, research, and community engagement. The Cartagena based activity has run for a decade (2009 to 2018) with 30 US students and 27 Colombian students participating (6 cohorts) [9]. Similarly, in 2012 in Feira de Santana (FDS), the International Research program in Brazil was initiated via collaboration with the *Universidade Estadual de Feira de Santana* (UEFS) centered in the area of Biodiversity and Environmental Science with the one-on-one model. In this model, NYC-LSAMP students are paired with a Brazilian faculty researcher at UEFS working on a research project supervised by the faculty of UEFS. To date (2013 to 2018), 31 NYC-LSAMP students have participated in the Brazil International Research program.

Feira de Santana (FDS) is the second largest city in the Brazilian state of Bahia with a population of 600,000 that is expected to increase to 1,000,000 by 2040. FDS continues to be major hub for commerce in the North East of the state of Bahia (Brazil). The importance of FDS is related to the ideal geographical location, the close proximity to Salvador's ports and the well-connected highway infrastructure that is around FDS that continue to support FDS as one of the focal points for economic activity in Bahia state. Public transportation in the city is road transport, primarily

in the form of taxi, bus and van lines. The bus network in FDS is part of the *Sistema Integrado de Transporte* (SIT) and is comprised of an integrated network of six bus terminal and close to 100 privately operated bus routes. The operation scheme of the SIT is essentially a private-public partnership, with terminals operated by the city and bus fleets managed by private companies. In a ten-year span (2000 to 2010), the population of FDS increased 15% (70,000 additional residents), and the trend points to a current population of over 650,000 residents in 2016 (a census is due in 2020). The SIT has operated in FDS for fourteen years and provides increased mobility for residents by offering free bus transfers at terminals. Registered van lines offer services to outer neighborhoods and smaller towns/cities. However, over the fourteen-year period of operation, the population of FDS has seen an increase of over 100,000 additional residents.

The Transportation study we report was conceived/initiated by the NYC-LSAMP after three years (2013 to 2015) of operating in the Biodiversity and Environmental Science areas in consultation with the International Office at UEFS. A team of three NYC-LSAMP Civil Engineering undergraduate students were selected to work on the project in the Spring semester conducting literature based research and developing potential areas of research in Transportation. This was followed by travel to FDS during the summer for two months (June and July) to work collaboratively with Faculty and students at UEFS in designing a Comprehensive Transportation Survey for subsequent online deployment and in-person deployment at the FDS bus terminals (conducted by students at UEFS), the university (UEFS) and in communities across FDS.

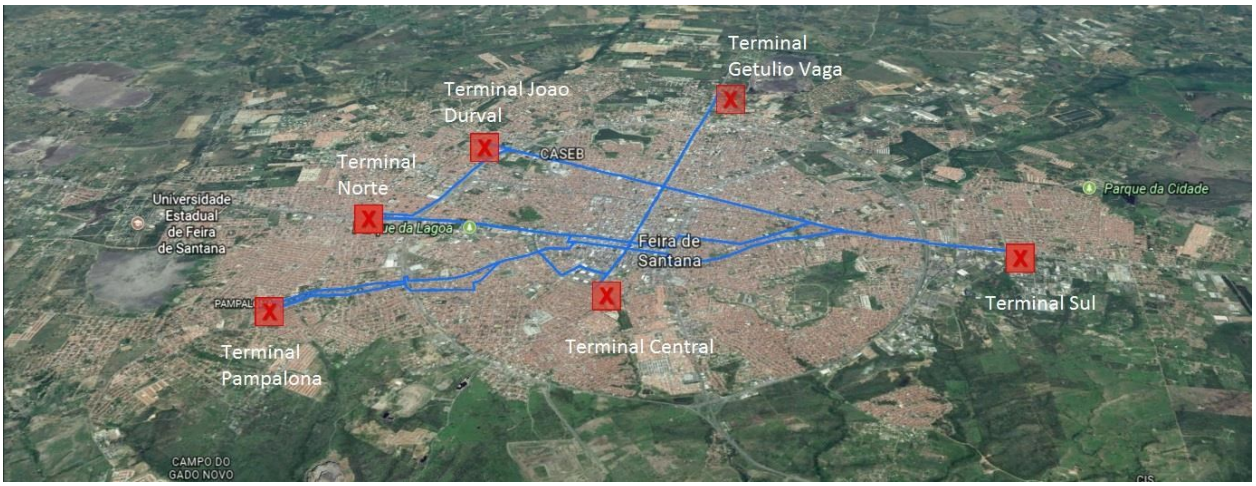

Figure 1: Google Map of Feira de Santana, with added routes of the buses and terminals

One approach to address the projected increase in ridership due to population increases is the implementation of a Bus-Rapid Transit (BRT) system to complement the existing SIT. The proposed plan for FDS by the municipality includes the construction of two BRT routes, three additional bus terminals, and an operations control center station. BRT systems exist in other Brazilian cities (Sao Paulo) and across Latin American cities (Bogota and Cali in Colombia).

However, surveys on passenger behavior from the southern states of Brazil may not be relevant to the North East and specifically FDS.

METHODOLOGY: **Duplicating the International Summer Research Model**

The approach implemented in Cartagena (Colombia) allowed the NYC-LSAMP Scholars to integrate an International Experience into their undergraduate studies [9]. In FDS, each NYC-LSAMP student was paired with a student of UEFS (called a 'buddy') selected by the International Office of UEFS, and language instruction for the NYC-LSAMP students in Portuguese were held daily (five days per week, two hours each session), led by the Portal Language Program at UEFS. The language instruction allowed the NYC-LSAMP students to increase their abilities to communicate in Portuguese during their stay in FDS, as well as facilitate greater cultural integration during the summer stay. An onsite coordinator served as the liaison between the NYC-LSAMP students, the International Office and the UEFS student team. The onsite coordinator (an American graduate student studying at UEFS) also trained and managed the team of twelve (12) UEFS students that were selected to participate in the deployment of the surveys across Feira de Santana over a three-month period. All surveys were uploaded to a web-based system and the collected data sets made available for review, analysis and possible curriculum integration at the NYC-LSAMP university and the international site (UEFS).

The instrument used to gather data on the individual travel behavior and identify various transportation characteristics is a self-fabricated transportation survey, which will act as a form of a National Household travel survey. Information for the development of surveys was based on IGBE data and Oregon's Travel & Activity Survey data [11]. While the survey serves as a form of a national household travel survey (HTTS), the elaborated survey aims to serve as a basis for Millennial and BRT studies.

The in-person survey designed by the team of NYC-LSAMP students and UEFS students contains thirty-four questions and is a comprehensive list of the following parameters: General Information, which includes Demographics, Socio-Economic Status, and Household Characteristics. The second section of the survey corresponds to Travel information, which inquires Private Vehicle Information, Origin and Destination Locations for commuting trips, Mode of Transportation, Time of Travel, Work and School Flexibility, and Transportation Costs, and Travel Satisfaction. A digital form of the survey containing the total sixty-four questions is to be posted as an online survey, which can be completed at house or university.

The survey can also reveal key characteristics of millennials (further study) such as:

- *Age and Occupations of Students Chart*: Key to attaining the age groups and, consequently, identifying millennials who would be used for further analysis in future research.
- *House Location for UEFS Students*: This is important for comparison purposes, as mentioned before, US millennials typically live longer at home. Due to transportation

difficulties, Brazilians may have different approaches, such as, moving and living near campus to avoid traffic delays and, as a result, decrease or extinguish travel time.

- *Number of People per Household*: In combination with the previous question, this would further inquire their household characteristics. This aims to identify if students prefer sharing their residence with other students alike, and its benefits, such as decreasing their cost of living.
- *Vehicle Ownership*: Identify the percentages of individuals who own a private vehicle versus those who do not.
- *Main Mode of Transportation*: To identify millennial' preferred mode of travel. The main modes of transportation covered by this survey are: Cars, Motorcycles, Bus, Van, Walking and Other, where the participant can list other modes of transportation not mentioned previously. This would also recognize if millennials prefer private or public transportation.
- *Average Delay per Mode of Transportation:* To identify the common delays suffered by each mode of transportation. Example: A private car may suffer high delays versus a motorcycle, which could avoid delays as Feira de Santana has a high motorcycle usage. An investigation was done to understand 1) the traveler's perceived satisfaction of their travel time, 2) their wiliness to move due to travel time, 3) their perception of the transportation over a year, and 4) whether they can get to work if a problem occurs. In these cases, post hoc paired-comparison with Bonferroni correction for Kruskal-Wallis H-test is used to interpret and eliminate bias generated[12].

RESULTS AND DISCUSSION

Profile of Travelers in FDS

Approximately 65% of the respondents reported to be female, and the age distribution depict that 32% are within the 18 – 24 age range, 26% in the 25 – 34 age range, 20% in the 35 – 44 age range, 11% in the 45 – 54 age range, and 11% in the 55 – 75+ age range. The demographic profile of FDS (Figure 2 and 3) illustrates that most of the respondents are employed (41%) with at least a High School diploma (495) and can be identified as mixed (43%), Black (35%) or White (18%).

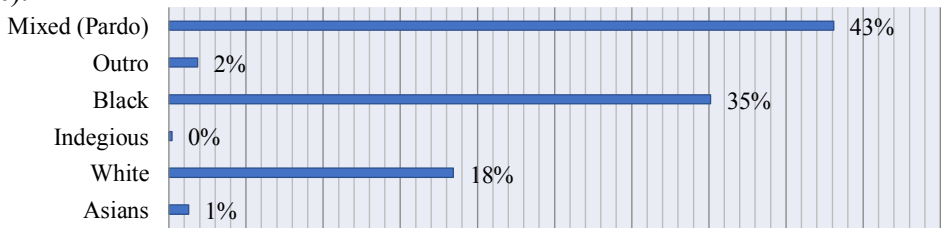

Figure 2: Ridership Distribution by Race/Ethnicity

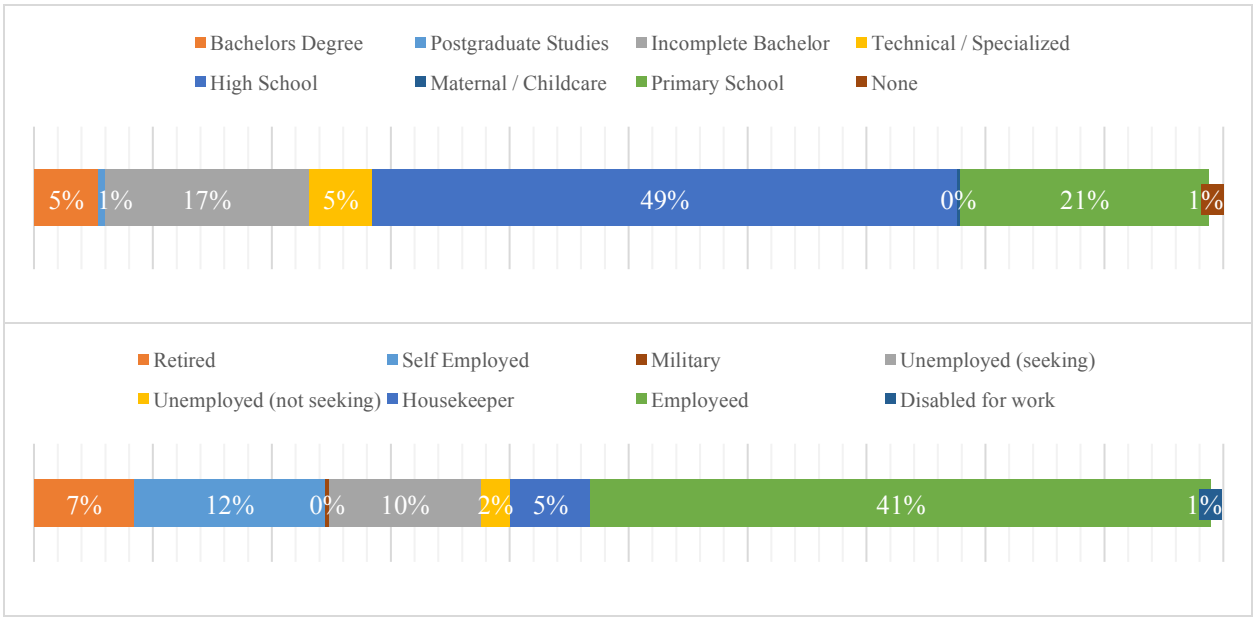

Figure 3: Distribution of Education Levels (top) and Employment Status (bottom)

Household Characteristics

The characteristics of the household will also have an influence on travel behavior. In addition, an increased household size influences income, the number of people employed, vehicle availability, and the frequency of traveling and use of public transportation. Moreover, household income and household size can also be used to estimate traveling frequency.

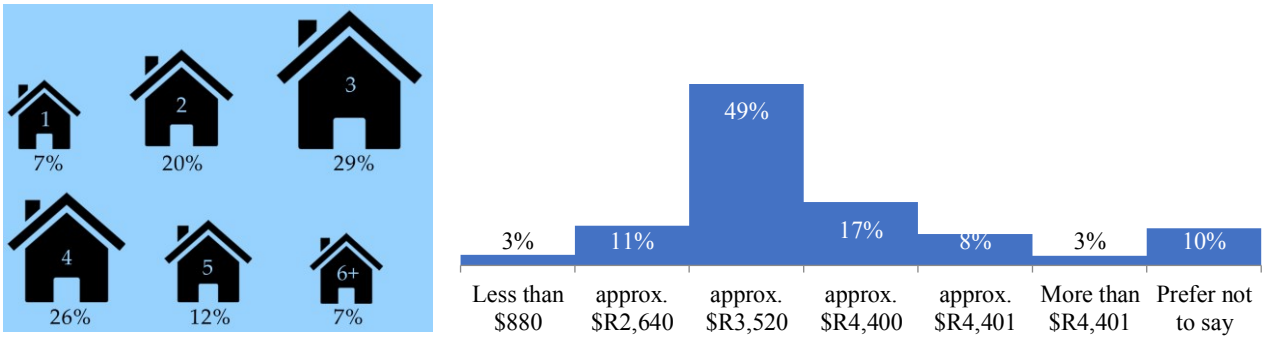

Figure 4: Distribution of Households by Household Size and Income Range

Self-Report on Travelers' Experiences

Of the respondents, only 376 (17%) of the respondents owned a personal vehicle, whereas 83% of the respondents do not own a personal vehicle. They would instead use a bus (94%), walk (3%), a van (2%), a bike (1%), or a taxi (0%) for transportation. Their age range lies within 25-

34 and a majority are females of Black race/ethnicity who are employed with a high school education earning about $R 2,640 ($850 USD). Of those who own a vehicle, we found that there is a relationship with those who use their personal vehicle for work/school, and how often they use a personal vehicle for work or school ($\rho = 0.59$, $p < 0.01$). Thirty-four percent (n = 118) are frequently use a personal vehicle, that is, they would use their vehicle every day of the week for work/school. The major travel patterns have 35% using their personal vehicle between 6:00 AM – 8:00 AM to go to school, 25% and 32% use it between 12:00 PM – 1:00 PM and 10:00 PM – 11:00 PM for returning from school. Given that most of the respondents are employed, there is high likelihood that individuals traveling during the night hours for school are adults who are furthering their education. In addition, 71% use their personal vehicle from 5:00 AM – 8:00 AM to going to work and 50% use it from 4:00 PM – 7:00 PM returning from work.

The major populous travel patterns for respondent who do frequently use/own a personal vehicle are 50% traveling between 6:00 AM – 8:00 AM to go to school, 23%, 18% and 20% traveling between 12:00 PM – 1:00 PM, 5:00 PM – 6:00 PM and 10:00 PM – 11:00 PM for returning from school. In addition, 63% travel from 6:00 AM – 9:00 AM to going to work and 41% travel from 5:00 PM – 7:00 PM as they are returning from work. Figure 5 depicts these peak hours when owners of a vehicle and users of public transportation are actively traveling. Between the hours of 6:00 AM to 8:00 AM, there is a likelihood of more vehicles on the road, and this would include personal vehicles and various public transportation modes. At 5:00 PM – 6:00 PM, a larger number of individuals are traveling and requiring access to various public transportation modes.

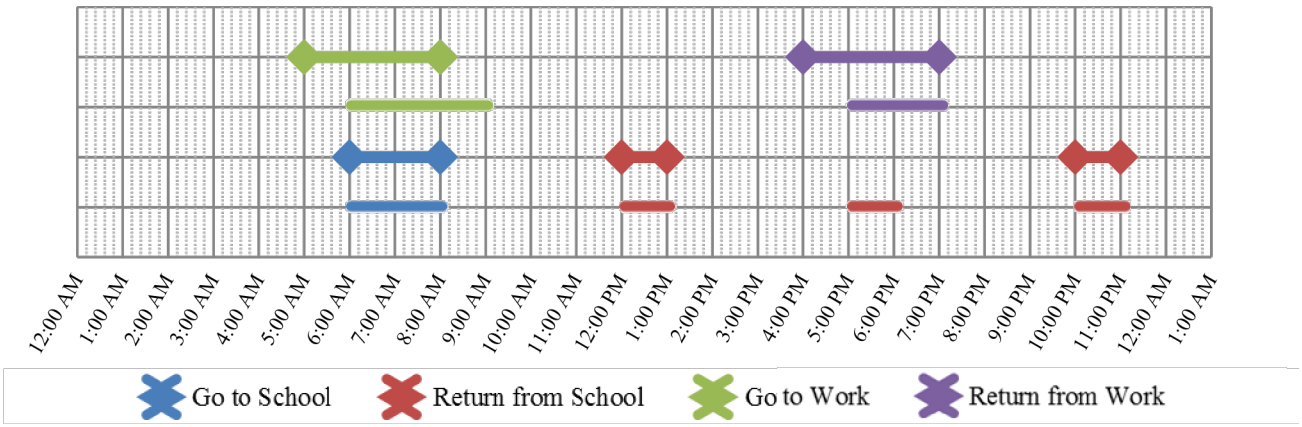

FIGURE 5 Peak Hours of Activities from Those Who Frequently Use a Personal Vehicle (⟷) mirrored to Those Who Do Not Frequently Use a Personal Vehicle (—)

Only 11% of those who frequently use a personal vehicle will go to work/school around the same area they live, while 89% do not work/go to school in the same area they live. Spearman rank correlation also showed that there is a weak positive correlation with owning a vehicle and travel time satisfaction in which case suggest that owning a vehicle positively correlates with being

satisfied with the respondent's travel time ($\rho = 0.09$, $p < 0.01$). While on the other hand, nearly 18% of those who infrequently use their personal vehicle go to school/work in the same area they live. For those who choose to not frequently to use their personal vehicle for work/school, they would instead use a bus (50%), walk (24%), a van (4%), a bike (3%), or a taxi (0.6%) for transportation. It is also statistically significant that there is an association which suggests that those who frequently use the bus instead of a personal vehicle are more dissatisfied with their travel time, ($\rho = 0.09$, $p < 0.01$). However, there is no evidence to justify the respondents' satisfaction with any of the other modes of transportation (i.e. bike, van, taxi, or walking).

To explore the association of common reasons for delayed travel time and satisfaction of travel time, the Kruskal-Wallis H test was used. The analysis showed that there were significant differences in the satisfaction levels and the reasons for being delayed (χ^2 (1, 4) = 24.7, $p < 0.05$). A post hoc paired-comparison with Bonferroni correction after Kruskal-Wallis H-test was performed to pinpoint where the differences may lie. It was found that more delay caused by fleet reduction rather than accidents, in addition to road congestion, both resulted in dissatisfaction ($p < 0.05$). Similarly, it was also statistically significant that more delay caused by driver negligence rather than road congestion resulted in dissatisfaction ($p < 0.05$).

CONCLUSION

The above model utilized is the standard Research Experience for Undergraduates (REU) model with a scientific theme, (Transportation), augmented with Language and Culture. This program format can be used as a template to increase the level of STEM students who are able to integrate the international research experience into their curriculum and develop global competencies. Our previous program activity in Cartagena in the thematic area of Environmental Monitoring has resulted in five additional cohorts of students participating since inception in 2009 (30 US students and 27 Colombian students participating). NYC-LSAMP students from Cartagena have included five community college students and 17 different participating colleges. The majors have included students majoring in chemical engineering, biomedical engineering, biochemistry, psychology, economics, mathematics, computer science, environmental science, civil engineering, mechanical engineering, geology and nursing. Utilizing the Transportation theme, we envision a similar diversity in the outcomes in FDS as in Cartagena. Thus far seven NYC-LSAMP students have participated, two have completed the BS degree, and two were community college students.

The long-term research goal is to identify the feasible transportation systems that would increase the mobility and performance for urban passengers in a mid-sized city, in a developing country. As stated earlier, FDS is the second largest city in the Brazilian state of Bahia and the population of 600,000 is expected to increase to 1,000,000 in 24 years.

Since the last deployment of students, additional survey periods were planned along with the utilization of the online, more expansive survey. Future survey cohorts of CUNY/UEFS teams will also focus on the vehicle, that is whether private van usage, BRT implementation, bicycle, and motorcycle ridership. Increased participation from students at UEFS and CUNY will further

expand the scope of the CTS by the addition of crime rate statistics, traffic congestion data and current bus routes. An interactive geo-referenced map of FDS (google maps) was created that is being utilized to generate origin-destination profiles and significant flow analysis. It will be utilized in future studies/student activities such as community mapping. Additionally, three additional survey periods are planned to assess the travel patterns over different periods annually.

While the sample size of the self-reported data can be considered small compared to other self-reported transportation databases [12], the initial results set the bases on who are the travelers of Feira de Santana that utilizes its transportations system. The peak hours and satisfaction levels already give an invaluable indication of where to address the increased ridership projected for Feira de Santana as the population is projected to increase to one million by the year 2040. The average profile of the current client is a female of either mixed or black race, 1844 years old, and an average household monthly income of $R3520 ($US 1120). A general ridership that is predominantly female will have a profound influence on the planned development in areas such as crime prevention, pricing, and equity in transportation.

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