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# Table of Contents



**On the cover:** Railroads and agriculture have a mutually beneficial relationship. Agricultural shippers are able to reach distant export ports and domestic processing locations. Agricultural traffic is a major market for railroads. Torshizi and Gray explore this relationship in “Export Spread, Farmer Revenue and Grain Export Capacity in Western Canada.”

# A Message from the JTRF Co-General Editors

The Spring 2017 issue contains the usual wide variety of contemporary transportation topics that is the distinguishing characteristic of JTRF. Topics in this issue include the following:

- Undergraduate transportation management education
- Impact of travel time reliability on elderly drivers safety
- Airline ancillary services
- Safety tools for two-lane highways
- Transportation coordination and end-user quality of life
- Export spread and grain export capacity

In "An Analysis of the Status of Undergraduate Transportation Management Education in the United States," Richard Stewart and co-authors examine 170 of the non-engineering undergraduate degrees in the fields of supply chain management, logistics, and transportation. The curriculum for each degree was evaluated to determine the extent to which students were taught transportation and related courses. The authors found that transportation related business degrees, including supply chain management, have increased but remain a low percentage of available degrees offered by the universities reviewed.

Emmanuel Kidando and co-authors evaluate how travel time reliability might be associated with crashes involving elderly drivers in "Safety Analysis Considering the Impact of Travel Time Reliability or Elderly Drivers." The authors use several TTR (travel time reliability) metrics to estimate their influence on elderly crash frequency and severity of the crash on freeways and arterial highways. The authors found that TTR is statistically significant in affecting both elderly crash frequency and the severity of a crash involving an elderly driver. The authors found that a one unit increase in the probability of congestion reduces the likelihood of an elderly severe crash by 22%. A variety of variables were included in the analysis, indicating traffic density, road characteristics, land use characteristics, driver characteristics, temporal factors, and travel time.

In "Airline Ancillary Services: An Investigation into Passenger Purchase Behavior," Steve Leon and Nizam Uddin evaluate antecedents to purchase intention and actual purchase behavior of airline ancillary services using logistic regression and generalized linear model (GLM) and data collected from Amazon Mechanical Turk. The authors found differences in airline passenger preferences when purchasing ancillary services. The number of times a passenger flies per year and the trip purpose are significant, while age and gender are not.

Ben Nye and co-authors determine the effectiveness of the usRAP for three rural two-lane corridors, including a U.S. highway, a Kansas highway, and a rural secondary road in "Demonstration of the United States Road Assessment (usRAP) as a Systematic Safety Tool for Two Lane Roadways and Highways in Kansas." The usRAP is a systematic tool that determines areas of risk based on roadway characteristics. The authors found the usRAP predicted a star rating (indicator of crash risk) for each corridor if all countermeasures above a benefit-cost ratio of 1.0 were implemented. Although substantial risk improvements were predicted for U.S. 40 and K-5, RS20 and RS25 were predicted to remain constant because substantial reconstruction was needed to upgrade the safety of the corridor.

In "Impacts of Mobility Management and Human Service Transportation Coordination Efforts and End-User Quality of Life," Jeremy Mattson and co-authors develop an evaluation method to examine the effectiveness of mobility management and coordination programs in a community.

The authors conducted a series of surveys of both transit users and stake-holders in communities across the U.S. They found that the results from the surveys suggest improvements have occurred in efficiencies, ease of access, and quality of service. Most respondents to the stakeholder survey reported benefits that have been realized. Results from an ordered probit model demonstrate the positive impacts that improved mobility has on life satisfaction.

Mohammad Torshizi and Richard Gray develop an economic framework that incorporates the derived demand for grain exports within a spatial model, involving four production regions and four export points in "Export Spread, Farmer Revenue, and Grain Export Capacity in Western Canada." Using data from 2012 to 2015, the authors estimate export impacts of limited grain export capacity. The ex-ante aspect of the study addresses the need for future grain export capacity. To assess the need to expand export capacity, the authors forecast future grain production levels and use a model of rational expectations to estimate future export spreads. The authors found that with no change in export capacity, the expected cost of limited export capacity could exceed $5.6 billion.

Michael W.Babcock
Co-General Editor-*JTRF*

James Nolan
Co-General Editor-*JTRF*

# An Analysis of the Status of Undergraduate Transportation Management Education in the United States

**by Richard D. Stewart, Natalie Burger, Erica Hansen, and Gavin Johnson**

*This paper examines 170 of the non-engineering undergraduate degrees in the fields of supply chain management, logistics, and transportation, including joint majors, present within universities in the United States. The curriculum for each degree was evaluated to determine the extent to which the students were taught transportation and related courses. Each university's website was also examined to catalog additional best practices in education, such as required internships, used to support teaching transportation outside of formal classroom instruction.*

## BACKGROUND

Frequently, the questions of what is the discipline of transportation and what universities teach it are raised by undergraduate students, parents, and administrators. Transportation as an academic business discipline focuses on the five modes (rail, land, marine, air, and pipeline), examining their economics, operations, and management. Transportation has been a discipline at some U.S. universities for close to a century. Syracuse University started its first transportation and traffic specialization in 1919 and the H. H. Franklin Chaired Professorship in Transportation was endowed in 1920 (Whitman School of Management 2015).

Business logistics has been taught as a distinct subject since the 1960s when companies began to adopt the total cost approach. One of the first business logistics courses was taught at Michigan State University in 1960 (Ballou 2006). Logistics became embraced as an academic subject and at times replaced transportation. Business theory practices focused on the total cost approach evolved, and by the mid-1990s, the concept of supply chain management (SCM) emerged as a distinct discipline at universities. While industry and academics debate if SCM evolved from logistics, includes logistics, or intersects logistics, it is increasingly being recognized as a separate academic discipline (David 2013). SCM theory holds that while disciplines such as transportation, procurement, marketing, warehousing, finance,, and distribution can be taught separately they should be integrated because of their interrelationship and interdependency in the supply chain. As Southern concluded in his summary of the transition of transportation to SCM, not all companies have adopted SCM theory but many are moving down that path and more will in the future (Southern 2011).

Business leaders recognize that transportation can greatly affect their bottom line. Transportation as a cost of SCM has increased over the past five years. A shortage of truck drivers, increased regulatory requirements, fuel prices, and congestion have all contributed at various times to the rise in the cost of transportation. Managers are trying to find ways to address this spending, which means that they, and new managers they hire, need to understand the role and operations of transportation (Russell et al. 2014).

Transportation as an academic discipline has waxed and waned over the decades. Rationale for its periods of decline include a lack of understanding of the importance of transportation by academics, few quality textbooks, a movement toward generalization in business schools, and a periodic lack of demand by employers for students with an educational background in transportation (Ferris et al. 1972). The fact that transportation is and has been an academic discipline does not answer the question of which universities currently offer transportation degrees or even teach transportation courses in a school of business.

A 1977 survey of institutions teaching transportation and business logistics courses by Gilmore found that the demand for these students, measured by post-graduation placement, was as great as any other field in the business schools (Gilmour 1978). The author also found that only 40 programs were offering majors in transportation and/or logistics. Ozment & Keller (2011) published their research on universities that taught transportation, logistics, and supply chain management education. The study focused only on universities that were accredited by the Association to Advance Collegiate Schools of Business (AACSB) (Ozment and Keller 2011).

## METHODOLOGY

The University of Wisconsin-Superior (UWS) research team focused on analyzing the best practices in transportation management education at the undergraduate level in non-engineering degrees, starting with determining which universities offered related business degrees. Urban planning degrees and engineering degrees can focus on transportation planning and infrastructure, but the scope of this research did not include those degrees. The first task in this analysis was to create an inventory of universities which advertise that they offer a related undergraduate management major.

The team was unable to find a single comprehensive published inventory of all the universities in the U.S. that provide a list of relevant bachelor's degrees. The research team decided to revisit the Ozment and Keller (2011) sample group and to expand it to include schools that were not accredited by AACSB. The rationale for this expansion was first to try and capture as many programs as possible, and second, while AACSB accreditation is highly regarded, accreditation by one body was not felt to be a sufficient rationale for limiting the study group. The findings would update the Ozment and Keller (2011) study and provide a larger pool of schools.

This list would also provide the research team with a base that could be useful in determining common themes and best practices. In order to address the topic of best practices in transportation education, a decision was made to limit the scope of the research by the following parameters:

a. Limit the list of universities for further analysis to those offering bachelor's degrees with a major in transportation, logistics, SCM or a combination of those disciplines, and market themselves as teaching transportation, because each of these management disciplines sees transportation as a component of their field of study.
b. Limit the list to those schools that required all students in the above major to have at least one course in transportation, logistics, or SCM. This would ensure a student with that major would have discipline-specific courses.
c. Engineering schools may teach a variety of transportation courses as part of a civil, marine, mechanical, or other engineering major. However, it was decided that data collection and analysis of these programs should be part of a future study, and not included in the scope of this research.
d. Urban planning programs also teach transportation planning courses. However, such programs were not evaluated as the focus of this research was on management degrees.

The UWS team revisited the AACSB university listing and decided to expand the data set. The team examined professional organizations and societies that publish a listing of universities with degrees in the relevant disciplines. The team also looked at the five federal service academies whose graduates are required to have a military service commitment. The services and their respective academies have a longstanding focus on logistics. These academies are U.S. Military Academy (West Point), U.S. Naval Academy, (Annapolis), U.S. Air Force Academy, U.S. Coast Guard Academy, and the U.S. Merchant Marine Academy (Kings Point). State maritime academies were included because of their mission in preparing students to serve in the maritime transportation industry while earning an undergraduate degree. State maritime academies are located in the following states:

Michigan (Great Lakes), Massachusetts, New York, Texas, California, and Maine. The following list includes the sources that were examined:

a. Universities accredited by the Association to Advance Collegiate Schools of Business (AACSB)
b. American Society of Transportation and Logistics (AST&L) blanket waiver schools. A blanket waiver school is a university with a degree program that has been reviewed by the AST&L board of examiners and approved. Approval enables graduates to earn the Certified in Transportation and Logistics (CTL) designation upon graduation.
c. Council of Supply Chain Management, (CSCMP)
d. Institute of Supply Management, (ISM)
e. Council of University Transportation Centers, (CUTC)
f. Society of Logistical Engineers, (SOLE)
g. The five federal service academies
h. The state maritime academies

The list of sources was divided by the research team. Each researcher analyzed all universities falling under the source's listing. The AACSB website offers a search into the different types of programs it accredits. When searching the 2015 AACSB University listing for supply chain management, logistics, and transportation programs, the research team initially searched using language from the Ozment and Keller (2011) study, but discovered the search issued zero results. This appears to be because the AACSB has changed its search engines since 2010. The research team then went through the AACSB listing for general business programs, reviewing them for relevant degrees in order to expand the inventory of universities.

Academic institutions listed by the professional organizations were researched. The military academies were examined because of the critical value of logistics to the military. The five federal academies were also reviewed for relevant programs. Lastly, maritime academies were analyzed, as they have been teaching transportation courses for many decades.

An Excel database was created to house the inventory of relevant degrees. Universities that were found to offer SCM, logistics, or transportation programs were added to the inventory. For each university listed, the research team reviewed related university publications and/or websites to collect the following data:

a. University name
b. Location
c. Contact information
d. Website link to degree details
e. Degree offered (Note: if more than one relevant bachelor's degree is offered at a university, each degree has an individual listing)
f. Which source(s) listed in the prior section that the university was listed in

In order to collect the relevant data listed above, the research team examined the websites of each university in the list of sources. Data analysis was complicated by the lack of a common format in how each university's websites are constructed. This fact meant that each website had to be methodically examined to extract the relevant data. Once the relevant program was found, the information on the curriculum found in Tables 2, 3, 4, and 5 was found on that page or a nearby link, in the academic catalog, or a combination of these. The other, more qualitative, data found in Table 5 were found by looking throughout the website of the department or college in which the relevant degree was housed.

## LIMITATIONS OF METHODOLOGY

The research team at the University of Wisconsin-Superior decided on investigating the universities' websites to collect data on best practices for transportation education. The research team understood the inherent limitations of using websites as a resource. University websites offer what the people in the university or program find most important to display to the general public. The target markets that universities reach out to include prospective students and also companies that seek graduates with education relevant to the transportation industry. Another issue in accessing the websites was the inconsistent updating of website information. Some websites had been recently updated, others had information that was years old, and frequently there was a mix of old and new data. This made it difficult to determine with absolute certainty that all information gathered was current as of 2015. The reality is that university websites can be more of a marketing tool than a repository of accurate and current information.

When the team looked at individual websites, considerable time was spent following the many different links while looking for critical information. Multiple links had to be reviewed before relevant information was found, if it was found at all.

One of the major difficulties the research team ran into was not always having a clear listing of the required and elective courses offered for one of the relevant degrees. Online catalogs provided courses, but it was not always clear at that link alone. In the course catalog, course numbers and abbreviations were used instead of the full course name. When this happened, it was necessary to look at other links to get the full name and which parameters the course would fall into.

The team felt that accessing university websites designed to convey information about degree programs would provide more data than a survey with typical low return rates. A survey of certain degrees may be useful for future research in order to get more in-depth information on particular programs.

## DEGREE ANALYSIS

A summary of the relevant majors collected from university websites can be found in Table 1. All of the listed degrees were advertised in the cited sources as teaching transportation as part of their curriculum**.** This study's sample includes a total of 162 U.S. universities listing 170 relevant bachelor's degrees that were found after looking at 583 universities. The listing is a significant sample but should not be considered an inclusive listing of all the universities in the U.S. that teach transportation.

**Table 1: An Inventory of 170 Bachelor's Degrees from 162 U.S. Universities in Supply Chain, Logistics, Transportation, or a Combination of Those Disciplines**

| Degree Titles | Total Number of Each Degree |
|---|---|
| Logistics and SCM | 22 |
| Information Systems and SCM | 2 |
| Accountancy and SCM | 1 |
| Logistics and Operations | 1 |
| Transportation and Logistics | 4 |
| Supply Chain Management | 90 |
| International Business and Logistics | 2 |
| Operations and SCM | 29 |
| SCM and Transportation Management | 1 |
| Logistics Management | 4 |
| Purchasing and SCM | 1 |
| International Transportation and Trade | 1 |
| Maritime and SCM | 2 |
| Transportation and Urban Infrastructure | 1 |
| Marine Transportation | 2 |
| Industrial Distribution and Logistics | 1 |
| Manufacturing and SCM | 1 |
| Transportation | 1 |
| Logistics Information Systems | 1 |
| Logistics and Intermodal Transportation | 2 |
| SCM, Logistics, and Transportation | 1 |
| Total Number of Degrees | 170 |

## ANALYSIS OF COURSES

Ozment and Keller's (2011) research found that "approximately one-third of the AACSB schools examined had a required introductory transportation logistics supply chain management (TLOG/SCM) course in the business core." This finding raised the question: Are transportation courses required in these majors? A best practice in teaching transportation would be to offer courses, either mandatory or elective, in transportation. This step analyzed each of the courses offered in the related degrees. Courses may cover more than one discipline. The broad and complex nature of SCM means that a textbook introducing the student to all aspects of SCM will allocate only a small portion of its content to transportation. A typical SCM textbook will have at least one chapter, out of 14 or more, on transportation (Wisner, Tan and Leong 2014). Some textbooks may have two. While the student may have been introduced to the subject of transportation, this course cannot compare to an in-depth course focused on transportation using a transportation textbook. Indeed, it is also common for a transportation or logistics textbook to introduce the subject of SCM in a single chapter (Coyle, Novak and Gibson 2015). This raises the question: are supply chain management courses required for other relevant majors assessed in this study?

The research team reviewed each of the 170 bachelor degree programs and determined the following:

a. Course name, course number, and amount of credits in required courses that have the name transportation, SCM, or logistics in them must be taken by students in that major as a core course.
b. Course name, course number, and amount of credits in elective courses that have the name transportation, SCM, or logistics in them may be taken by students in that major.

This step of the research process was undertaken in order to further determine the level of education that is given on the topic of transportation.

**Required Course Analysis**

Table 2 analyzes all 170 relevant undergraduate degrees that have at least one required course in SCM, logistics, or transportation. The sum of the total number of degrees noted on the table is greater than 170 because some programs require courses in more than one of the relevant areas. The research team took note of required core courses that did not have the words transportation, logistics, or SCM in the title but seemed as though the nature of the topic would be transportation related.

- SCM was the most frequently required course with 81.76% of the universities requiring an SCM course.
- A logistics course is required for 44.70% of the degrees.
- A course in transportation is required for 25.88% of the 170 degrees.
- A total of 1.18% of the degrees analyzed required a combination transportation and SCM course.
- Degree programs that require a combined course of transportation and logistics total 17.66% of the degrees reviewed.
- Degree programs that require separate core courses in both SCM and transportation represent 17.66% of the degrees evaluated.

**Table 2: Analysis of 170 Relevant Undergraduate Business Degrees by Required Courses in SCM, Transportation, Logistics and Other Courses**

| Analysis of Relevant Degree Programs in U.S. by Required Course | | | |
|---|---|---|---|
| | | **Number of Degrees** | **Percentage of all Degrees** |
| 1 | Degrees with transportation core courses required | 44 | |
| | Percentage of all degrees | | 25.88% |
| 2 | Degrees with logistics core courses required | 76 | |
| | Percentage of all degrees | | 44.70% |
| 3 | Degrees with SCM core courses required | 139 | |
| | Percentage of all degrees | | 81.76% |
| 4 | Degrees with transportation/SCM core courses required | 2 | |
| | Percentage of all degrees | | 1.18% |
| 5 | Degrees with logistics/transportation core courses required | 30 | |
| | Percentage of all degrees | | 17.66% |
| 6 | Degrees with logistics/SCM core courses required | 30 | |
| | Percentage of all degrees | | 17.66% |
| 7 | Degrees with other required core courses that may have transportation component not included in list 1 of this table | 47 | |
| | Percentage of all degrees with other required core courses with transportation component | | 27.65% |
| 8 | Degrees that require both transportation & SCM courses | 30 | |
| | Percentage of all degrees | | 17.65% |
| 9 | Universities that provide a required transportation course per lists 1,4,5,7. Overlapping has been removed | 95 | 55.88% |
| 10 | Universities that do not provide required transportation courses per lists 1,4,5,7 | 75 | 44.12% |

**Degrees Requiring More Than One Relevant Course**

The next analysis looked at each of the undergraduate degree programs by the major disciplines of transportation, logistics, and SCM to assess how many of these majors required more than one course in their respective disciplines. The research was done to determine how in-depth the subject matter of the discipline was covered. The results for each of the three disciplines were then compared by percentage, to first, the universe of all the degree programs in their stated major, and secondly, against all 170 degree programs.

**Table 3: Analysis of U.S. Undergraduate Programs That Require More Than One Relevant Course in the Respective Subject Area.**

| | | |
|---|---|---|
| Number of transportation programs requiring more than one transportation course | 11 | |
| Percentage of the 44 transportation programs | | 25% |
| Percentage of total 170 programs | | 6.4% |
| | | |
| Number of logistics programs requiring more than one logistics course | 19 | |
| Percentage of the 75 logistics programs | | 25.33% |
| Percentage of total 170 programs | | 11.18% |
| | | |
| Number SCM programs that require more than one SCM course | 81 | |
| Percentage of the 139 SCM programs | | 58.27% |
| Percentage of total 170 degrees | | 47.65% |

**Elective Course Analysis**

The research team analyzed elective courses offered on the three relevant topics of transportation, logistics, and SCM. Elective courses related to transportation were specifically analyzed. Figure 1 displays the frequency of electives offered relating to the topic of transportation. This graph shows how many degrees offer elective courses related to transportation. For example, there are 71 universities that do not offer an elective course in transportation, logistics, supply chain management, or a combination of those courses. These findings raise the question of why there are not more transportation related electives offered in the degree programs? Further research into each program would be required to determine the rationale for not offering more related electives.

**Figure 1: Elective Courses Related to Transportation**

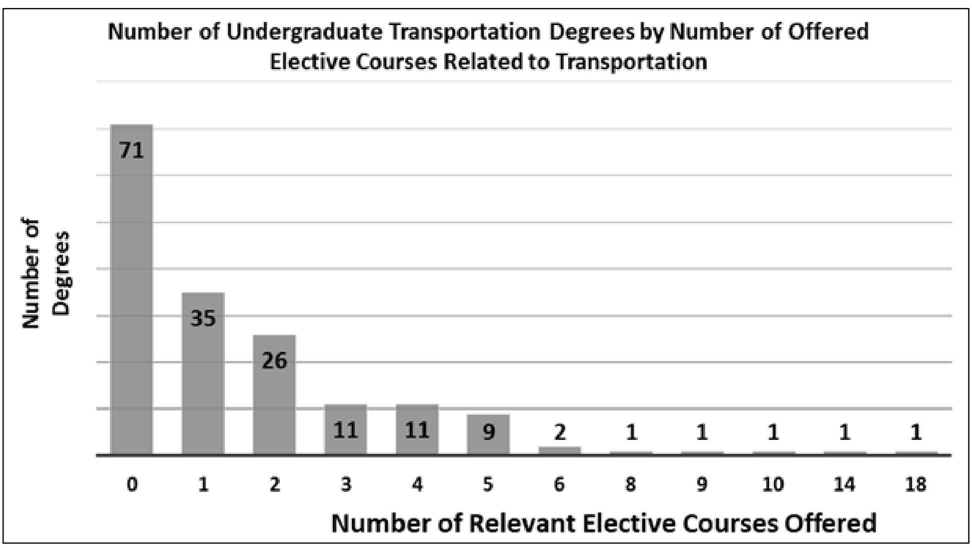
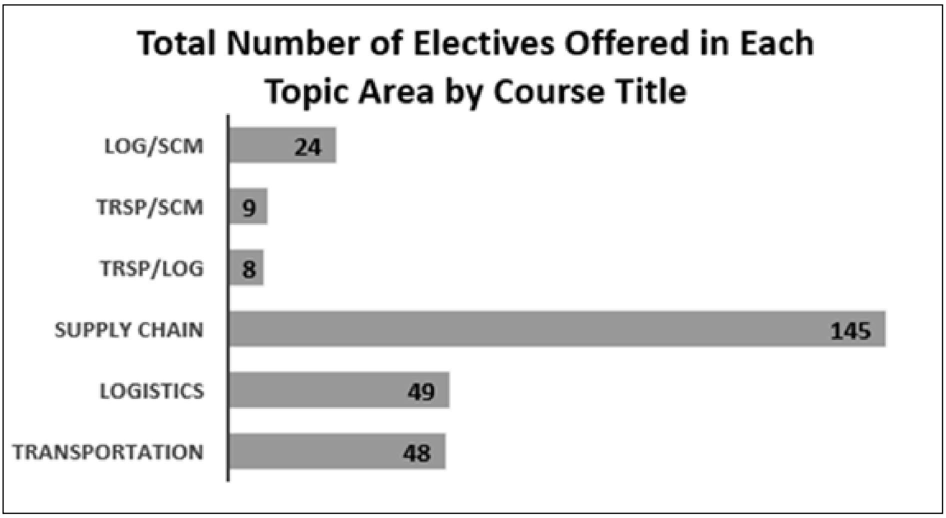


Figure 2 lists the number of electives offered in each of the three relevant topics. Courses were sorted into the topic areas by analyzing the title of each elective course. To be deemed relevant, the elective course needed to have the words transportation, logistics, or supply chain management in the title. Elective courses with a combination of these words were also included. SCM elective courses were by far the most frequently offered electives followed by logistics/SCM combinations and transportation electives last. The study did not assess the frequency of elective course offering, only if electives were listed in the program. Further research would be needed to determine if the elective courses listed are offered on a regular basis, (annually or bi-annually), or infrequently (on demand or every three years or more).

**Figure 2: Electives Offered**




## ADDITIONAL INDICATORS OF BEST PRACTICES IN TEACHING TRANSPORTATION MANAGEMENT

### Student Clubs

The research team also looked into whether or not each university offered a student club specific to the relevant degree. Student clubs offer leadership opportunities, interaction with peers, interaction with professionals, frequent publication of newsletters, and the possibility of improved morale. Student clubs may be segmented into two types, branded and non-branded. Branded clubs may have affiliations to professional organizations such as a Student Council of Supply Chain Management (CSCMP) Round Table hosted by the students of a specific university. Non-branded clubs may closely interact with professional organizations, but are not formally branded by a professional organization. The Transportation and Logistics (T&L) Student Club, the student club at the University of Wisconsin, Superior, is an example of this. The research team observed that very few of the student clubs did not offer some type of networking opportunities for the club members. It was determined 111 of the 170 programs had student clubs. No academic literature was found discussing the advantages or limitations of the club's branding to a professional organization and the impacts on the organization, the students, or the university.

**Relations with Professional Organizations**

The research team noted that another common practice of transportation management programs is to be affiliated with various industry-specific professional organizations. The initial plan for this information was to categorize the professional organizations into formal and informal interactions. Formal interactions included donations for scholarships, research fellowships, and supporting a student chapter of the organization. Informal interactions would include the organization being listed on the website, or if the students attended a meeting. These types of data were difficult to find on the websites and even more difficult to categorize into these two groups.

It was noted that most universities affiliated with professional organizations had student clubs sponsored by a professional organization. The student clubs could be chapters of the organizations or just a recognized student organization through the university with ties to the professional organization. Many programs had a student chapter of the professional organization, such as American Production and Inventory Control Society (APICS) and CSCMP. The research team noted that in a few schools, professional organizations sponsored case study competitions, as well as research fellowships. A common practice when looking for these affiliations was the types of activities that a professional organization may offer a program. Typical practices included networking with industry professionals, attending seminars and conferences, as well as having speakers on campus. Affiliation was not essential for a student club to engage in these best practices. The activities were usually supported by an active student club or a center within the academic department specific to the program.

Colston (2003) stated, “It has become increasingly important for organizations to be actively involved in workforce education and learning in order to develop and retain a high performing workforce” (Colston 2003). One of the major issues the study found with these partnerships is that there is often a lack of management, and another is the cost associated with these programs. Both are problems that prevent the start or continuation of such programs. When organizations are looking to invest in higher education programs they are looking for high quality programs that can translate to on-the-job application. Richard Burke (2003) wrote a paper that also looked into the importance of partnerships between schools and professional organizations (Burke 2003). He discussed the challenges our country is facing with the switch from a manufacturing economy to a knowledge based economy. The transition stresses the importance of educational-professional partnerships. The author believes that involvement between employers and educational institutions working together to develop programs will create a workforce for today's and tomorrow’s global economy.

The association between schools and professional organizations was one of the key indicators the research team looked at in determining whether there were any connections between the school’s programs and a related professional organization. A professional organization can have benefits for all parties involved. The school, the student, and the professional organization can all benefit from each other’s involvement with one another. One of the many reasons organizations would want to partner with schools is to help develop a workforce that would better suit their needs. The formal involvement also means that the school can learn what employers are looking for in future employees.

We looked into formal and informal connections between schools and professional organizations. The team defined a formal connection as a school and organization having planned networking, meetings, or any other events that connect the two. This information was found on most websites. This was indicated by a student chapter of the organization or some type of logo of the professional organization on the website. An example is Texas A&M University and CSCMP, where the university has a student round table on its campus (Texas A&M CSCMP Student Roundtable Website 2014). The partnership is listed on both of their websites, so the team would consider this a formal partnership. For an informal partnership, the team looked at relationships where there may be contact such as the exchange of newsletters or giving updates to one another. The difficulty in determining the level of involvement from the university websites resulted in the findings from this portion of the research being a qualitative rather than quantitative set of results.

**Admission Requirements**

A common feature of business schools is admission requirements. Admission to a school or department of business normally requires the completion of required courses, achieving an acceptable grade point in those required courses, and an acceptable grade point average for all courses taken at the university. The purpose of the admissions process is to limit entry to the school to only those students who have proven they should be capable of success in the higher level courses. The research team assessed if a program required the student to achieve a specific status before being admitted to the college, department, or program. The team found that 132, or 77.65% of the programs, required this admission in order for the student to take upper level courses (300+ and 400+).

**Internships**

Internships in business schools have long been considered a very valuable educational process, and in majors such as accounting there is an expectation that students will complete an internship. The literature on logistics internships indicate that internships serve three stakeholders: students, companies, and educators. Among other benefits, internships improve business school curriculums (Gerken et al. 2012). Internships have been found to make students more marketable and increase their pay (Gault, Leach and Duey 2010). Hiring managers look at a potential employee's resume for work experience, but the type of knowledge of a specific sector an internship can offer is what sets graduates with internship experience apart. Many new hires may have an idea of what the industry is about from classroom learning, but that cannot replace the basic skills a student gains from experiential learning such as an internship (McCrea 2012). Knemeyer and Murphy's (2001) study on logistics internships assessed company and student expectations for internships and listed multiple benefits for each group. In their conclusion they stated that further research on the structure of logistics internships is needed to develop the future talent pool. However, the survey did not address if companies, institutions, or students believed that internships should be required.

The review of literature establishing the value of internships led to the question of how many of the 170 programs offered internships. From the data available on the universities' websites, the research team noted: whether the program required an internship in order for the students to complete the program, offered an internship as an elective for the program, or did not have an internship specifically as part of the degree progress but the department or college recommended that the students take part in one.

**Table 4: Internships Requirements**

| **Analysis of 170 Transportation Management Undergraduate Degrees in the U.S. by Common Internship Practices** | **Number of Schools** | **Percentage** |
|---|---|---|
| Program requires an internship in order to earn the degree | 25 | 14.71% |
| Program offers internship to be completed as an elective | 39 | 22.94% |
| Program recommends internship, not specifically part of degree progress | 68 | 40% |
| Degrees that require an internship and a course in transportation | 9 | 5.29% |

**Accreditation**

It was also noted that many of the relevant programs were housed in a college or school that is accredited by the AACSB. In the 2010 study by Ozment and Keller (2011), there were 59 degree programs accredited by 475 AACSB accredited universities. This number has increased by 62 since the 2010 paper for a total of 121 relevant programs offered by 454 AACSB accredited universities. The 121 programs represent 26.65% of the 454 total programs offered by AACSB universities. The research team also analyzed how many of the programs accredited by AACSB required a course specifically with the word "transportation" in the course name. Based on the analysis, it would appear that non-AACSB accredited programs would be more likely to offer named transportation courses. There was no determination made as to why there was this variation.

**Table 5: AACSB and Non-AACSB Relevant Programs and Courses**

| Analysis of AACSB and non-AACSB accredited Transportation Management Undergraduate degrees in the U.S. (total of 170 programs) | Number of programs | Percentage 170 degrees with relevant major |
|---|---|---|
| AACSB accredited relevant programs | 121 of the total 170 | 71.18% |
| AACSB schools that require a course in transportation (has the name transportation in the title) as a percentage of AACSB relevant programs | 29 of the 121 | 23.9% |
| Number of AACSB schools that require a course in transportation (has the name transportation in the title) as percentage of all relevant programs | 29 of the total 170 | 17.09% |
| Number of non-AACSB relevant programs | 49 of the total 170 | 28.82% |
| Non-AACSB schools that require a course in transportation (has the name transportation in the title) as a percentage of Non-AACSB relevant programs | 16 of the total of 49 | 32.65% |
| Number of non-AACSB relevant programs that require a course in transportation as percentage of all relevant programs | 16 of the total 170 | 10.66% |

## FUTURE RESEARCH

This study has raised several questions which could be possible areas of research to build on in the future.

This study found there was not a single database where transportation management degrees could be found. A database that includes all undergraduate transportation degrees could be built with listings of transportation degrees and which academic institutions offer them. Future research should be done to determine which of the disciplines (SCM, logistics, or transportation) is growing or declining and the rationale for the changes.

This study did not replicate the research by Ozment and Keller (2011) on the number of faculty teaching in the relevant disciplines or the number of graduates from the programs. These two topics should be revisited to gain an idea of how these factors have expanded along with the number of programs.

This study does not recommend what level of transportation education students earning a management degree should have. It looked at what related courses are being taught currently. The question of what minimum level of education undergraduate management students should have in transportation remains unanswered.

Student success could also be looked at when comparing students who are required to take a transportation internship. Possible criteria could be job placement, advancement, and job satisfaction.

The study did not assess the benefits or costs of student clubs being formally affiliated with a professional organization or being unaffiliated.

Future research into transportation education could include other undergraduate degrees such as planning, engineering, and economics, as this study did not look into those types of degrees. This could help determine what the optimal level of transportation education is needed to plan and operate our nation's transportation systems efficiently and sustainably.

An area of interest that needs further research is the level of education required for a student to undertake an internship. The research noted that some universities required admission to the school of business, relevant upper level courses, or a combination of them. However, it was also observed that some institutions apparently allowed internships to be taken at any stage of the student's academic career.

## CONCLUSIONS

Transportation related business degrees, including SCM, have increased but remain a low percentage of available degrees offered by the 583 universities reviewed. This study found that the number of AACSB accredited business schools offering relevant degrees has increased since the Ozment and Keller (2011) study. UWS researchers found 170 relevant degrees at 162 universities. SCM, a recent discipline, had the most degree programs with a total of 90 that were titled as supply chain management majors.

Of the 170 relevant degrees, transportation courses are the least required for graduation, with 44, or 25.88%, of the 170 degrees requiring at least one core course in this discipline. This finding raises the unanswered question, why, when transportation is such a critical element of the supply chain, is it not taught in more detail? One supposition is that there may be a lack of faculty educated in and willing to teach transportation courses at the undergraduate level. As far back as the 1960s studies have cited a shortage of faculty with the relevant experience and education to teach transportation (Farris et al. 1972). The Ozment and Keller (2011) study found that in AACSB universities about 1.1% of the faculty were teaching TLOG/SCM courses. They also noted the very limited number of Ph.D. programs in the relevant disciplines, creating a lack of new faculty entering the market.

SCM electives are more available than transportation or logistics electives. However, there are electives offered in all the subject areas, although not at every university.

Of the 170 programs researched, 111 offered a related student club, which is 65.29%. The research team observed that very few of the student clubs did not offer some type of networking opportunities for the members of the club. There is a clear indication in these disciplines of involvement in professional organizations, either formally or informally. The review of websites did not allow for an accurate quantitative measure. A survey may be the best tool for determining the numerical level of involvement in each category.

It is interesting to note the low percentage of schools that require an internship to graduate. Internships by their nature require significant resources in order to establish relationships with companies, maintain relationships, prepare students, monitor student internships, and measure the quality of the internship experience. This demand on scarce resources may be a reason why so few schools require internships even though their benefits are well understood and documented.

The number of AACSB accredited business schools offering relevant degrees has increased. Future research should be done to determine if the increase is mostly in teaching SCM rather than other disciplines.

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**References**

Ballou, Ronald, H. "The Evolution and Future of Logistics and Supply Chain Management." *Production* 16(3), (2006): 375-386.

Burke, Richard Kent. "Workforce Education and Training in Southwest Kansas: Perceptions of the CEOs of Businesses, Industries, Professional Services and Governmental Agencies." PhD diss., Kansas State University, 2003.

Colston, Carol Lynn. "A Descriptive Study of Learning Partnerships between Organizations and Higher Education Institutions to Support Workforce Development and Retention: Organizational Perspectives." PhD. diss. Capella University, 2003.

Coyle, John, Robert Novack and Brian Gibson. *Transportation: A Global Supply Chain Perspective 8th Edition*, Cengage, Boston, 2015.

David, Pierre. *International Logistics 4th Edition*, Cicero Books, Berea, Ohio: 2013.

Farris, Martin T., Gilbert Gifford, Donald Harper, Warren Rose, Hugh Norton, and James Bennett. "Transportation Education: An Evaluation." *Transportation Journal* 11 (4), (1972): 26-39.

Gerken, Maike, Bart Rienties, Bas Gieshers, and Karen Konings. "Enhancing the Academic Internship Learning Experience for Business Education – A Critical Review and Future Directions, Chapter 2," *Learning at the Crossroads of Theory and Practice, Research on Innovative Learning Practices*, edited by P Van Der Bossche, W.H. Gijselaers, and R.G. Milter. Springer, Netherlands: 2012.

Gault, J., R. Leach, and M. Duey. "Effects of Business Internships on Job Marketability: The Employers' Perspective," *Education & Training* 52(1), Accessed January 20, 2015. (2010):76-88. http://digitalcommons.wcupa.edu/cgi/viewcontent.cgi?article=1002&context=mark_facpub

Gilmour, Peter. "The Current Status of Business Logistics Education." *Transportation Journal* 18(2), (1978): 71-78.

Knemeyer, Michael, and Paul, Murphy. "Logistics Internships: An Employers Perspective." *Transportation Journal* 41 (1), (2001): 16-26.

McCrea, Bridget. "What Hiring Managers are Looking for Today." *Supply Chain Management Review, Special Edition, (2012):1-4.* Accessed July 24, 2015. http://www.scmr.com/article/what_hiring_managers_are_looking_for_today/D2

Ozment, John, and Scott B. Keller. "The Future of Logistics Education." *Transportation Journal* 50 (1), (2011): 65-83.

Russell, Dawn, John J. Coyle, Kusumal Ruamsook, and Evelyn A. Thomchick. "Logistics: The Real Impact of High Transportation Costs." *CSCMP's Supply Chain Quarterly*. 2014. Accessed July 24, 2015. http://www.supplychainquarterly.com/archives/2014/01/

Southern, R. Neil. "Historical Perspective of the Logistics and Supply Chain Management Discipline." *Transportation Journal* 50(1), (2011): 53-64.

Wisner, Joel, Keah-Choon Tan, and Keong Leong. *Principles of Supply Chain Management: A Balanced Approach, 4th Edition*. South-Western, Mason, Ohio, 2014.

Whitman School of Management. "Historical Highlights," Accessed February 10, 2015, https://whitman.syr.edu/programs-and-academics/academics/scm/pdf/MS_SCM_2013_web.pdf

***Richard Stewart** has taught undergraduate and graduate courses in transportation and supply chain management for 30 years. He has been a fleet manager of vessels, a small business owner, a master of oceangoing vessels and a captain in the U.S Naval Reserve. Stewart has been principal investigator for over $9 million in research grants. He serves on public advisory boards at the federal, state, and local levels. He has authored numerous journal articles and co-authored a textbook and several book chapters.*

***Natalie Burger**, BS, worked as a research assistant in the Transportation and Logistics Research Center and graduated in May 2016. Burger is currently a finance and logistics specialist for Lake Superior Warehouse Inc. in Duluth, Minnesota.*

***Erica Hansen**, BS, worked as a research assistant, in the UW-Superior Transportation and Logistics Research Center and graduated in May 2016. Hansen is now a manager for JB Hunt in Little Rock, Arkansas.*

***Gavin Johnson**, BS, worked as a research assistant in the Transportation and Logistics Research Center and graduated in December 2016. Johnson is now a supply chain manager for Polaris Corporation in Wisconsin.*

# Safety Analysis Considering the Impact of Travel Time Reliability on Elderly Drivers

**by Emmanuel Kidando, Ren Moses, Yassir Abdelrazig, Eren Erman Ozguven**

*The main goal of this research was to evaluate how travel time reliability (TTR) might be associated with crashes involving elderly drivers, defined as those age 65 and above. Several TTR metrics were used to estimate their influence on elderly crash frequency and severity of the crash on freeways and arterial highways. The results suggest that TTR is statistically significant in affecting both elderly crash frequency and the severity of a crash involving an elderly driver. In particular, the analysis of risk ratios illustrates that a one-unit increase in the probability of congestion reduces the likelihood of the elderly severe crash by 22%.*

## BACKGROUND

Although older drivers (defined as those age 65 and above in this paper) are less involved with speeding, alcohol use, and night driving, they are vulnerable to severe crashes (Insurance Institute for Highway Safety 2016). The major contributing factors for severe injury crashes include frailty and medical complications (AbdelRazig et al. 2016). Furthermore, researchers point out that the risk of an elderly crash to occur rises more on elderly drivers who are 70 years of age or older. For instance, research indicates that in 2008 the odds of this age group being involved in fatal crashes were nearly three times greater than the population between 35 and 54 (Cicchino and McCartt 2014). The risk of crash occurrence for this age group also rises due to hearing difficulties, a decrease in processing skills, and cognitive problems (Souders, et al. 2015).

Even though the frequency and severity of the crashes involving elderly drivers have been decreasing over the last few years (Highway Loss Data Institute 2014), studies suggest that the American population is growing older. According to population estimates and projections, by 2030 the population of elderly drivers will reach 20% of the American population (Colby and Ortman 2015). With this projected increase in senior adult population, there is a need for research to investigate ways to assist older drivers to be familiar with their changing abilities and help adapt their driving practices appropriately.

Travel time reliability (TTR) has recently been recognized as one of the traffic mobility measures (Yang and Wu 2016). However, to the authors' best knowledge, no study has evaluated the influence of this traffic mobility measure on elderly drivers' crash risk analysis. This study attempts to conduct safety analyses to provide insight on how TTR may be influencing the elderly drivers' crash frequency and severity of injuries. In the analysis, the study explores both the categorical model (binary logit) and negative binomial (NB) model to reveal significant factors affecting the probability of severe injury crash occurrence and the frequency of crashes, respectively. The study uses police-reported crash and travel speed reports from northern Florida to conduct the crash risk analysis. TTR metrics are estimated using traffic speed data, which were collected between 2010 and 2011. While four-year crash data from 2009 through 2012 were used in the analysis.

## LITERATURE REVIEW

Unlike other measures of the traffic mobility, such as level of service, delays, and volume to capacity ratio, TTR estimates the consistency of a travel time beyond the average travel time (Taylor 2015). It also represents the road user experience of using a particular road over a long period of observation. In addition, TTR is easily understood by the public compared with other measures. In the literature, several metrics exist that quantify the reliability of a travel time. These metrics consider travel time variation, which measures the stability of the traffic performance (Cambridge Systematics, Inc. and Texas Transportation Institute 2005). Examples of the established indicators of this proposed TTR metric are the standard deviation, variance, the coefficient of variation, and skew statistic of the travel time. Other groups of TTR metrics are the statistical index and probabilistic methods (Kaparias et al. 2008; Chien and Liu 2012). The statistical index metrics include a buffer time, planning time, misery index, and a travel time index. The statistical index metrics are used by some state highway agencies and have also been proposed by the Federal Highway Administration (FHWA) as a measure to quantify TTR (Taylor 2015). Nevertheless, the mean-based metrics such as buffer index and travel time index obscure some of the information for heavily skewed distributions due to congestion onset and congestion offset (Pu 2010). The probabilistic group includes metrics such as congestion frequency and a percentage of on-time arrivals. In this study, measures from all three groups of TTR metrics – that is, variation, statistical index, and probabilistic – are used in evaluating the possible influence of TTR on the elderly crash risk analysis. In particular, TTR metrics selected for the analysis are the probability of congestion, the planning time index, and the standard deviation of the travel time.

Coupled with the growing elderly population, a significant effort has been undertaken to investigate the contributing factors on elderly crash frequency and severity of the crash injury. In analyzing human factors that significantly influence elderly crash severity in Florida, Alam and Spainhour (2008) indicate that older drivers have higher risk of being involved in crashes at intersections than on roadway segments. This finding is also confirmed by a later study conducted by Clarke et al. (2010). There are many factors that contribute to older drivers' involvement in intersection crashes. These studies suggest that misjudging speeds of other vehicles, cognitive failure, ignoring traffic signals, and improper left turns are examples of the major errors that lead to higher intersection crashes. The literature also indicates that injury severity of elderly drivers is significantly influenced by seatbelt use and alcohol or drug impairment. Drivers impaired by alcohol or drugs have higher risks of being injured than unimpaired drivers (Abdel-Aty and Abdelwahab 2000). The role of other factors such as gender, land use, traffic control, road geometry, weather, and traffic data have also been well established by previous studies on the injury severity analysis (Abdel-Aty and Radwan; Dissanayake and Lu 2002; Clarke et al. 2010; Ulak et al. 2017).

Previous research efforts in determining the influencing factors on the frequency of elderly crash occurrence have provided insights that help develop effective crash countermeasures. Examples of the significant factors that have been extensively investigated through statistical analysis are traffic data and segment variables, which are normally considered as exposure variables in safety analysis (Shi and Abdel-Aty 2016). Furthermore, land use, speed, road geometry (such as lane width, the number of lanes, etc.), and temporal variation have also been investigated. Nevertheless, investigations on the impact of TTR have received little attention among researchers. Among the few studies that recently explored the impact of TTR is Shi and Abdel-Aty (2016). This study conducted a safety analysis on the urban expressway and found that TTR influences multi-vehicle crashes more significantly than single vehicle crashes. It is indicated that the reason for such a finding is attributed to unexpected driver behavior, such as unsafe lane changing.

In addition, none of the existing studies have addressed the impact of TTR on roadway safety by considering different age groups. This study concentrates on determining the influence of TTR on the frequency and the severity of injury of the aging driver. In addition to TTR factor, other variables, including road geometric features, land use, and traffic data, are included in the model. It is envisaged that the findings of this study can assist transportation agencies in a deeper understanding of the impact of this new traffic mobility measure and assist in devising traffic crash risk reduction strategies.

**METHODOLOGY**

As mentioned earlier, two models i.e., negative binomial model and binary logit model, were used in this paper.

**Negative Binomial Modeling**

In modeling of the crash frequency, the literature review revealed that the negative binomial (NB) model is the foremost model used to investigate significant variables affecting crashes (Lord and Mannering 2010). This model is derived from the Poisson model to account for overdispersion of the data (Jung et al. 2014). In particular, the overdispersion takes into consideration random crash probabilities associated with differences in reaction times, driving experience, vehicle characteristics, and other influencing factors (Hermans et al. 2006). The negative binomial, which is also the Poisson with a gamma-distributed error with mean $\mu$ and variance $v$, is given by (Lord and Mannering 2010):

(1) $$p(y_i) = \frac{\Gamma(y_i+\alpha^{-1})}{\Gamma\left(\frac{1}{\alpha}\right)\Gamma(y_i+1)} \left(\frac{1}{1+\alpha\mu_i}\right)^{\frac{1}{\alpha}} \left(\frac{\alpha\mu_i}{1+\alpha\mu_i}\right)^{y_i}$$

(2) $$\mu_i = \exp(\beta X_i + \varepsilon_i)$$

(3) $$v_i = \mu_i + \alpha\mu_i^2$$

whereby $y_i$ is the number of crashes of a segment, $i$, represents a mean rate of crash, $v_i$ is the variance, $\alpha$ is the over-dispersion parameter, Γ(.) is the gamma function, and $\varepsilon_i$ is the error term which is gamma distributed.

**Binary Logit for Injury Severity Modeling**

The logit and probit are commonly used methods of modeling discrete outcomes such as crash severity. The literature review reveals that the logit model is preferred to the probit model in the crash analysis because it offers a better interpretation of variables through odd ratios (Hermans et al. 2006; Peng and Ingersoll 2002). Thus, the binary logistic model was chosen to evaluate the influence of explanatory variables on the severity of elderly crashes. Consider the random variable $y_i$ as an elderly crash. The representation of crashes can be formulated as follows:

(4) $$y_i = \begin{cases} 1 & \textit{if the } i^{th} \textit{ crash is severe} \\ 0 & \textit{otherwise} \end{cases}$$

Understanding the relationship between the probabilities with independent variables $P(y_i = 1|X) = P_i$, the logit function with a linear relationship is used. The following mathematical form describes this relationship (Czepiel 2002):

(5) $$logit\,(P_i) = ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta X_i$$

(6) $$P_i = \frac{1}{1+\exp(-[\beta_0 + \beta X_i])}$$

where $\beta_0$ and $\beta_i$ are regression coefficients, $X$ represents a vector of explanatory variables, and $P$ represents the probability of a crash.

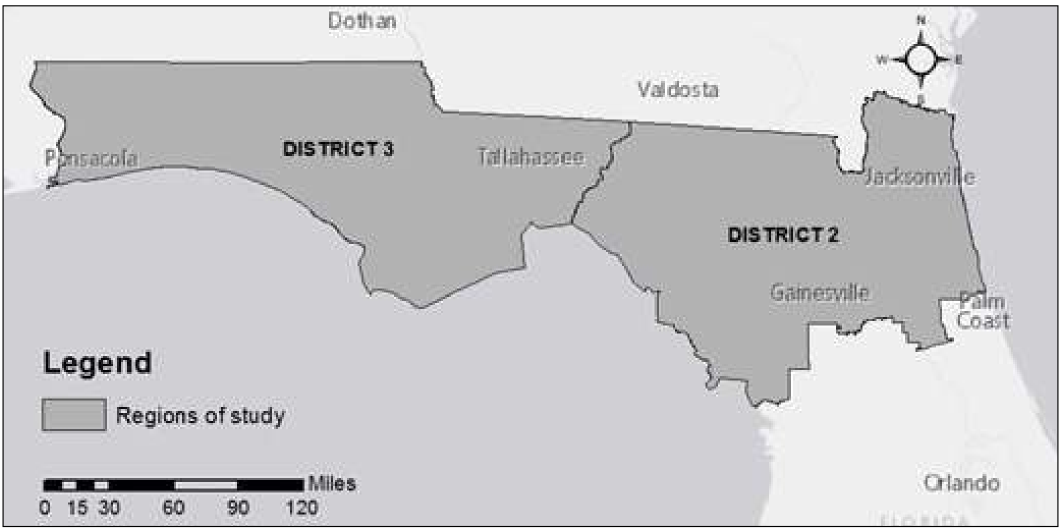
To examine the impact of the significant variables in influencing the crash severity, odds ratio (OR) values are used for comparison. The OR (in percent) of a particular variable is estimated by taking the natural exponential of the variable's parameter (OR = exp($\beta_i$) ∗ 100%). For the variables that raise the risk of severe crash occurrences, normally their OR value are greater than 100% and those which reduce the risk have OR less than 1. The effectiveness of variables that reduce the risk of severe crashes is estimated as follows (Dissanayake and Ratnayake 2008):

(7) Effectiveness of the variable = (100% – OR)

**DATA DESCRIPTION AND SCREENING**

Data were acquired from three sources and were then merged. The Florida Department of Transportation provided data from its crash information database and road geometry/traffic database. The third data source was INRIX, a private vendor company from which historical traffic speeds were acquired and used to compute TTR. The case study involved freeways and arterial roads located in Districts 2 and 3, which are Florida DOT administrative regions. Figure 1 shows the location of these regions in Florida. The following paragraphs summarize the characteristics of each of the attributes used in the model.

**Figure 1: The Case Study Area**




**Traffic Speed and Reliability Metrics**

As mentioned above, the study used INRIX traffic data to compute TTR. INRIX uses vehicle probes and traffic sensors to collect operating traffic speeds. The traffic speeds are summarized and reported at the Traffic Message Channel (TMC) level (INRIX Inc. 2008). The TMC is a type of road segmentation whereby traffic and weather information can be broadcast in real time. More information regarding the segment definition and its applicability to collect speed data can be found in the INRIX report (INRIX Inc. 2008). This study utilized this segmentation approach in conducting the crash analysis. The characteristics of the TMC segments, including average, minimum, and maximum length, is presented in Table 1.

The traffic speed data used to estimate TTR were aggregated on a 15-minute basis. These data were collected for one year from June 2010 to June 2011 on freeways and arterial roads. Specifically, TTR was determined by comparing traffic operating speeds to the free-flow speeds on each segment. Due to lack of other 15-minute traffic data, such as traffic volume and density, the free-flow speed was estimated by adding five miles per hour (mph) to the posted speed limit value, similar to an approach applied by McLeod et al. (2012) study. The planning time index, the standard deviation of the travel time, and the probability of congestion were used as metrics of TTR. The planning time index measures travelers' travel time in relation to free-flow travel time. An index value greater than one represents extra travel time beyond the free-flow travel time. The planning time (PT) index was computed as follows (Lomax et al. 2003):

$$(8)\quad PT\ index = \frac{95^{th}\ Percentile\ TMC\ travel\ time}{Travel\ time\ at\ free\ flow\ speed}$$

Besides the PT index and standard deviation of the travel time, this study also evaluated the impact of the probability of congestion on highway safety. This measure was estimated following the Florida reliability method procedure. This method estimates the percentage of the trips in a given corridor that take no longer than the acceptable threshold. The percentage threshold range is between 5%, and 20% (Al-Deek and Emam 2006; Florida Department of Transporation 2000). In this study, the probability of congestion was computed by determining the percentage of trips that were less than the free-flow speed by 10 mph. This speed drop indicating congestion occurrences is consistent with a study by Al-Deek and Emam (2006).

$$(9)\quad Probability\ of\ congestion = \frac{Number\ of\ observed\ speed\ less\ than\ 10\ mph\ of\ a\ free\ flow\ speed}{Total\ number\ of\ observed\ speed\ samples\ at\ each\ TMC}$$

**Descriptive Statistics of the Variables Affecting Crash Frequency**

The crash data for analysis were provided by the Florida Department of Transportation in a GIS shape file. In the file, each crash record is reported with associated feature including traffic data, driver characteristics, and road geometry. The variables considered in modeling the crash frequency analysis are traffic volume, road geometry, and TTR metrics. These variables were aggregated at the TMC segment level using the average value of each variable. The summary of the attributes is presented in Table 1. Review of descriptive statistics in this table reveals that many elderly crashes occur when the PT index is 1 or 2 with few crashes occurring above index 2.

Prior to modeling, the association among independent variables was analyzed. The Pearson correlation (PC) method is commonly used to check whether a correlation exists between variables. However, PC only tests the linear relationship between the variables (Kobelo et al. 2008; Dissanayake and Roy 2014). To address the weakness of the PC method, the study also used the maximal information coefficient (MIC) to capture the nonlinear relationships between variables. The MIC uses mutual information theory to detect the association between two variables. The mathematical expression of MIC can be found in the studies by Reshef et al. (2013) and Zhao et al. (2013).

The PC coefficients displayed in Table 2 show an association among the variables considered in the analysis. These findings are also confirmed by the MIC values displayed in Table 2 as well. Although the PC coefficient of AADT and the surface width indicated a moderate linear relationship (PC = 0.58 or MIC = 0.57), both variables were included in the final model because their association is not strong. On the other hand, TTR metrics such as the PT_index and the standard deviation of the travel time had the highest correlation (PC = 0.9 or MIC = 0.58) followed by the PT_index and the probability of congestion (PC = 0.58 or MIC = 0.84). In modeling the crash severity analysis, each TTR metric is separated and evaluated with other variables as independent models.

### Table 1: Descriptive Statistics of Data Used in a Crash Frequency Analysis

| Metrics | AADT | Med. width | Surf. Width | Shoul. width | TMC distance (miles) | PT Index (TTR metric) | Standard deviation of the travel time (TTR metric) | Pro. of congestion (TTR metric) | Crash frequency |
|---|---|---|---|---|---|---|---|---|---|
| Mean | 23203.7 | 20.88 | 24.33 | 4.42 | 1.77 | 1.49 | 0.15 | 43.59 | 6.75 |
| Standard deviation of data | 21621.3 | 19.74 | 6.76 | 2.61 | 2 | 0.59 | 0.2 | 40.57 | 7.94 |
| Minimum | 1170.83 | 4 | 10 | 1.5 | 0.02 | 0.65 | 0 | 0.01 | 0 |
| 25% | 9243.01 | 13 | 21.61 | 2 | 0.55 | 1.16 | 0.06 | 2.73 | 2 |
| 50% | 17107.2 | 14.44 | 24 | 4 | 1.04 | 1.33 | 0.1 | 32.02 | 4 |
| 75% | 29041.1 | 20.85 | 24.33 | 5 | 2.12 | 1.61 | 0.17 | 89.91 | 9 |
| Maximum | 143444 | 458.28 | 48 | 17 | 20.22 | 8.57 | 2.94 | 100 | 76 |

### Table 2: Correlation Analysis of Variables Used in a Crash Frequency Analysis

| Variables | AADT | Med. width | Surf. Width | Shoul. width | TMC length | Pro. of congestion (TTR metric) | Standard deviation of the travel time (TTR metric) | PT index (TTR metric) | Crash frequency |
|---|---|---|---|---|---|---|---|---|---|
| **AADT** | - | | | | | | | | |
| Median width (ft.) | 0.22 | - | | | | | | | |
| Surface width (ft.) | 0.58 | 0.19 | - | | | | | | |
| Shoulder width | 0.42 | 0.43 | 0.21 | - | | | | | |
| TMC length (miles) | -0.19 | 0.26 | -0.04 | 0.25 | - | | | | |
| Probability of congestion **(TTR metric)** | -0.10 | -0.16 | 0.01 | -0.27 | -0.17 | - | | | |
| Standard deviation **(TTR metric)** | 0.02 | -0.09 | -0.01 | -0.13 | -0.33 | 0.34 | - | | |
| Planning time index **(TTR metric)** | -0.03 | -0.12 | -0.004 | -0.20 | -0.30 | 0.58 | 0.90 | - | |
| Elderly crash frequency | 0.13 | -0.04 | 0.14 | -0.14 | 0.04 | 0.10 | -0.06 | 0.02 | - |
| **Maximal Information Coefficient (MIC)** | | | | | | | | | |
| AADT | - | | | | | | | | |
| Median width (ft.) | 0.42 | - | | | | | | | |
| Surface width (ft.) | 0.57 | 0.46 | - | | | | | | |
| Shoulder width (ft.) | 0.37 | 0.33 | 0.34 | - | | | | | |
| TMC length (miles) | 0.37 | 0.26 | 0.29 | 0.29 | - | | | | |
| Probability of congestion **(TTR metric)** | 0.32 | 0.24 | 0.23 | 0.27 | 0.25 | - | | | |
| Standard deviation of the travel time **(TTR metric)** | 0.35 | 0.28 | 0.25 | 0.32 | 0.49 | 0.42 | - | | |
| Planning time index **(TTR metric)** | 0.37 | 0.26 | 0.24 | 0.32 | 0.36 | 0.84 | 0.58 | - | |
| Elderly crash frequency | 0.35 | 0.24 | 0.23 | 0.27 | 0.27 | 0.27 | 0.26 | 0.26 | - |

**Descriptive Statistics of the Variables Influencing Injury Severity**

A total of 6,757 crashes and 1,546 TMC links were identified for modeling. In the developed binary model, incapacitating injury and fatal injury crashes were grouped as severe crashes while non-injury, possible injury, and non-incapacitating injury were grouped as non-severe crashes. The descriptive statistics indicated that severe crashes accounted for about 7.3% of the total crashes in the dataset (Figure 2). Meanwhile, 92.7% of crashes were of the "no injury" category. Tables 3 and 4 show the definition of categorical variables and the descriptive statistics of each continuous variable used in the model, respectively.

**Figure 2: Descriptive Statistics of Elderly Crash Severity**

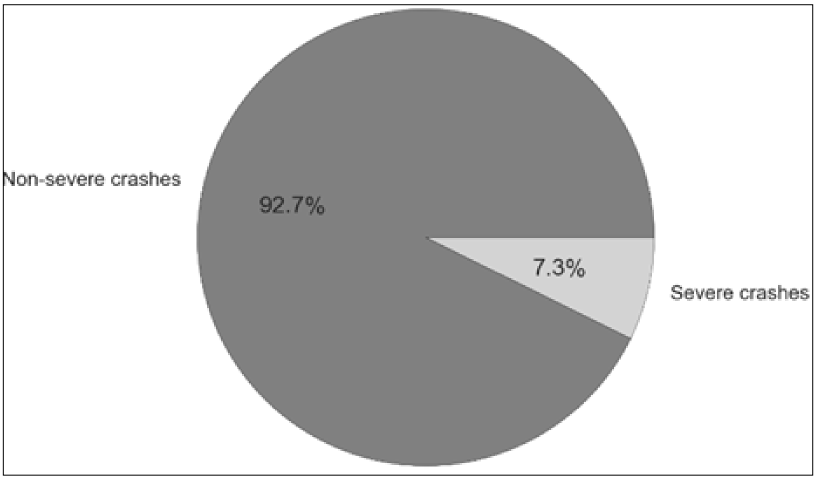



**Table 3: Description of Categorical Data Used in Crash Severity Analysis**

| Categorical Data Definitions | | |
|---|---|---|
| **Variables** | **Description** | **Code for modeling** |
| Alcohol | 0= none, 1 = alcohol involved, 2 = drugs involved, 3 = alcohol and drugs involved, 4 = undetermined | 1, 2 and 3 =1 else 0 |
| Land use characteristics | Urban and rural | Rural = 1 else 0 |
| Road characteristics | 1 – divided, 2 – undivided | Divided 1 else 0 |
| Safety belt usage | categorical | Usage = 0 else 1 |
| Speed | Posted speed limit (categorical) | Less than 45 mph = 0 else 1 |
| Age | Categorical | Between 65 and 75 = 0, greater than 75 = 1 |
| Skid number | Continuous variable | Less than 28 = 0 else 1 |
| Visibility | Smoke, fog, inclement weather conditions, load on vehicles, parked vehicles and vision not obscured | Not obscured = 0 else 1 |
| Median width | Continuous variable | Less than 25 ft. = 1 else 0 |
| Time | Peak hours and off-peak hours | Peak hours 6 a.m. to 9 a.m. and 4 p.m. to 7 p.m. = 0 else off-peak hours = 1 |
| Day of a week | Weekend days and week days | Weekend days and week days |

**Table 4: Descriptive Statistics of Continuous Data Used in Crash Severity Analysis**

| Metrics | AADT | % of truck volume | Med. Width (ft.) | Surf. Width (ft.) | Shoul. Width (ft.) | TMC distance (miles) | PT Index (TTR metric) | Probability of congestion (TTR metric) | Standard deviation of the travel time (TTR metric) |
|---|---|---|---|---|---|---|---|---|---|
| **Mean** | 29513.3 | 6.27 | 21.23 | 24.98 | 4.06 | 1.76 | 1.5 | 46.54 | 0.15 |
| **Standard deviation** of data | 19666 | 6.12 | 27.83 | 7.62 | 3.02 | 2.12 | 0.44 | 39.39 | 0.15 |
| **Minimum** | 2600 | 0.71 | 3 | 10 | 1.5 | 0.01 | 0.65 | 0.01 | 4.9E-3 |
| **25%** | 16600 | 2.2 | 13 | 24 | 1.5 | 0.6 | 1.21 | 3.85 | 0.07 |
| **50%** | 26500 | 4.07 | 13 | 24 | 2 | 1.07 | 1.43 | 43.42 | 0.12 |
| **75%** | 35000 | 7.85 | 20 | 26 | 5 | 1.78 | 1.69 | 89.6 | 0.17 |
| **Maximum** | 172000 | 35.84 | 999 | 48 | 15 | 20.22 | 8.57 | 100 | 2.94 |

## RESULTS AND DISCUSSION

### Negative Binomial Model Results

A total of 8,745 elderly crashes were identified in 1,290 TMC segments for crash frequency analysis. The results of the three developed models (i.e., with the planning time index, the standard deviation of the travel time, and the probability of congestion) are presented in Table 5. To compare the goodness of fit of these models, the Akaike information criterion (AIC) is used. The AIC balances between the model complexity and model prediction accuracy (AIC = -2**log-likelihood** + 2* *number of free parameters*) to reduce the over-fitting problem (Hilbe 2011). Over-fitting is a problem in statistics. It occurs when a model fits well the data used to estimate parameters but fails to generalize on a new dataset. The model with the smallest AIC score value usually is selected over other models (Hilbe 2011). The results in Table 5 suggest that model 1 and model 2 have no statistical difference in goodness of fit. On the other hand, model 3 indicates a strong difference with rest of the model, by having a difference of nearly 13 scores. A score difference greater than 10 is usually considered a strong difference between the models (Hilbe 2011). Thus, these results suggest that model 3 is more appropriate for fitting the dataset than model 1 or 2.

The results of model 3 show that the standard deviation of the travel time is significant at 99% confidence level. This finding suggests that higher standard deviation in travel time reduces the likelihood of a crash. Particularly, a unit increase of the standard deviation of travel time indicates a reduction in the crash frequency. Although all age groups were considered in the analysis, finding by Shi and Abdel-Aty, 2016, contrast with our results, which suggest that the increase in standard deviation of the travel time increases the crash frequency occurrence.

The probability of congestion was found significant in influencing the crash frequency occurrence. Higher likelihood of congestion on the road segment is associated with high traffic density and characterized by shorter headways. Vehicle interactions are increased when headways are shorter, thus increasing the likelihood of crash occurrence. This result is consistent with the findings in the literature (Kononov et al. 2008; Rothenberg et al. 2007; Shi and Abdel-Aty 2016). The planning time index (in model 2), on the other hand, was found insignificant in our study.

**Table 5: Model Results of Elderly Drivers' Crash Frequency**

| Models | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| **Variables** | **Model coefficient** | **Model coefficient** | **Model coefficient** |
| Intercept | -2.92 *(0.000)* | -2.95 *(0.000)* | -2.95 *(0.000)* |
| TMC length (miles) | 0.20 *(0.000)* | 0.19 *(0.000)* | 0.18 *(0.000)* |
| log(AADT) | 0.71 *(0.000)* | 0.70 *(0.000)* | 0.70 *(0.000)* |
| log (Median width [ft.]) | -0.46 *(0.000)* | -0.50 *(0.000)* | -0.45 *(0.000)* |
| log (Surface width [ft.]) | -0.23 *(0.026)* | -0.22 *(0.035)* | -0.23 *(0.021)* |
| log (Shoulder width [ft.]) | -0.39 *(0.000)* | -0.41 *(0.000)* | -0.40 *(0.000)* |
| Posted speed limit (mph) (less than 45 = 0 else 1) | -0.24 *(0.000)* | -0.28 *(0.000)* | -0.30 *(0.000)* |
| log (Probability of congestion) | 0.029 *(0.040)* | - | - |
| Planning time index | - | -0.063 *(0.671)* | - |
| Standard deviation of the travel time | - | - | -0.61 *(0.000)* |
| Log-likelihood at convergence | -3725.5 | -3725.7 | -3719.5 |
| Akaike information criterion (AIC) | 7468.93 | 7467.46 | 7455.03 |

Note: Log(variable name) represents a logarithmic transformation of variables and value in a parenthesis is p-values

Moreover, in models 1 and 3, road geometry, including the median width, the surface width, and the shoulder width, is statistically significant suggesting that increases in the values of these variables reduce the likelihood of elderly crash frequency. Shi and Abdel-Aty (2016) suggest that increasing the values of these variables increases the freedom of drivers in avoiding a traffic conflict. Similar to other crash modeling studies, traffic volume (AADT) and segment length revealed a positive relationship with elderly crash frequency (Kononov et al. 2008; Shi and Abdel-Aty 2016; Quddus et al. 2010). The findings suggest that longer travel length and higher traffic volume contribute to the rise in the likelihood of crash occurrence.

### Binary Logit Model Results

The results of the binary logit model are reported in Table 6. In the table, four model results are presented. The model with the probability of congestion as a TTR metric (model 4) provides the most variables, which significantly influence the severity of the crash with at least a 90% confidence level**.** Overall, the model fitted data fairly well with 66% as the area under the curve (AUC) of the receiving operating characteristic curve (ROC). The area under ROC measures the performance trade-off between the true positive and false positive error rate by changing the threshold value in classifying response groups (Fawcett 2006). Understanding the model performance, the AUC above 54% is normally accepted that the model can fit the dataset with reasonable accuracy; on the other end, the perfect model is the one with AUC score equal to 100% (Fawcett 2006). Although model 4 revealed the best fit, there is no significant difference among model 1, 2, 3, and 4 based on their AUC and AIC values (see Table 6).

### Travel Time Reliability and Traffic Density

The results of the analysis of TTR metrics revealed that only the probability of congestion is significant (at 90% confidence level) in influencing the severity of a crash. Higher probability of congestion is found to be associated with the lower elderly severe crash. The risk of a severe crash is reduced by 22% with a one-unit increase of this variable. This value was estimated by taking the difference between 100% and the odds ratio (see equation 7). Moreover, the probability plot of categorical variables in Figure 3 shows that the probability of congestion has a negative linear relationship with the odds of severe crashes. This finding is consistent with the literature, which shows that congested highways have relatively low speeds, thus reducing the probability of a severe crash to occur (Duncan et al. 1998; Chang 2003). Nonetheless, this result contradicts the results of a study conducted by Quddus et al. (2010) on the M25 orbital motorway in London. This study suggests that congestion has no significant influence on the likelihood of a severe crash. Our results further show that the planning time index and the standard deviation of the travel time were not significant in influencing the severity of the crash.

In the modeling results, the impact of traffic density was found to be significant, suggesting that as the traffic density increases, the risk of injury decreases. The likelihood of severe crash occurrence decreases by 9% (see equation 7 and result of the odds ratio in Table 6) when the traffic density increases by a unit. Figure 3 indicates a non-linear relationship with a sharp decrease in the odds of a severe crash up to nearly 100 vehicles per mile, thereafter there is a gradual decrease. This could be attributed to the fact that when density is high, headways are reduced, which yield slower speeds, thus reducing the possibility of a crash being severe. These findings mirror the results found by other researchers (Duncan et al. 1998; Chang 2003).

**Driver Characteristics and Time of a Day**

Analysis shows that impaired elderly drivers are associated with higher risks of severe crashes than unimpaired drivers. The risk ratio is 2.18, suggesting that the probability of a severe crash on impaired drivers is 2.18 higher compared with unimpaired drivers. This result is consistent with the results of previous studies (Dissanayake and Roy 2014; Quddus et al. 2010). The result of proper seatbelt use was found to reduce the severity of a crash by 45% as compared with unbelted drivers. The finding of seatbelt effectiveness is consistent with the study conducted by Ratnayake (2006), which also found that seatbelt usage reduces the severity of a crash by 56%. Furthermore, the result shows that the likelihood of a crash for a driver 75+ years of age is higher than those aged 65 to 74 by 27%. This is a very important result, which may be related to diminished or reduced cognitive and physical capabilities with age.

The visibility factor is reported in the crash database to reflect vision obstruction. The factors that impair visibility listed in a database include smoke, fog, inclement weather conditions, parked vehicles, and others. The model's findings revealed that poor visibility reduces the severity of a crash by 37% as compared with clear conditions. Similar findings were documented by Pisano et al. (2008) who argued that in inclement weather conditions, drivers adjust their behavior sufficiently (e.g., by reducing speed and driving more cautiously), thus reducing the probability of a severe crash.

**Table 6: Model Results of the Crash Severity Analysis**

| | All variables | | | Significant variables | | |
|---|---|---|---|---|---|---|
| **Variables** | **Model 1 Coef.** | **Model 2 Coef.** | **Model 3 Coef.** | **Model 4 Coef.** | **Odd ratio** | **Marginal effect (dy/dx)** |
| **Traffic data** | | | | | | |
| Log (Traffic density) | -0.097* | -0.09 | -0.12 | -0.10 (*0.095*) | 0.91 | -0.006 |
| Percentage of truck volume | 0.34 | 0.42 | 1.23 | - | - | - |
| | | | | | | |
| **Road Characteristics** | | | | | | |
| Shoulder width | -0.06* | -0.05*** | -0.05*** | -0.06 *(0.019)* | 0.94 | -0.004 |
| Median width | -0.18 | -0.17** | -0.37** | -0.22 *(0.093)* | 0.80 | 0.015 |
| Surface width | -0.01 | -0.01 | -0.0057 | - | - | - |
| Road characteristics | -0.32** | -0.33** | -0.32** | -0.30 *(0.013)* | 0.74 | -0.019 |
| Speed | 0.53** | 0.54*** | 0.55*** | 0.54 *(0.002)* | 1.71 | 0.035 |
| Skid number | -0.72** | -0.74*** | -0.74*** | -0.72 *(0.028)* | 0.49 | -0.047 |
| **Location of the highway** | | | | | | |
| Land use characteristics | 0.81*** | 0.81*** | 0.81*** | 0.85 *(0.000)* | 2.24 | 0.055 |
| **Driver characteristics** | | | | | | |
| Safety belt use | -0.59*** | -0.60*** | -0.60*** | -0.60 (*0.000*) | 0.55 | -0.039 |
| Age | 0.23** | 0.23** | 0.24** | 0.24 *(0.016)* | 1.27 | 0.015 |
| Alcohol | 0.79*** | 0.80*** | 0.80*** | 0.78 *(0.001)* | 2.18 | 0.051 |
| Visibility | -0.45* | -0.45** | -0.44** | -0.46 *(0.030)* | 0.63 | -0.030 |
| **Temporal factors** | | | | | | |
| Time | 0.22* | 0.22* | 0.22* | 0.22 *(0.023)* | 1.25 | 0.015 |
| Day of a week | -0.11 | -0.10 | -0.11 | - | - | - |
| **Travel time reliability** | | | | | | |
| Probability of congestion | -0.22 | - | - | -0.24 *(0.083)* | 0.78 | -0.016 |
| Planning time index | _ | -0.02 | - | - | - | - |
| Standard deviation | _ | - | 0.19 | - | - | - |
| Intercept | -0.42 | -0.48 | -0.52 | -0.63 | - | - |
| **Number of observation** | 6757 | 6757 | 6757 | 6757 | | |
| **ROC** | 0.66 | 0.66 | 0.65 | 0.66 | | |
| **Akaike information criterion (AIC)** | 3375.9 | 3378.12 | 3378.0 | 3372.4 | | |
| **Restricted log-likelihood** | | | | -1765.1 | | |
| **Log-likelihood at convergence** | | | | -1672.2 | | |

**(Table 6 continued)**

| Variables | All variables | | | Significant variables | | |
|---|---|---|---|---|---|---|
| | **Model 1 Coef.** | **Model 2 Coef.** | **Model 3 Coef.** | **Model 4 Coef.** | **Odd ratio** | **Marginal effect (dy/dx)** |
| ***p*-value** | | | | 1.073e-32 | | |

Note: Traffic density = AADT/segment length, *** represents p < 0.01, ** is p < 0.05 and * is p < 0.1 and value in a parenthesis is the *p*-value.

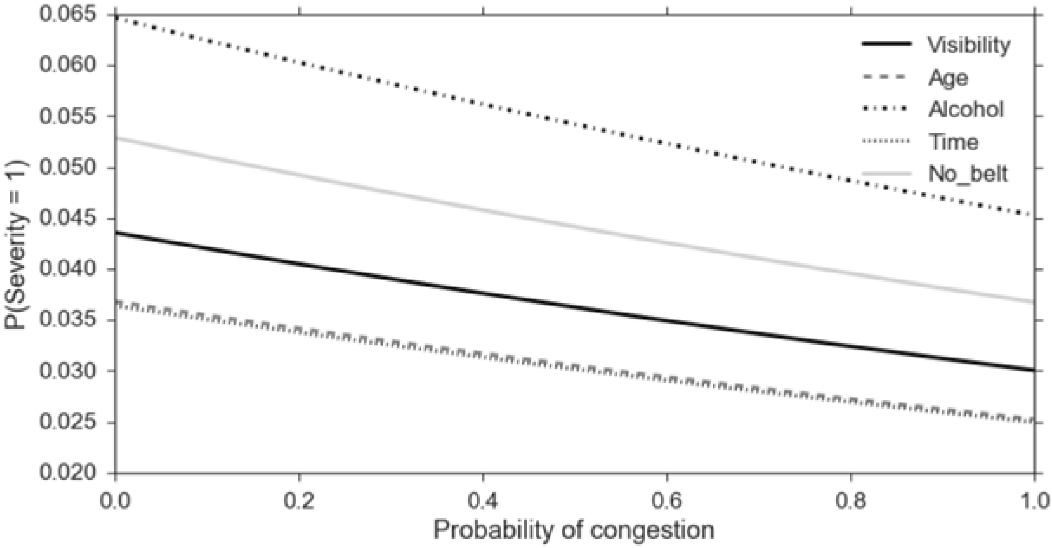
## Road Characteristics and Location of the Highway

Analysis of rural versus urban characteristics of a road shows that the odds of a severe crash rise in rural areas by 2.24. There might be many possible explanations for this phenomenon. One explanation perhaps could be that urban roadways are more congested with slower speeds than rural roadways, resulting in less severe crashes. The results further show that divided highways reduce crash severity by 26% compared with undivided highways. The median provides an area for the driver to avoid collisions with other vehicles, which in turn reduces crash severity. Moreover, the analysis of posted speed limit (PSL) indicates that the probability of a severe crash increases by 1.71 for highways with PSL higher than 45 miles per hour (mph) compared with lower speeds. Similar results were found by other researchers (Dong et al. 2015; Duncan, et al. 1998).

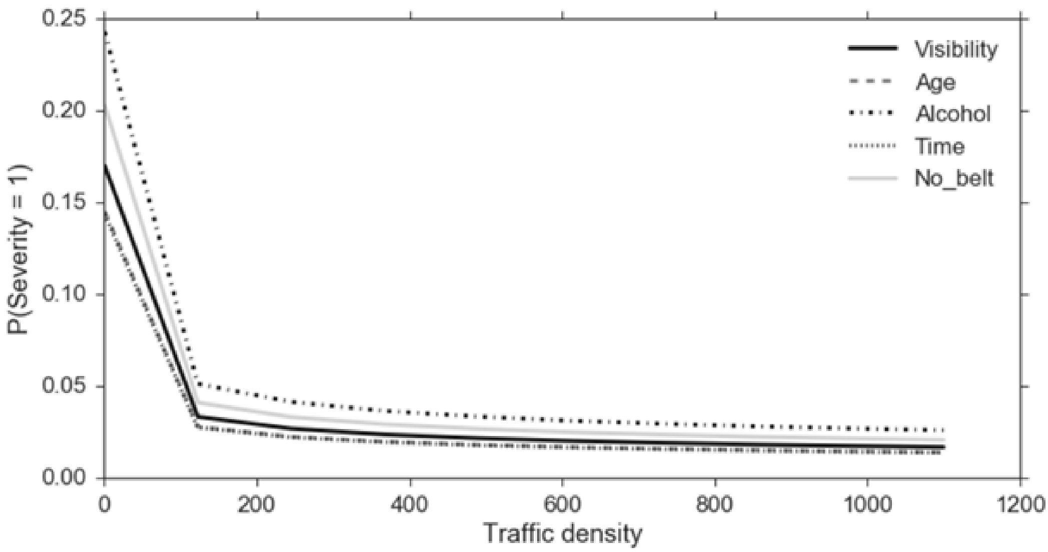
Analysis of road geometry shows that median widths wider than 15 feet reduce the odds of a severe crash by 20% compared with those less than 15-feet wide. A similar pattern was observed on shoulder width, indicating that one unit change of this variable reduces the severity of a crash by nearly 6%.

A skid number less than 28 (friction number from locked wheel testing at 40 mph using a ribbed tire) is considered insufficient and could contribute to crashes (Federal Highway Administration 2014). In our study, the results show that highway crashes with a skid number higher than 28 reduces the severity of a crash by 51%. Moreover, Figure 3 illustrates that, of all road geometry factors, the skid number has the highest impact on crash severity. On the other hand, road characteristics (divided or undivided) revealed the least impact compared with the rest of the variables. The results further show that surface widths, the day of the week, and the percentage of trucks, the planning time index, and the standard deviation of the travel time have minimal influence on crash severity.

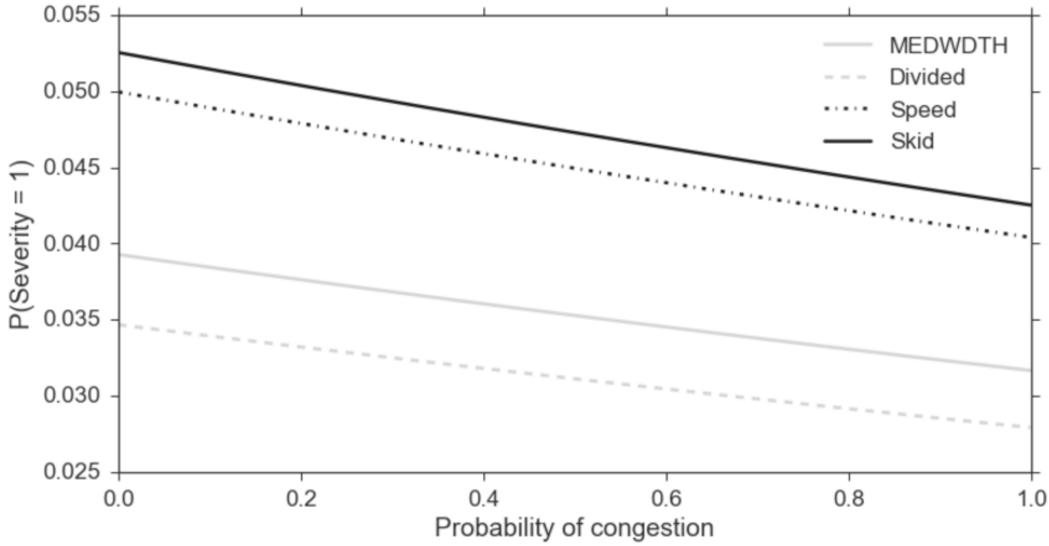
**Figure 3: The Influence of Variables on Elderly Crash Severity**



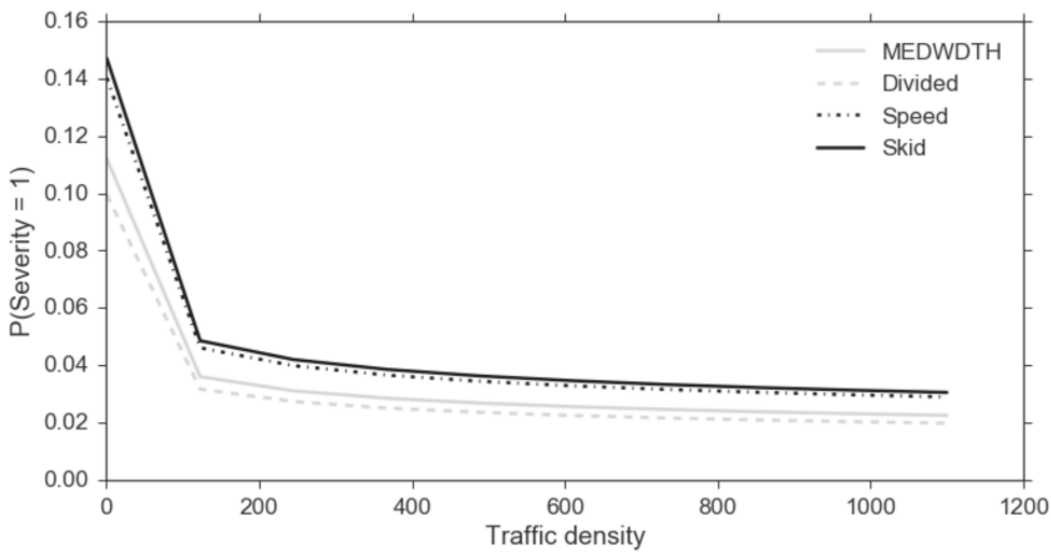

(a) Driver characteristics against probability of congestion




(b) Driver characteristics against traffic density




(c) Road characteristics against probability of congestion




(d) Road characteristics against traffic density

The analysis of hours of travel showed the significance of off-peak hours on severe crashes. The odds of a crash being severe during off-peak hours were 25% more compared with peak hours. Further, a review of graphs of the driver characteristics shows that the impaired driving with alcohol or drugs in both traffic density and probability of congestion is associated with the highest probability of injury (Figure 3).

## CONCLUSIONS AND RECOMMENDATIONS

As the proportion of the elderly driving population continues to grow, coupled with increased congestion on U.S. highways, the safety of the driving public will continue to be a major focus of transportation research. Given that congestion affects the travel time reliability (TTR), the main goal of this research was to evaluate how TTR might be associated with crashes involving elderly drivers. TTR metrics used in the modeling were the planning time index, the standard deviation of the travel time, and the probability of congestion. Speed data for calculating TTR metrics were acquired from the INRIX database comprising 1,290 traffic-messaging channels (TMCs). Four-year crash data were acquired from the Florida Department of Transportation. A total of 8,745 crashes involving elderly drivers were identified as occurring in the study area. In addition to TTR metrics, important geometric and traffic variables were also included in the modeling process as the predictors of crashes.

The negative binomial model was used to evaluate variables that could be influencing elderly crash frequency, while the binary logit model was used to evaluate variables that could be influencing elderly crash severity. The results of the negative binomial modeling showed that the probability of congestion and the standard deviation of travel time were statistically significant in affecting the number of crash occurrences. A unit increase of the probability of congestion was associated with the increase of crash frequency, while a unit increase in the standard deviation of the travel time reduced the crash frequency. The binary logit model revealed that only one TTR metric, i.e., the probability of congestion, was significantly associated with crash severity. As the probability of congestion increases in a segment, lower levels of crash severity involving elderly drivers were experienced as the odds of severe crashes dropped by 22% with each unit increase in the probability of congestion.

This study is not without limitations. Crashes involving elderly drivers were isolated and modeled separately; thus, it is not clear if similar results would apply if crashes involving drivers of all age groups were included in the modeling process. In future studies, exploring the impact of the TTR for other age groups is needed to answer the aforementioned question. It is also worth noting that the study area comprised freeway links whose high-speed operating characteristics pose high cognitive, sensory, motor, and physical demands on elderly drivers compared with surface streets. Additional qualifications are in order. The crash data used were from 2009 to 2012 while the travel time data used were from one year, mid-June 2011 to mid-June 2012. Although care was taken to exclude data from weekends, holidays, and days in which incidents occurred in order to smoothen the TTR, it would have been better to use TTR data encompassing the four years from which crash data were extracted. Unfortunately, such data were not available and future studies may strive to correct this shortcoming by using other regression models.

### References

Abdel-Aty, A.M., and H.T. Abdelwahab. "Exploring the Relationship between Alcohol and the Driver Characteristics in Motor Vehicle Accidents." *Accident Analysis & Prevention* 32(4), (2000): 473–482.

Abdel-Aty, A.M., and A.E. Radwan. "Modeling Traffic Accident Occurrence and Involvement." *Accident Analysis & Prevention* 32 (5), (200):633-42.

AbdelRazig, Y., R. Doczy, W.R. Boot, E.E. Ozguven, and R. Moses. "Spatial Context Roadway Safety Analysis for the Aging Population: A Hybrid 3-Dimensional Visualization and Human Factors Simulation Approach." *Transportation Research Board*, *2016 Annual Meeting*, Washington D.C., 2016.

Alam, B.M., and L.K. Spainhour. "Contribution of Behavioral Aspects of Older Drivers to Fatal Traffic Crashes in Florida." *Journal of the Transportation Research Board* 2078, (2008):49–56.

Al-Deek, H., and E.B. Emam. "New Methodology for Estimating Reliability in Transportation Networks with Degraded Link Capacities." *Journal of Intelligent Transportation Systems: Technology, Planning and Operations* 10 (3), (2006): 117-129.

Cambridge Systematics, Inc. and Texas Transportation Institute. "Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation." Federal Highway Administration, 2005.

Chang, Gang-Len. *The Relationship Between Congestion Levels and Accidents*. Maryland State Highway Administration, Baltimore MD, 2003.

Chien, S., and X. Liu. "An Investigation of Measurement for Travel Time Variability." *Intelligent Transportation Systems* 51 (0347), (2012): 978-953.

Cicchino, J.B., and A.T. McCartt. "Trends in Older Driver Crash Involvement Rates and Survivability In The United States: An Update." *Accident Analysis & Prevention* 72, (2014): 44 -54.

Clarke D.D., P. Ward, C. Bartle, and W. Truman. "Older Drivers' Road Traffic Crashes in the UK." *Accident Analysis & Prevention* 42, (2010):1018–1024.

Colby, S.L., and J.M. Ortman. *Projections of the Size and Composition of the U.S. Population: 2014 to 2060: Population Estimates and Projections*. U.S. Census Bureau, Washington, D.C., 2015.

Czepiel, Scott. A. *Maximum Likelihood Estimation of Logistic Regression Models: Theory and Implementation,* Available at http://czep.net/stat/mlelr.pdf, 2012.

Dissanayake, S., and I. Ratnayake. "Effectiveness of Seat Belts in Reducing Injuries: A Different Approach Based on KABCO Injury Severity Scale." *Journal of the Transportation Research Forum* 47 (4), (2008): 135-146.

Dissanayake, S., and J. J. Lu. "Factors Influential in Making an Injury Severity Difference to Older Drivers Involved in Fixed Object–Passenger Car Crashes." *Accident Analysis & Prevention* 34 (5), 2002: 609 - 618.

Dissanayake, S., and U. Roy. "Crash Severity Analysis of Single Vehicle Run-off-Road Crashes." *Journal of Transportation Technologies,* (2014): 1-10.

Dong, C., S.H. Richards, B. Huang, and X. Jiang. "Identifying the Factors Contributing to the Severity of Truck-Involved Crashes." *International Journal of Injury Control and Safety Promotion* (2015): 1745-7300.

Duncan, C.S., A.J. Khattak, and F.M. Council. "Applying the Ordered Probit Model to Injury Severity in Truck-Passenger Car Rear-End Collision." *Transportation Research Record: Journal of the Transportation Research Board* 1237, (1998): 63-71.

Fawcett, Tom. "An Introduction to ROC Analysis." *Pattern Recognition Letters* 27 (8), (2006): 861-874.

Federal Highway Administration. "State Practices to Reduce Wet Weather Skidding Crashes - State Practices to Reduce Wet Weather Skidding Crashes." *Speed Management*, Washington, DC, Federal Highway Administration 2014, Section 3.

Florida Department of Transporation (FDOT). *The Florida Reliability Method*. http://www.dot.state.fl.us/planning/statistics/mobilitymeasures/reliability.pdf, 2000.

Hermans, E., B. Tom, S. Tim, and O. Col. "The Impact of Weather Conditions on Road Safety Investigated on an Hourly Basis." *Transportation Research Board*, Washington, D.C., 2006.

Highway Loss Data Institute, "Older Drivers' Crash Rates Continue to Drop." *Status Report,* 20 February 2014.

Hilbe, Joseph. M. *Negative Binomial Regression*, Second Edition. Cambridge University Press, 2011.

INRIX, Inc. NRIX Historical Traffic Flow Product Interface Guide. INRIX, Inc., 4055 Lake Washington Blvd NE, Suite 20. Kirkland, WA 98033, 2008.

Insurance Information Institute. Insurance Institute for Highway Safety, May 2016. [Online]. Available: http://www.iii.org/issue-update/older-drivers. [Accessed 05 May 2016].

Jung S., K. Jang, Y. Yoon, and S. Kang. "Contributing Factors to Vehicle to Vehicle Crash Frequency and Severity Under Rainfall". *Journal of Safety Research* 50, (2014): 1–10.

Kaparias, I., M.G. Bell, and H.A. Belzner. "New Measure of Travel Time Reliability for In-Vehicle Navigation Systems". *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations* 12 (4), (2008): 202-211.

Kobelo, D., V. Patrangenaru, and R. Mussa. "Safety Analysis of Florida Urban Limited Access Highways with Special Focus on the Influence of Truck Lane Restriction Policy." *Journal of Transportation Engineering* 134 (7), (2008): 297-306.

Kononov, J., B. Bailey, and B.K. Allery. "Relationships Between Safety and Both Congestion and Number of Lanes on Urban Freeways." *Journal of the Transportation Research Board* 2083, (2008): 26-39.

Lomax, T., D. Schrank, S. Turner, and R. Margiotta. "Selecting Travel Reliability Measures." Texas Transportation Institute, 2003.

Lord, D., and F. Mannering. "The Statistical Analysis of Crash-Frequency Data: A Review and Assessment of Methodological Alternative." *Transportation Research Part A: Policy and Practice* 44 (5), (2010): 291–305.

McLeod, D., L. Elefteriadou, and L. Jin. "Travel Time Reliability as a Performance Measure: Applying Florida's Predictive Model on the State's Freeway System." *Transportation Research Board,* Washington D.C., 2012.

Peng, C.J., K.L. Lee, and G.M. Ingersoll. "An Introduction to Logistic Regression Analysis and Reporting." *The Journal of Educational Research,* (2002): 1-14.

Pisano, P.A., L.C. Goodwin, and M.A. Rossetti. "U.S. Highway Crashes in Adverse Road Weather Conditions" *Proc., 24th Conference on IIPS*, 2008.

Pu, Wenjing. "Analytic Relationships Between Travel Time Reliability Measures." *Transportation Research Board*, Washington D.C., 2010.

Quddus, M.A., C. Wang, and S.G. Ison. “Road Traffic Congestion and Crash Severity: Econometric Analysis Using Ordered Response Models.” *Journal of Transportation Engineering* 136 (5), (2010): 424-435.

Ratnayake, Indike. “Effectiveness of Seat Belts in Reducing Injuries: A Different Approach Based on KABCO Injury Severity Scale. “*Midwest Transportation Consortium,* Iowa State University, 2006.

Reshef, D., Y. Reshef, M. Mitzenmacher, and P. Sabeti. “Equitability Analysis of the Maximal Information Coefficient, with Comparisons.” *arXiv preprint arXiv:* 1301.6314, (2013).

Rothenberg, H., M.A. Knodler Jr, J. Kennedy, and S.A. Metzger. “Evaluation of the Impact of Congestion on Crash Frequency, Severity and Crash Characteristics.” *Transportation Research Board,* 2007.

Shi, Q., and M. Abdel-Aty. “Evaluation of the Impact of Travel Time Reliability on Urban Expressway Traffic Safety.” *Transportation Research Board*, Washington D.C., 2016.

Souders, D.J., B. Gepner, and J.A. Wekezer. “User-Centered Literature Review of Safety and Human Factors Issues Involving Older Adults as Cutaway Bus Passengers.” *Transportation Research Board,* Washington D.C., 2015.

Taylor, Rich. *Travel Time Reliability: Making It There On Time, All The Time.* Federal Highway Administration (FHWA), 20 10 2015. [Online]. Available: http://ops.fhwa.dot.gov/publications/tt_reliability/brochure/. [Accessed 30 05 2016].

Ulak, B.M., E.E. Ozguven, L. Spainhour, and O.A. Vanli. “Spatial Investigation of Aging-Involved Crashes: A GIS-based Case Study in Northwest Florida.” *Journal of Transport Geography* 58, (2017): 71–91.

Yang, S., and Y. Wu. “Moving Ahead to Mixture Models for Fitting Freeway Travel Time Distributions and Measuring Travel Time Reliability.” *Transportation Research Board*, Washington D.C., 2016.

Zhao, X., W. Deng, and Y. Shi. “Feature Selection with Attributes Clustering by Maximal Information Coefficient.” *First International Conference on Information Technology and Quantitative Management* 17, (2013): 70-79.

***Emmanuel Kidando*** *is a Ph.D. candidate and research assistant at FAMU-FSU College of Engineering, Florida State University. His research areas include traffic operation and safety analysis, probabilistic modeling of the travel time reliability application of statistics, and artificial intelligence in transportation engineering.*

***Ren Moses*** *is a professor in the department of civil and environmental engineering at FAMU-FSU College of Engineering, Florida A&M University. His research projects are related to highway safety, traffic operations, intelligent transport systems (ITS), and development of workforce in the highway construction industry.*

***Yassir Abdelrazig*** *is an associate professor in the department of civil and environmental engineering at FAMU-FSU College of Engineering, Florida A&M University. His research areas include unformation technology applications, artificial intelligence applications, infrastructure management, scheduling and project management, and applications of GIS.*

***Eren Erman Ozguven*** *is an assistant professor in the department of civil and environmental engineering at FAMU-FSU College of Engineering, Florida State University. His research interests include transportation accessibility, modeling of emergency evacuation operations, simulation and modeling of transportation networks, traffic safety, urban mobility analysis, and intelligent transportation systems.*

# Airline Ancillary Services: An Investigation into Passenger Purchase Behavior

**by Steven Leon and Nizam Uddin**

*U.S. airlines have a vested interested in the intentions and purchase behavior of their domestic airline passengers, especially their willingness to pay for assorted ancillary services. For this research, antecedents to purchase intention and actual purchase behavior of airline ancillary services were evaluated using logistic regression and generalized linear model (GLM) and data collected from Amazon Mechanical Turk. The results show differences in airline passenger preferences when purchasing ancillary services. The number of times a passenger flies per year and the trip purpose are significant, while age and gender are not.*

## INTRODUCTION

Ancillary service fees have become a popular revenue stream as airlines look for ways to grow revenue. Ancillary revenue strategies and à la carte pricing have long been used and the trend does not appear to be slowing (Tuzovic et al. 2014). Baggage fees and cancellation or change fees account for a significant amount of revenue for airlines in the United States. IdeaWorksCompany (2015) estimated that airline ancillary revenue reached $59.2 billion worldwide in 2015, a 163% increase from 2010. In 2015, U.S. airlines collected more than $3.8 billion in baggage fees and amassed more than $3.0 billion in reservation cancelation and change fees (USDOT Bureau of Transportation Statistics 2015).

Ancillary service fees, or à la carte pricing, refers to companies unbundling service offerings and charging for supplementary services that were previously provided free of charge (Garrow et al. 2012, Tuzovic et al. 2014). Holloway (2008) views ancillary service fees as "unbundling the traditional airline product and charging for product attributes that were formerly encompassed within the ticket price or were available only to travelers in premium cabins." Sorenson (2012) and Wittmer et al. (2012) most closely match how we define ancillary service revenue: "Revenues beyond the sale of tickets and [that] are indirectly seen as part of the travel experience." These fees are considered non-ticket revenues and are not required for travel. The fees are only paid when passengers choose the service.

As airlines allocate resources for implementing new ancillary services, there is a risk that customers will not purchase them. Traditionally, airline employees randomly ask passengers if they want to purchase ancillary services or the airlines create marketing and selling strategies based largely on a segmentation approach. Neither approach is sufficient, because neither adequately captures the individual preferences among passengers. Airlines may be missing revenue maximization opportunities and optimal resource allocation by not providing appropriate ancillary services or developing marketing and sales strategies to account for the complexity of customer choice drivers (Teichert et al. 2008). Consequently, it is important for airlines to understand the ancillary services passengers are likely to purchase and which passengers will purchase them.

Even though airlines collect massive amounts of data about their customers and their purchases, it cannot be assumed that they are collecting the most useful data or that employees have access to the data. Organizational policies, processes, and IT infrastructure hinder timely data collection and data access. Just as important, they do not have access to non-customer data or data related to new or untested ancillary service offerings. An opportunity to take the guesswork out of trying new services could be to use pools of online survey respondents to test ideas and gain customer purchase behavior insights. Airline analysts and decision-makers would benefit from readily available and accessible data drawn from the surveys. These respondents may provide insights into passenger ancillary service purchase intentions and actual purchase behavior, prior to allocating significant organizational resources and also circumvent organizational roadblocks. Therefore, we set out to answer three research questions:

RQ1. Which ancillary services should airlines sell to and who should they sell?

RQ2. Can airlines use *intention* to purchase to predict if customers will purchase ancillary services?

RQ3. Can we make reasonable inferences using pools of online survey respondents?

The remainder of this paper is organized as follows: literature review, research methodology, data analysis and results, and discussion and conclusion.

## LITERATURE REVIEW

### Ancillary Services

Although many air transportation choice and behavior studies have been conducted, such as, airline choice (Hess et al. 2007), airline itinerary choice (Brey and Walker 2011), and airport choice (Leon 2011), minimal airline ancillary service research has been conducted. Ødegaard and Wilson (2016) state that the sale of ancillary and secondary services is a relatively undeveloped research area and according to Espino et al. (2008), more research should be done in this focus area. Despite the prevalence and growing importance of ancillary service fees, few studies have examined the factors that lead to customers purchasing ancillary services and their willingness to pay fees for such services (Mumbower et al. 2015). Table 1 provides a detailed account of airline ancillary service research as it relates to passenger behavior.

Of the airline ancillary service studies that have been conducted, many of them used stated choice experiments to identify passenger purchase behavior (Balcombe et al. 2009, Chen and Wu 2009, Correia et al. 2012; Espino et al. 2008, Martin et al. 2008, and Wittmer and Rowley 2014). While stated choice studies and experiments provide insight into how customers may behave in actual purchase situations, these studies have some drawbacks. They limit the number of attributes and levels in the experiment because increasing them greatly increases the size of the experimental design. Consequently, they limit the number of insights that can be found surrounding passenger heterogeneity. Further, stated choice experiments essentially ask passengers at the time of booking which airline they would choose given a particular combination of attributes. However, what is not being asked and answered is if a passenger would purchase or intends to purchase a particular ancillary service. Moreover, these studies omit actual purchase behavior of ancillary services. Lastly, many of the previously stated choice studies collected data at the airport, as it is a time-consuming endeavor for research teams.

Other ancillary service studies narrowly focused on examining passenger seating. Lee and Luengo-Prado (2004) compared business and leisure travelers and their willingness to pay for additional legroom on two U.S. legacy airlines. Their results were mixed. Mumbower et al. (2015) investigated system factors that influence airline customers' purchase of premium coach seats at JetBlue Airlines. They found that passengers were more willing to purchase premium seats if no free reserved aisle or window seats were available.

Finally, two studies took a descriptive approach. Garrow et al. (2012) provide a review of product unbundling trends that have occurred in the U.S. airline industry, whereas O'Connell and Warnock-Smith (2013) provided an account of international passenger acceptance of ancillary fees. Though these studies are important and provide interesting accounts of ancillary services, they do not seek to understand passengers' intent to purchase or actual purchase behavior.

**Table 1: Summary of Relevant Literature Review**

| Author(s) | Data Collection | Ancillary Service | Antecedents/Attributes[1] | Region/Airline | Findings |
|---|---|---|---|---|---|
| Balcombe et al. (2009) | Focus Groups, Interviews, Survey, Travel Company Website | Seat Pitch, Width, Meal, Entertainment | Age, Income, Gender, Education, Ticket Price | UK, LCC and Charter International Flights | Age, Gender, and Income are significant |
| Chen and Wu (2009) | Survey, Two Airports | Meal Service, Onboard Entertainment, Change Ticket | Business, Non-Business | LCC, Direct Flight Between Taiwan and China, Hypothetical Airlines | Difference are found between Business and Non-Business travelers |
| Correia et al. (2012) | Survey, Airport | Luggage, Meal, Sports Equipment Allowed | Leisure Passengers | LCC at Faro International Airport, Portugal | Baggage, sports equipment fee important to leisure passengers |
| Espino et al. (2008) | Survey, Airport | Latent Variables-Service Quality Changes, Penalty Ticket Changes, Food On Board | Trip Purpose, Fare Class | Gran Canaria and Madrid, Hypothetical Airlines | Differences based on model used |
| Lee and Luengo-Prado (2004) | Online Government Database | Legroom | Business/Leisure Travelers, Market Share, On Time, Nonstop, Fare, Distance, Frequency, Firm Financial Performance | United States / United Airlines & American Airlines | UA achieved fare premium, AA did not |
| Martin et al. (2008) | Survey, Airport | Penalty Ticket Changes, Food On Board, Comfort, | Trip Purpose, Traveler Pays Ticket, Age | Las Palmas de Gran Canaria and Madrid, Two Virtual Airlines | Trip purpose is significant |
| Mumbower et al. (2015) | Automated web robot to query airline website | Premium Coach Seats | Seat Fee, Advance Ticket Purchase, Number Of Passengers Traveling Together, Load Factor | United States / JetBlue | Purchase of premium coach seats with extra legroom and early boarding privileges when no free reserved regular coach window or aisle seat is available, timing of ticket purchase correlates with seat fees paid |
| O'Connell and Warnock-Smith (2013) | Interviews and Online Survey via FlyerTalk Forum | Priority Boarding, Legroom, Baggage Seat Reservation | None | Not specified, International Travellers | Checked baggage yields greatest acceptance and willingness to pay |
| Wittmer and Rowley (2014) | Survey, Airport | Seat Selection, Internet, Security Lane, Priority Check-In, Priority Baggage Delivery, Priority Boarding Lane | Economy Class, Long Haul, Short Haul | European Full-Service Network Carrier at Zurich, Switzerland Airport | Economy passengers display a general intention to purchase preferred seat selection, internet access, priority baggage delivery |

**Note:** 1. Antecedents/Attributes in stated preference models otherwise dependent variables in regression models.

### Amazon Mechanical Turk

Amazon Mechanical Turk (MTurk) is a quick and inexpensive approach to collecting data. Researchers from diverse domains such as health (Boynton and Richman 2014), retail (Munzel 2016), and tourism (Dedeke 2016) have used this approach for collecting data. However, transportation studies using MTurk have been scarce. Krupa et al. (2014) studied the market penetration of plug-in hybrid electric cars, and Winter et al. (2017) examined consumer perceptions and the use of pilot medication. Even though researchers who have used crowd-sourced respondents usually acknowledge potential issues regarding their use or cite previous studies that have used these sources as a reason to use crowd-sourced data, generally there is no attempt to validate their research conclusions or models. Crowdsourcing is a practice by which information is collected or work completed by a readily available crowd or large pool of people. Participants are usually solicited from an online platform and may or may not be paid for their work.

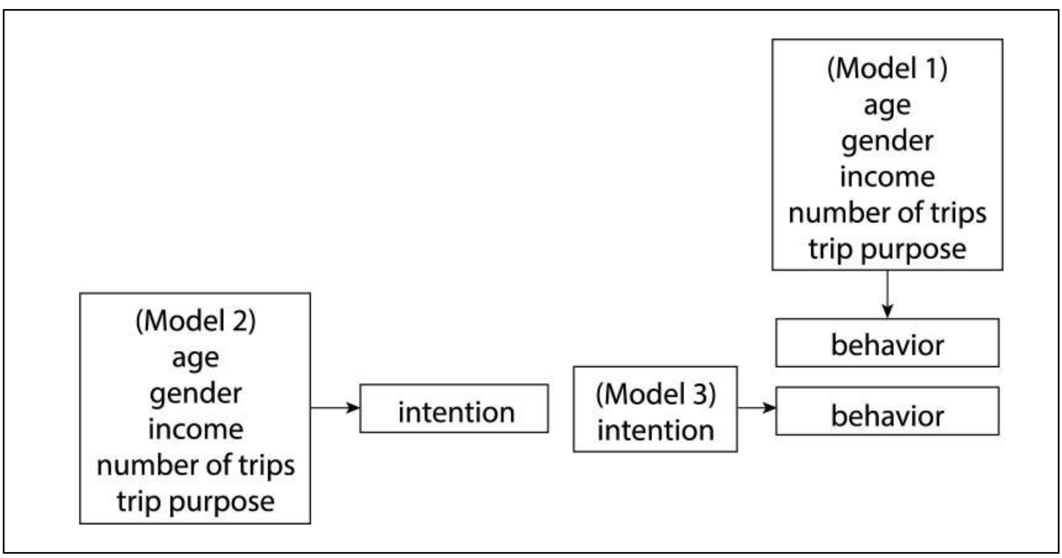
The literature review highlights the areas of airline ancillary service research that could be examined further. Previous research studies generally examined a limited number of ancillary services, narrowed the study (by region or airline), or only compared large customer segments, such as business vs. non-business travelers. In addition, many of the studies had collected data using approaches considered time consuming.

Since there appears to be a need to add to the airline ancillary services stream of research, this paper sets out to make several research contributions. First, we provide a comprehensive analysis of which ancillary service customers are willing to purchase by exploring airline passenger heterogeneity and purchase intentions. Second, we add to the limited ancillary service research about the United States market. Since our research is not restricted to leisure or business travelers, low cost or legacy airlines, or to a particular route or airline we provide generalized results. Last, we introduce the transportation domain to a readily available pool of useful online respondents revealing a quick and simple data collection method.

## RESEARCH METHODOLOGY

This research includes three separate analyses as shown in Figure 1.

**Figure 1: Overview of Research**



Model 1 uses logistic regression with categorical independent variables and a binary dependent variable to identify how the covariates affect actual purchase behavior. This helps us answer RQ1, which ancillary services should airlines sell and to whom should they sell? Model 2 uses a general linear model (GLM) with categorical independent variables and a continuous dependent variable to identify significant covariates as they relate to intention to purchase. This also helps us to answer RQ1. Model 3 uses logistic regression with metric independent variables and a binary dependent variable to identify if intention to purchase can predict actual purchase behavior. This helps us to answer RQ2, can airlines use *intention* to purchase to predict if customers will in fact purchase ancillary services. We use model 3 to answer RQ3, can we make reasonable inferences using readily available online pools of respondents from the likes of Amazon's Mechanical Turk?

Model 3 was guided in part by Theory of Planned Behavior (TPB). Fishbein and Ajzen (1975) suggest behavior can be predicted based on the intention to perform the behavior. TPB views behavioral intention as the immediate source of behavior. The stronger the intention, the more likely the behavior will be performed. Therefore, TPB, in part, was chosen for a two reasons: 1) TPB has had a pronounced impact on explaining decision-making and choice behaviors (Crano and Prislin 2008), and 2) TPB has been used to explain behavior in the transportation domain (Bamberg et al. 2003, Chaney et al. 2013, Chen et al. 2016, and Schniederjans and Starkey 2014).

Following the analyses, the Brier score was used to validate the predictive power of the logistic regression probability equations and the research findings. The Brier score is a measure of the deviation from a perfect model fit (Bukszar 2003).

**Data Collection Instrument**

To collect data, an online survey was developed using items from previous research articles. The survey was pretested on several subjects who would be typical survey respondents and only non-substantive changes were deemed necessary.

The categorical independent variables used for model 1 and 2 are discussed next and are shown in Table 2. Usage frequency, number of trips, and previous experience have been widely used in previous studies (Balcombe et al. 2009, Harris and Uncles 2007, Jou et al. 2013, Olson and Kendrick 2008, and Venkatesh and Agarwal 2006). Thus, respondents were asked, on average, how many times they fly on domestic flights (DF) per year. Categories included 0, 1-2, 3-5, and more than 5 times. The reference category is more than 5 times. Respondents were also asked, on average, how many times they fly on international flights (IF) per year. Categories included 0, 1-2, and more than 2 times. The reference category is more than 2 times.

Trip purpose, age, gender, and total annual household income were included in previous studies and were included in this study as well (Balcombe et al. 2009; Harris and Uncles 2007; Jou et al. 2013). Survey respondents were asked to select one: On most occasions, I am a *(business or leisure)* traveler (TP_B and TP_L). Leisure traveler is the reference category. Generations of people are generally explained by the differences in their characteristics. Initially, we selected four generational categories in our survey. However, data collected for two of the categories did not return an adequate number of responses for analysis. Therefore, age was divided into two categories: born in 1981 and earlier (AGE_B), and born in 1982 and later (AGE_A) (Pew Research Center 2011). The split in years was done to group Generation Y/Millennials into one group and to group earlier generations into another. Since there is great interest in understanding Millennial behavior, this split was deemed most appropriate. The reference category is 1981 and earlier. The reference category for gender (GEN) is male. Total annual household income (INC) contains five categories, whereas more than $120,000 is the reference category.

The dependent variables (Table 3) for this study were identified from Garrow (2012), O'Connell and Warnock-Smith (2013), Sorenson (2012), and Wittmer and Rowley (2014). For model 1, respondents were asked to answer 13 behavior items related to actual purchases of various ancillary services on domestic flights. Behavior is a categorical dependent variable. An example of one of the 13 behavior items in the survey is, "On a past domestic flight, I have paid extra airline fees for an aisle seat. Yes, No, Not an Option." Each of the 13 behavior items is listed in Table A.1.

Respondents were also asked to answer 13 intention items related to their intention to purchase various ancillary services on domestic flights. Intention is a metric dependent variable for model 2. Intention is used again as an independent metric variable for model 3. An example of one of the 13 intention items in the survey is, respondents were asked, using a five-point Likert scale anchored by 1 = Definitely Would Not and 5 = Definitely Would, "When I travel by air, I would pay extra fees for an aisle seat." Each of the 13 intention items is listed in Table A.1.

**Data Collection Process**

Sample data were collected from MTurk in October 2015 over a four-day period. It took an average of five minutes and five seconds to complete the survey. MTurk has been shown to be a viable data collection source used to obtain high-quality data economically and quickly, and where data obtained are at least as reliable as those obtained through traditional methods (Buhrmester et al. 2011, Germine et al. 2012, and Holden et al. 2013). To entice completion of the survey, $20 was offered to respondents who completed the survey. To ensure completion and lessen the likelihood of duplicates, respondents were notified that the survey must be completed in full to receive payment and that surveys from the same IP address would not be counted. Gentle warnings have been shown to increase attentiveness without creating ill will among survey respondents (Huang et al. 2015).

## DATA ANALYSIS AND RESULTS

The survey targeted airline passengers who have flown on U.S. domestic flights. The original sample size consisted of 525 responses. Eight responses had identical IP addresses and were removed from the analysis. Eliminating these responses reduced the possibility of duplicate responses or responses that were intentionally altered to collect the cash reward. Incomplete surveys were also removed from the analysis. Further, if the respondent did not fly at least one domestic flight in a year, their responses were removed from the analysis. In addition, if respondents answered that they did not have an option to purchase ancillary services on their flights, their responses were removed from the behavior model analysis. The net sample size resulted in 357 useable responses available for behavior data analysis (models 1 and 3) and 493 useable responses available for intention data analysis (model 2).

Tables 2 and 3 summarize the responses from MTurk and the variable coding. Table 3 shows that airline passengers show a higher intention score to purchase onboard WiFi, extra legroom, and onboard meals, though these score are not particularly high and the other ancillary services intention scores are even lower. This would suggest that ancillary services are not widely popular among passengers. This is corroborated by airline passengers' actual purchase behavior of ancillary services.

**Table 2: Summary of Independent Categorical Variables**

| **Categorical Variable** | **Variable Code** | **Model 1 and 3 Behavior Frequency (%)** | **Model 2 Intention Frequency (%)** |
|---|---|---|---|
| Age | | | |
| 1981 and before [a] | AGE_B | 115 (32.21) | 171 (34.69%) |
| 1982-1998 | AGE_A | 242 (67.79) | 322 (65.31%) |
| Gender | | | |
| Female | GEN_F | 179 (50.14) | 245 (49.70%) |
| Male [a] | GEN_M | 178 (49.86) | 248 (50.30%) |
| Income | | | |
| Less than $25,000 | INC_0 | 66 (18.49) | 89 (18.05%) |
| $25,000 - $45,000 | INC_1 | 88 (24.65) | 133 (26.98%) |
| $45,001 - $75,000 | INC_2 | 117 (32.77) | 153 (31.03%) |
| $75,001 - $120,000 | INC_3 | 59 (16.53) | 86 (17.44%) |
| More than $120,000 [a] | INC_4 | 27 (7.56) | 32 (6.49%) |
| Domestic Flights Flown | | | |
| 1-2 | DF_1 | 208 (58.26) | 292 (59.23%) |
| 3-5 | DF_3 | 105 (29.41) | 147 (29.82%) |
| More than 5 [a] | DF_5 | 44 (12.32) | 54 (10.95%) |
| International Flights Flown | | | |
| 0 | IF_0 | 82 (22.97) | 117 (23.73%) |
| 1-2 | IF_1 | 204 (57.14) | 285 (57.81%) |
| More than 2 [a] | IF_2 | 71 (19.89) | 91 (18.46) |
| Trip Purpose | | | |
| Business | TP_B | 91 (25.49) | 130 (26.37%) |
| Leisure [a] | TP_L | 266 (74.51) | 363 (73.63%) |
| n = | | 357 | 493 |

**Note:** a = reference category.

**Table 3: Summary of Intention and Behavior Dependent Variables**

| Ancillary Service | Behavior Model 1 and 3 | | | Intention Model 2 |
|---|---|---|---|---|
| | Yes Frequency (%) | No Frequency (%) | Not an Option Frequency (%) | Mean (Std. Dev.) |
| Aisle Seat | 75 (15.40) | 282 (57.91) | 130 (26.69) | 2.60 (1.41) |
| Extra Legroom | 100 (20.53) | 274 (56.26) | 113 (23.20) | 2.96 (1.42) |
| Window Seat | 111 (22.79) | 262 (53.80) | 114 (23.41) | 2.89 (1.44) |
| Seat Front of Airplane | 70 (14.37) | 300 (61.60) | 117 (24.02) | 2.59 (1.37) |
| Priority Boarding | 114 (23.41) | 279 (57.29) | 94 (19.30) | 2.63 (1.39) |
| Priority Deplaning | 57 (11.70) | 288 (59.14) | 142 (29.16) | 2.60 (1.39) |
| Reserved Seat | 165 (33.88) | 239 (49.08) | 83 (17.04) | 3.16 (1.43) |
| Reserved Overhead Space | 63 (12.94) | 272 (55.85) | 152 (31.21) | 2.72 (1.41) |
| Onboard Meals | 161 (33.06) | 242 (49.69) | 84 (17.25) | 3.01 (1.38) |
| Onboard Movies | 118 (24.23) | 276 (56.67) | 93 (19.10) | 2.70 (1.39) |
| Onboard TV | 86 (17.66) | 297 (60.99) | 104 (21.36) | 2.70 (1.39) |
| Onboard WiFi | 133 (27.31) | 264 (54.21) | 90 (18.48) | 3.18 (1.44) |
| Mobile Tablets Provided by Airline | 56 (11.50) | 216 (44.35) | 215 (44.15) | 2.57 (1.47) |

**Note:** Intention – Behavior (model 3) uses intention data as the independent metric variable.

The intention survey items show good reliability with a Cronbach's alpha reliability coefficient of 0.94 (Nunnally 1978). Since independent and dependent variables were collected from the same survey instrument, a number of steps were taken to minimize the occurrence of common method variance. The survey was developed and administered in accordance with the recommendations from Podsakoff et al. (2003). Careful attention was given to the order and position of the survey items to create temporal distance. In addition, the independent and dependent items were displayed in different formats, using five-point Likert scales and dichotomous rating scales. Harman's single-factor procedure was also conducted, and it was found that a single factor accounts for less than the majority of the variance at 37.32% (Podsakoff et al. 2003). Using separation, scale differences, and statistical methods provides added confidence in our research findings.

### Model 1 Behavior Results

The dependent variable behavior represents the choice between, Yes, I bought the ancillary service, and No, I have not bought the ancillary service. This is modeled using logistic regression, which is an acceptable method of analysis when modeling discrete choice behavior and is commonly employed when studying choice behavior. It facilitates the understanding of individual purchases, provides predictions, and includes characteristics of consumers and their behaviors (Harris and Uncles 2007). We use the same approach as Leon and Uddin (2016) did in a previous study that modeled behavior antecedents directly using logistic regression.

We find the probability of selecting, Yes, I bought the ancillary service, using the general formulation (1), where K is the number of independent variables in the equation.

$$(1)\quad P(B) = \frac{e^{\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k}}{1 + e^{\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k}}$$

Thirteen (13) binary logistic regressions, one for each ancillary service, were conducted with the results shown in Table A.2 of the appendix. The column labeled Reciprocal of Odds Ratio exists to show the reciprocal of the odds ratio when it is less than one. This helps to show which variables are most prominent and provides a more intuitive meaning of the results with less room for misinterpretation.

The number of times a traveler flies on domestic and international flights in a year is found to be a significant factor. The odds of fliers who fly more than five domestic flights a year choosing to purchase onboard movies over not purchasing onboard movies is 4.95 times than that of fliers who fly one or two domestic flights a year. Similarly, the odds of fliers who fly more than five domestic flights in a year choosing to purchase seats in front of the airplane over not purchasing seats in front of the airplane is 4.484 times than that of fliers who fly one or two domestic flights a year. The odds of fliers who fly more than two international flights in a year choosing to purchase reserved overhead space on domestic flights over not purchasing reserved overhead space on domestic flights is 4.444 times than that of fliers who fly zero (0) international flights in a year.

Trip purpose and income are significant factors as well; however, age and gender are not. The odds of business travelers choosing to purchase an aisle seat over not purchasing an aisle seat is 1.858 times than that of leisure travelers. Similar results are seen for extra legroom, window seats, and reserved seats. Surprisingly, the odds of travelers with income less than $25,000 choosing to purchase onboard movies over not purchasing onboard movies is 2.516 times than that of those travelers with income levels of more than $120,000.

**Model 2 Intention Results**

SAS Proc GLM (General Linear Model) was used to identify significant independent variables as they relate to the metric dependent variable intention to purchase. Since each of the independent variables is categorical, GLM is an appropriate analysis method. GLM has become a popular means of estimating ANOVA and MANOVA models because of its flexibility and simplicity in model design (Hair et al. 2006).

GLM analysis was conducted 13 times, one for each ancillary service. The results of the analysis, including Least Square Means (LSMeans - SAS keyword) and significant differences between air traveler characteristics when the dependent variables are intention to purchase ancillary services, are displayed in Table 4.

The number of times a traveler flies on domestic and international flights in a year is significant. When fliers were asked about their intention to purchase ancillary services on domestic flights, fliers who flew more domestic flights were generally more inclined to purchase various seating options, boarding and deplaning priority, overhead space, and onboard WiFi than those fliers who flew fewer domestic flights per year. The results show there are significant differences in purchase intention by domestic fliers for eight of the 13 ancillary services.

Air travelers who have flown internationally are more apt to purchase ancillary services on domestic flights than fliers who only flew domestically. Also, fliers who flew more than two international flights per year were more inclined to purchase domestic ancillary services than those who flew fewer international flights per year. The results show there are significant differences in purchase intention by international fliers for 12 of the 13 ancillary services.

Trip purpose is also a significant factor. When travelers were asked about their intention to purchase ancillary services, business travelers were more apt to pay for an aisle seat, extra legroom, and meals than leisure travelers. While there is no difference in the purchasing intention for priority boarding or deplaning, business travelers are more inclined to purchase seats near the front of the airplane and overhead space than leisure travelers. The results show there are significant differences in purchase intention by trip purpose for five of the 13 ancillary services.

**Table 4: GLM Ancillary Service Model 2 Results**

| Ancillary Service | Comparisons of Least Square Means | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **DF1** | **DF3** | **DF5** | **DF1 vs DF3** | **DF1 vs DF5** | **DF3 vs DF5** | **IF0** | **IF1** | **IF2** | **IF0 vs IF1** | **IF0 vs IF2** | **IF1 vs IF2** | **TP_B** | **TP_L** | **TP_B vs TP_L** |
| Aisle Seat | 2.67 | 3.01 | 3.21 | ** | ** | ns | 2.85 | 2.70 | 3.36 | ns | ** | *** | 3.21 | 2.72 | *** |
| Extra Legroom | 2.95 | 3.20 | 3.84 | * | *** | *** | 3.49 | 3.10 | 3.41 | ** | ns | * | 3.49 | 3.17 | ** |
| Window Seat | 2.89 | 3.12 | 3.55 | ns | *** | * | 3.26 | 2.83 | 3.46 | *** | ns | *** | | | |
| Seat Front of Airplane | 2.64 | 3.04 | 2.98 | *** | ns | ns | 2.78 | 2.64 | 3.23 | ns | ** | *** | 3.09 | 2.68 | *** |
| Priority Boarding | 2.55 | 2.91 | 3.37 | *** | *** | ** | 2.84 | 2.65 | 3.34 | ns | ** | *** | | | |
| Priority Deplaning | 2.57 | 2.98 | 3.18 | *** | *** | ns | 2.81 | 2.52 | 3.40 | * | *** | *** | | | |
| Reserved Seat | | | | | | | 3.29 | 2.90 | 3.79 | ** | ** | *** | | | |
| Reserved Overhead Space | 2.89 | 2.86 | 3.36 | ns | ** | ** | 2.96 | 2.74 | 3.42 | ns | ** | *** | 3.23 | 2.84 | *** |
| Onboard Meals | | | | | | | 3.06 | 2.98 | 3.55 | ns | ** | *** | 3.40 | 2.99 | *** |
| Onboard Movies | | | | | | | 2.63 | 2.58 | 3.25 | ns | *** | *** | | | |
| Onboard TV | | | | | | | 2.63 | 2.51 | 3.36 | ns | *** | *** | | | |
| Onboard WiFi | 3.06 | 3.18 | 3.81 | ns | *** | *** | | | | | | | | | |
| Mobile Tablets Provided by Airline | | | | | | | 2.48 | 2.34 | 3.42 | ns | *** | *** | | | |

**Note:** Numerical values are Least Square Means; *$p < 0.10$; **$p < 0.05$%; ***$p < 0.001$; ns and empty cells = not significant.

The level of income, age, and gender were not found to be significant factors, thus there is no difference in the purchase intention between fliers from different income brackets, age, or gender groups.

**Model 3 Intention - Behavior Results**

Intention is the single independent metric variable and behavior is the binary dependent variable. This is modeled 13 times, one for each ancillary service, using logistic regression (Ajzen 1991, Ajzen and Driver 1992)

These models seek to understand whether or not the choice behavior of purchasing ancillary services for domestic flights can be predicted by a respondent's stated intention to purchase the ancillary services. Thirteen binomial logistic regressions were conducted with behavior representing the choice of, *Yes*, I bought the ancillary service, or *No*, I have not bought the ancillary service.

From the previous equation (1), we reduce K to equal one (1) independent variable $X$, where $X$ is the intention score. Given the intention score, we are determining the probability of selecting, *Yes,* that a passenger will purchase the ancillary service using the general formulation in equation (2).

$$(2)\quad P(B) = \frac{e^{\beta_0 + \beta_1 X_1}}{1 + e^{\beta_0 + \beta_1 X_1}}$$

The results of the 13 binary logistic regressions are shown in Table 5 and indicate that intention may indeed predict behavior.

For each of the 13 domestic ancillary services, intention is significant. As intention scores increase, fliers tend to purchase the respective ancillary service. For example, a one-unit increase in a flier's intention to purchase an aisle seat will increase the odds of choosing to purchase an aisle seat over not purchasing an aisle seat by approximately 189% (odds ratio = 2.889).

**Model Validation**

We tested the prediction accuracy of intention – behavior ≈ probability models (model 3) by comparing the predicted outcome with the actual outcome using the Brier score.

The Brier score in equation (3) is the mean squared error of the probability forecast and is a measure of forecast accuracy. It was first introduced by Brier (1950) and is frequently used to examine forecast accuracy (Brozyna et al. 2016, Bukszar 2003).

$$(3)\quad \text{Brier Score} = \frac{1}{N}\Sigma_{t=1}^{N}(P(B)_t - B_t)^2$$

Where *P(B)* is the probability that was forecast, *B* is the actual behavioral outcome of the event at instance *t*, and N is the number of forecasting instances. The score is reported between and including 0 and 1, where a lower score is better. Zero implies a perfect prediction.

Using the general probability equation (2), a determination of the probability of *Yes*, that a passenger will purchase the ancillary service, is made. $P(B)$ is $\in(0,1)$, where $B$ is behavior and is either 0 or 1, $B_0$ and $B_1$ are coefficient estimates derived from the MTurk sample data, and $X$ is the intention score. The Brier score results, displayed in Table 5, are low, implying that the prediction models developed using MTurk sample data are reliable.

**Table 5: Intention-Behavior Model 3 and Validation Results**

| Dependent Variable | Intercept | Coefficient | Std. Error | Wald Chi-square | Significance | Odds Ratio | Brier Score |
|---|---|---|---|---|---|---|---|
| Aisle Seat | -4.7454 | 1.061 | 0.1354 | 61.4419 | <.0001 | 2.889 | 0.12 |
| Extra Legroom | -4.3893 | 1.002 | 0.1234 | 65.9249 | <.0001 | 2.724 | 0.15 |
| Window Seat | -4.0995 | 0.961 | 0.1178 | 66.5727 | <.0001 | 2.614 | 0.16 |
| Seat Front of Airplane | -5.1722 | 1.1273 | 0.1495 | 56.8766 | <.0001 | 3.087 | 0.12 |
| Priority Boarding | -3.5791 | 0.8905 | 0.102 | 76.175 | <.0001 | 2.436 | 0.16 |
| Priority Deplaning | -4.5835 | 0.9239 | 0.1374 | 45.2071 | <.0001 | 2.519 | 0.12 |
| Reserved Seat | -2.8977 | 0.7394 | 0.0925 | 63.9047 | <.0001 | 2.095 | 0.20 |
| Reserved Overhead Space | -4.026 | 0.7859 | 0.1258 | 39.0494 | <.0001 | 2.194 | 0.13 |
| Onboard Meals | -2.6554 | 0.6977 | 0.0901 | 60.0037 | <.0001 | 2.009 | 0.20 |
| Onboard Movies | -3.4567 | 0.8728 | 0.101 | 74.6927 | <.0001 | 2.394 | 0.16 |
| Onboard TV | -4.2935 | 0.9512 | 0.1221 | 60.7433 | <.0001 | 2.589 | 0.14 |
| Onboard WiFi | -3.9324 | 0.9328 | 0.1084 | 74.0013 | <.0001 | 2.542 | 0.17 |
| Mobile Tablets Provided by Airline | -3.9493 | 0.8017 | 0.1318 | 36.9805 | <.0001 | 2.229 | 0.14 |

## DISCUSSION AND CONCLUSION

This study comprehensively examined a number of airline ancillary services and factors that may influence the purchase of ancillary services. In the examination of ancillary services, we answered 1) which ancillary services should airlines sell and to whom should they sell, 2) can airlines use *intention* to purchase to predict if customers will purchase ancillary services, and 3) can we make reasonable inferences using readily available pools of online respondents.

Answering these questions has several managerial and research applications. The findings could assist airline management in developing current and prospective ancillary services. Additionally, the findings could assist in developing associated sales, marketing, and training strategies, leading to increases in revenue per passenger. Using a segmentation approach to selling and marketing can lead to missed sales opportunities and wasted resources. However, taking a pointed approach to direct sales and marketing efforts toward customers who are most likely to purchase ancillary services, airlines can increase revenue and reduce wasted resources.

Such a pointed approach requires keen understanding of passenger attributes that lead to ancillary purchases, and which ancillary services customers are willing to purchase. Previous studies have found age, gender, income, and trip purpose as significant factors (Balcombe et al. 2009, Chen and Wu 2009, Martin et al. 2008) when purchasing ancillary services. This study found that the number of domestic and international flights a passenger flies in a year, the trip purpose, and income (to a lesser degree) as significant factors. Moreover, the significance of these factors change based on the ancillary service in question. Our results show that neither age nor gender are significant factors in predicting intent to purchase or the actual purchase of ancillary services. While Generation Y/Millennial behaviors are different than other generations in many ways, we found that their ancillary service purchasing behavior is no different from older generations.

Generally, passengers are not fond of purchasing ancillary services in the first place. If passengers are grouped together and asked which ancillary services they have purchased or are likely to purchase, onboard WiFi, reserved seats, onboard meals, extra legroom, and window seats, rank higher than others. However, without taking the analysis further, we lose some of the heterogeneity among passengers, and airlines might be leaving money on the table. For example, instead of viewing premium seats as one category or limiting this category to pitch and width as previous studies have done (Balcombe et al. 2009, Lee and Luengo-Prado 2004, Martin et al. 2008, Mumbower et al. 2015), it may be more beneficial to expand this category as well as other categories. For example, passengers who have flown more than three domestic flights in a year are more likely to purchase window seats than those who have flown fewer flights; however, these same passengers are more likely to purchase extra legroom rather than window seats. Moreover, while paying extra for aisle seats does not appear high on the list of ancillary purchases, passengers who have flown three or more domestic flights or two or more international flights are more likely to purchase reserved aisle seats than other passengers. Given these types of insights, airlines that might otherwise forgo selling an ancillary service may reconsider their decision. Training front line employees, such as reservation agents, gate agents, and flight attendants, in sales techniques where they can offer the most relevant ancillary services, at the appropriate time, and to the most appropriate customers can pay dividends. Gate agents might upsell extra legroom to a business traveler or to someone who has flown on five or more domestic flights. Meanwhile, flight attendants can upsell onboard amenities such as mobile tablets to passengers who have flown two or more international flights. From the insights provided in this study, there is opportunity for airlines to improve sales of ancillary services for both those that are currently selling well and those that are not.

Evidence suggests that the intent to purchase predicts actual purchase behavior. If the factors that influence a traveler's intent to purchase can be identified, then we can reasonably predict which passengers are most likely to purchase ancillary services and which ones they are most likely to purchase. Airlines managers will not need to rely solely on their customers' actual purchase behavior to make all of their ancillary service decisions. The need to collect actual purchase data, which can be more difficult and time consuming to collect and may not capture the pertinent details necessary for future decision making, is lessened.

Airlines can survey customers and non-customers alike to obtain intent to purchase scores related to current and new ancillary service offerings in an effort to predict actual purchase behavior. Intent to purchase data are quick, easy, and inexpensive to collect via services similar to MTurk. Using MTurk or similar services can help airline decision makers obtain data that are otherwise not readily available or accessible.

While it is true that current customers are a valuable source of information, data collected from them are not always complete or timely. Incomplete and untimely data are a concern for all companies, and before airlines adjust IT systems for more appropriate data collection capabilities, data needs can be pretested first by using services similar to MTurk.

An unintended contribution of our research is that our findings can assist researchers with the identification and selection of suitable ancillary services and attributes for their airline's stated preference experiments, reducing the time and resources needed in their research. As Balcombe et al. (2009) noted, they identified relevant attributes for their stated choice experiment through focus groups and industry interviews, a time consuming endeavor. They further stated that finding the most appropriate attributes and levels for a stated choice experiment is important because of the possibility of an unwieldy survey design.

## Limitations and Future Research

This study followed the same approach as Donald et al. (2014), Mishra (2014), and Stran et al. (2016), where intention and behavior were measured at the same time. Even so, we took precautions to prevent common method variance and validated our results with the Brier score. Yet, a longitudinal study could reaffirm our results. Also, future studies could include additional factors that influence ancillary purchases. Understanding traveler purchase behavior while traveling in groups or families, whether or not the customer is a frequent flier, and the flight duration, including long-haul international flights, could lead to additional purchasing behavior insights. Two other areas of future research could include studying the effect of too many ancillary service choices, where non-choice could become a factor, and studying the effect of competition on ancillary service offerings when applying profit-maximizing strategies.

## References

Ajzen, I. "The Theory of Planned Behavior." *Organizational Behavior and Human Decision Processes* 50, (1991): 179-211.

Ajzen, I. and B.L., Driver. "Application of the Theory of Planned Behavior to Leisure Choice." *Journal of Leisure Research* 24 (3), (1992): 207-224.

Balcombe, K., I. Fraser, and L. Harris. "Consumer Willingness to Pay for In-Flight Service and Comfort Levels: A Choice Experiment." *Journal of Air Transport Management* 15 (5), (2009): 221–226.

Bamberg, S., I. Ajzen, and P. Schmidt. "Choice of Travel Mode in the Theory of Planned Behavior: The Roles of Past Behavior, Habit, and Reasoned Action." *Basic and Applied Social Psychology* 25 (3), (2003): 175–187.

Boynton, M.H., and L.S. Richman. "An Online Daily Diary Study of Alcohol Use Using Amazon's Mechanical Turk." *Drug and Alcohol Review* 33, (2014): 456–461.

Brozyna, J., G. Mentel, and T. Pisula. "Statistical Methods of the Bankruptcy Prediction in the Logistics Sector in Poland and Slovakia." *Transformations in Business & Economics* 15 (37), (2016): 93–114.

Brey, R., and J.L. Walker. "Latent Temporal Preferences: An Application to Airline Travel." *Transportation Research Part A* 45 (9), (2011): 880–895.

Brier, G. "Verification of Forecasts Expressed in Terms of Probability." *Monthly Weather Review* 78, (1950): 1–3.

Buhrmester, M., T. Kwang, and S.D. Gosling. "Amazon's Mechanical Turk: A New Source of Inexpensive, Yet High-Quality, Data." *Perspectives on Psychological Science* 6 (1), 2011: 3–5.

Bukszar, E. "Does Overconfidence Lead to Poor Decisions? A Comparison of Decision Making and Judgment Under Uncertainty." *Journal of Business and Management* 9 (1), (2003): 33-43.

Chaney, R.A., A.L. Bernard, and B.R.A. Wilson. "Characterizing Active Transportation Behavior Among College Students Using the Theory of Planned Behavior." *International Quarterly of Community Health Education* 34 (3), (2013): 283-294.

Chen, C.F., and T.F. Wu. "Exploring Passenger Preferences in Airline Service Attributes: A Note." *Journal of Air Transport Management* 15, (2009): 52–53.

Chen, H.Y.W., D. Birsen, L. Hoekstra-Atwood, and S. Marulanda. "Self-Reported Engagement in Driver Distraction: An Application of the Theory of Planned Behavior." *Transportation Research Part F* 38, (2016): 151–163.

Correia, A., A. Pimpão, and M. Tão. "Willingness to Pay for Frills When Travelling with Low-Cost Airlines." *Tourism Economics* 18 (6), (2012): 1161–1174.

Crano, W.D., and R. Prislin. *Attitudes and Attitude Change*. Psychology Press, New York, 2008.

Dedeke, A. "Travel Web-Site Design: Information Task-Fit, Service Quality and Purchase Intention." *Tourism Management* 54, (2016): 541–554.

Donald, I.J., S.R. Cooper, and S.M. Conchie. "An Extended Theory of Planned Behaviour Model of the Psychological Factors Affecting Commuters' Transport Mode Use." *Journal of Environmental Psychology* 40, (2014): 39-48.

Espino, R., J.C. Martín, and C. Román. "Analyzing the Effect of Preference Heterogeneity on Willingness to Pay for Improving Service Quality in an Airline Choice Context." *Transportation Research Part E* 44 (4), (2008): 593–606.

Fishbein, M., and I. Ajzen. *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research*. Addison-Wesley, Reading, MA, 1975.

Garrow, L.A., S. Hotle, and S. Mumbower. "Assessment of Product Debundling Trends in the US Airline Industry: Customer Service and Public Policy Implications." *Transportation Research Part A* 46, (2012): 255–268.

Germine, L., K. Nakayama, B.C. Duchaine, C.F. Chabris, G. Chatterjee, and J.B. Wilmer. "Is The Web as Good as the Lab? Comparable Performance from Web and Lab in Cognitive/Perceptual Experiments." *Psychonomic Bulletin and Review* 19, (2012): 847–857.

Hair, J., W. Black, B. Babin, R. Anderson, and R. Tatham. *Multivariate Data Analysis*. 6th ed. Pearson Prentice Hall, Upper Saddle River, NJ, 2006.

Harris, J., and M. Uncles. "Modeling the Repatronage Behavior of Business Airline Travelers." *Journal of Service Research* 9 (4), (2007): 297-311.

Hess, S., T. Adler, and J.W. Polak. "Modeling Airport and Airline Choice Behavior with the Use of Stated Preference Survey Data." *Transportation Research Part E: Logistics and Transportation Review* 43 (3), (2007): 221-233.

Holden, C.J., T. Dennie, and A.D. Hicks. "Assessing the Reliability of the M5-120 on Amazon's Mechanical Turk." *Computers in Human Behavior* 29, (2013): 1749–1754.

Holloway, S., *Straight and Level: Practical Airline Economics*. 3rd ed. Ashgate Publishing Limited, Aldershot, 2008.

Huang, J.L., N.A. Bowling, M. Liu, and Y. Li. "Detecting Insufficient Effort Responding with an Infrequency Scale: Evaluating Validity and Participant Reactions." *Journal of Business and Psychology* 30, (2015): 299–311.

IdeaWorks. "Airline Ancillary Revenue Projected to be $59.2 Billion Worldwide in 2015." Available at: http://www.ideaworkscompany.com/november-9-2015-press-release. (accessed on May 27 2016), 2015.

Jou, R.C., J.Y. Chien, and Y.C. Wu. "A Study of Passengers' Willingness to Pay for Business Class Seats of High-Speed Rail in Taiwan." *Transportmetrica A: Transport Science* 9 (3), (2013): 223-238.

Krupa, J.S., D.M. Rizzo, M.J. Eppstein, D.B. Lanute, D.E. Gaalema, K. Lakkaraju, and C.E. Warrender. "Analysis of a Consumer Survey on Plug-in Hybrid Electric Vehicles." *Transportation Research Part A* 64, (2014): 14–31.

Lee, D., and M.J. Luengo-Prado. "Are Passengers Willing to Pay More for Additional Legroom?" *Journal of Air Transport Management* 10, (2004): 377–383.

Leon, S. "Airport Choice Modeling: Empirical Evidence from a Non-Hub Airport." *Journal of the Transportation Research Forum* 50 (2), (2011): 5-16.

Leon, S., and N. Uddin. "Finding Supply Chain Talent: An Outreach Strategy." *Supply Chain Management: An International Journal* 21 (1), (2016): 20-44.

Martin, J.C., C. Román, and R. Espino. "Willingness to Pay for Airline Service Quality." *Transport Reviews* 28 (2), (2008): 199–217.

Mishra, S. "Adoption of M-commerce in India: Applying Theory of Planned Behaviour Model." *Journal of Internet Banking and Commerce* 19 (1), (2014): 1-17.

Mumbower, S., L.A. Garrow, and J.P. Newman. "Investigating Airline Customers' Premium Coach Seat Purchases and Implications for Optimal Pricing Strategies." *Transportation Research Part A* 73, (2015): 53–69.

Munzel, A. "Assisting Consumers in Detecting Fake Reviews: The Role of Identity Information Disclosure and Consensus." *Journal of Retailing and Consumer Services* 32, (2016): 96–108.

Nunnelly, J.C. *Psychometric Theory*. 2nd ed. McGraw-Hill, New York, 1978.

O'Connell, J.F. and D. Warnock-Smith. "An Investigation into Traveler Preferences and Acceptance Levels of Airline Ancillary Revenues." *Journal of Air Transport Management* 33, (2013): 12-21.

Ødegaard, F., and J.G. Wilson. "Dynamic Pricing of Primary Products and Ancillary Services." *European Journal of Operational Research* 251, (2016): 586–599.

Olson, M.A., and R.V. Kendrick. "Origins of Attitudes, Book: Attitudes and Attitude Change." W.D. Crano, and R. Prislin, eds. *Attitudes and Attitude Change*, New York: Psychology Press (2008).

Pew Research Center. "The Generation Gap and the 2012 Election." Available at: http://www.people-press.org/2011/11/03/the-generation-gap-and-the-2012-election-3/ (accessed 11/12/2015), 2011.

Podsakoff, P.M., S.B. MacKenzie, J.Y. Lee, and N.P. Podsakoff. "Common Method Biases in Behavioral Research: A Critical Review of the Literature and Recommended Remedies." *Journal of Applied Psychology* 88 (5), (2003): 879–903.

Schniederjans, D.G., and C.M. Starkey. "Intention and Willingness to Pay for Green Transportation: An Empirical Examination." *Transportation Research Part D* 31, (2014): 116–125.

Sorenson, J. The Amadeus Yearbook of Ancillary Revenue by IdeaWorks. IdeaWorksCompany.com LLC. 2012.

Stran, K.A., L.L. Knol, K. Severt, and J.C. Lawrence. "College Students' Intentions to Use Calorie Information on a Restaurant Menu: Application of the Theory of Planned Behavior." *American Journal of Health Education* 47 (4), (2016): 215–223.

Teichert, T., E. Shehu, and I. von Wartburg. "Customer Segmentation Revisited: The Case of the Airline Industry." *Transportation Research Part A* 42, (2008): 227–242.

Tuzovic, S., M.C. Simpson, V.G. Kuppelwieser, and J. Finsterwalder. "From 'Free' to Fee: Acceptability of Airline Ancillary Fees and the Effects on Customer Behavior." *Journal of Retailing and Consumer Services* 21, (2014): 98–107.

US Department of Transportation, Bureau of Transportation Statistics, Baggage Fees. Available at: http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/subject_areas/airline_information/baggage_fees/index.html. (accessed May 27 2016), 2015.

Venkatesh, V., and R. Agarwal. "Turning Visitors into Customers: A Usability-Centric Perspective on Purchase Behavior in Electronic Channels." *Management Science* 52 (3), (2006): 367–382.

Winter, S.R., S. Rice, T. Rains, and M. Milner. "A Longitudinal Study on the Alteration of Consumer Perceptions and the Use of Pilot Medication." *Journal of Air Transport Management* 59, (2017): 100-106.

Wittmer, A., A. Gerber, and P. Boksberger. "The Future of Ancillary Service Fees in Air Travel: An Exploratory Investigation of Budget Air Travelers." *International Journal of Aviation Management* 1 (4), (2012): 231-241.

Wittmer, A., and E. Rowley. "Customer Value of Purchasable Supplementary Services: The Case of a European Full Network Carrier's Economy Class." *Journal of Air Transport Management* 34, (2014): 17-23.

## APPENDIX

**Table A.1: Ancillary Service Survey Items**

| Intention | Ancillary Service | Behavior | Ancillary Service |
|---|---|---|---|
| When I travel by air, I would pay extra fees for … | Aisle Seat | On a past domestic flight, I have paid extra fees for… | Aisle Seat |
| | Extra Legroom | | Extra Legroom |
| | Window Seat | | Window Seat |
| | Seat Front of Airplane | | Seat Front of Airplane |
| | Priority Boarding | | Priority Boarding |
| | Priority Deplaning | | Priority Deplaning |
| | Reserved Seat | | Reserved Seat |
| | Reserved Overhead Space | | Reserved Overhead Space |
| | Onboard Meals | | Onboard Meals |
| | Onboard Movies | | Onboard Movies |
| | Onboard TV | | Onboard TV |
| | Onboard WiFi | | Onboard WiFi |
| | Mobile Tablets Provided by Airline | | Mobile Tablets Provided by Airline |

**Table A.2: Ancillary Service Behavior Model 1 Results**

| Dependent Variable | Independent Variable | Estimate | Std. Error | Wald Chi-square | Significance | Odds Ratio | Reciprocal of Odds Ratio |
|---|---|---|---|---|---|---|---|
| Aisle Seat | Intercept | -0.7429 | 0.3611 | 4.2333 | 0.0396 | | |
| | DF_1 | -1.0348 | 0.3845 | 7.2420 | 0.0071 | 0.355 | 2.817 |
| | DF_3 | -0.6966 | 0.3943 | 3.1200 | 0.0773 | 0.498 | 2.008 |
| | TP_B | 0.6193 | 0.2977 | 4.3291 | 0.0375 | 1.858 | |
| Extra Legroom | Intercept | -0.2552 | 0.3451 | 0.5468 | 0.4596 | | |
| | DF_1 | -1.2109 | 0.3626 | 11.1512 | 0.0008 | 0.298 | 3.356 |
| | DF_3 | -0.9208 | 0.3751 | 6.0259 | 0.0141 | 0.398 | 2.513 |
| | TP_B | 0.6278 | 0.2695 | 5.4259 | 0.0198 | 1.874 | |
| Window Seat | Intercept | -0.2340 | 0.3442 | 0.4621 | 0.4967 | | |
| | DF_1 | -0.9992 | 0.3590 | 7.7460 | 0.0054 | 0.368 | 2.717 |
| | DF_3 | -0.7197 | 0.3744 | 3.6946 | 0.0546 | 0.487 | 2.053 |
| | TP_B | 0.5309 | 0.2629 | 4.0794 | 0.0434 | 1.701 | |
| Seat Front of Airplane | Intercept | -0.4418 | 0.3021 | 2.1389 | 0.1436 | | |
| | DF_1 | -1.4988 | 0.3655 | 16.8105 | <.0001 | 0.223 | 4.484 |
| | DF_3 | -0.7701 | 0.3784 | 4.1423 | 0.0418 | 0.463 | 2.160 |
| Priority Boarding | Intercept | 0.1603 | 0.2838 | 0.3193 | 0.5720 | | |
| | DF_1 | -1.4876 | 0.3269 | 20.7074 | <.0001 | 0.226 | 4.425 |
| | DF_3 | -0.8143 | 0.3457 | 5.5489 | 0.0185 | 0.443 | 2.257 |
| Priority Deplaning | Intercept | -0.6931 | 0.3273 | 4.4840 | 0.0342 | | |
| | DF_1 | -1.4143 | 0.3976 | 12.6504 | 0.0004 | 0.243 | 4.115 |
| | DF_3 | -0.6318 | 0.4092 | 2.3842 | 0.1226 | 0.532 | 1.880 |
| Reserved Seat | Intercept | -0.5360 | 0.1200 | 19.9343 | <.0001 | | |
| | TP_B | 0.6115 | 0.2285 | 7.1627 | 0.0074 | 1.843 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Reserved Overhead Space | Intercept | -0.6506 | 0.2518 | 6.6754 | 0.0098 | | |
| | IF_0 | -1.4895 | 0.4507 | 10.9227 | 0.0009 | 0.225 | 4.444 |
| | IF_1 | -0.9780 | 0.3194 | 9.3784 | 0.0022 | 0.376 | 2.660 |
| Onboard Meals | Intercept | 0.1541 | 0.2782 | 0.3070 | 0.5795 | | |
| | DF_1 | -0.8081 | 0.3112 | 6.7407 | 0.0094 | 0.446 | 2.242 |
| | DF_3 | -0.3663 | 0.3321 | 1.2169 | 0.2700 | 0.693 | 1.443 |
| Onboard Movies | Intercept | -0.1248 | 0.4791 | 0.0678 | 0.7945 | | |
| | INC_0 | 0.9226 | 0.5205 | 3.1419 | 0.0763 | 2.516 | |
| | INC_1 | 0.7529 | 0.4970 | 2.2950 | 0.1298 | 2.123 | |
| | INC_2 | -0.0051 | 0.4880 | 0.0001 | 0.9917 | 0.995 | 1.005 |
| | INC_3 | 0.3882 | 0.5124 | 0.5739 | 0.4487 | 1.474 | |
| | DF_1 | -1.6003 | 0.3466 | 21.3164 | <.0001 | 0.202 | 4.950 |
| | DF_3 | -0.9802 | 0.3538 | 7.6743 | 0.0056 | 0.375 | 2.667 |
| Onboard TV | Intercept | 0.0697 | 0.3186 | 0.0479 | 0.8268 | | |
| | DF_1 | -0.9987 | 0.3954 | 6.3793 | 0.0115 | 0.368 | 2.717 |
| | DF_3 | -0.6413 | 0.3827 | 2.8088 | 0.0937 | 0.527 | 1.898 |
| | IF_0 | -0.5039 | 0.4170 | 1.4603 | 0.2269 | 0.604 | 1.656 |
| | IF_1 | -0.8641 | 0.3225 | 7.1777 | 0.0074 | 0.421 | 2.375 |
| Onboard WiFi | Intercept | 0.1224 | 0.2862 | 0.1828 | 0.6690 | | |
| | DF1 | -1.1627 | 0.3238 | 12.891 | 0.0003 | 0.313 | 3.195 |
| | DF3 | -0.5553 | 0.3410 | 2.6513 | 0.1035 | 0.574 | 1.742 |
| Mobile Tablets Provided by Airline | Intercept | 0.0419 | 0.3488 | 0.0144 | 0.9044 | | |
| | DF_1 | -1.1865 | 0.477 | 6.1884 | 0.0129 | 0.305 | 3.279 |
| | DF_3 | -0.8824 | 0.4547 | 3.7659 | 0.0523 | 0.414 | 2.415 |
| | IF_0 | -1.7746 | 0.6915 | 6.5860 | 0.0103 | 0.170 | 5.882 |
| | IF_1 | -0.5170 | 0.3816 | 1.8363 | 0.1754 | 0.596 | 1.678 |

***Steven Leon** is an assistant professor of supply chain management in the CIS and SCM Department of the Walker College of Business, Appalachian State University. His research interests are in the areas of air transportation, global supply chain strategy, and performance. His research has appeared in a variety of journals including* SCM: An International Journal, International Journal of Logistics Management, Transportation Journal *and* Journal of the Transportation Research Forum. *He is the author of Sustainability in Supply Chain Management Casebook: Applications in SCM, and Financial Intelligence for Supply Chain Managers: Understand the Link between Operations and Corporate Financial Performance. Prior to his transition to academia, Steve spent many years in the air transportation industry. His PhD is in transportation and logistics from North Dakota State University and his MBA is in international business from Loyola University Maryland.*

***Nizam Uddin** is a professor at the Statistics Department of University of Central Florida. He earned his BSc and MSc in statistics, both from Dhaka University, Bangladesh, and MSc in mathematics from the University of Saskatchewan, Canada. He completed his Ph.D. in statistics at Old Dominion University, Norfolk, Virginia. His Ph.D. dissertation works include Optimality and Construction of Experimental Designs. Since earning his Ph.D., he has worked on many funded and unfunded research /consulting projects with colleagues from various departments and organizations. His refereed articles have appeared in a variety of core statistics journals including* Biometrika, Annals of Statistics, Journal of Statistical Planning and Inference, Communications in Statistics, *and in many other applied journals in psychology, transportation, health care, and environmental science areas.*

# Demonstration of the United States Road Assessment (usRAP) as a Systematic Safety Tool for Two Lane Roadways and Highways in Kansas

**by B.G. Nye, E.J. Fitzsimmons, and S. Dissanayake**

*The United States Road Assessment Program (usRAP) is a systematic tool that determines areas of risk based on roadways characteristics. To determine the effectiveness of the usRAP tool, three rural two-lane corridors, a US highway, a Kansas highway, and a rural secondary road, were selected for this study. Data collection for the usRAP software included manual speed data collection, system-wide centerline miles and crashes, crash costs, countermeasure costs, and manual roadway coding data every 100 m. The usRAP software evaluated and developed a star rating and a Safer Roads Investment Plan for each corridor.*

## BACKGROUND

According to the National Highway Traffic Safety Administration (NHTSA), in 2012, approximately 19% of the United States population lived in a rural area, but crashes in rural settings accounted for 54% of all traffic fatalities (National Highway Traffic Safety Administration [NHTSA] 2014). Due to the high percentage of rural fatalities compared to the population, rural road and highway vehicle crash prevention are topics of serious concern for state transportation agencies, counties, and local jurisdictions (Kansas included). During the 2013 calendar year, the 2013 Kansas Traffic Accident Facts developed by the Kansas Department of Transportation (KDOT) reported 36.4% of the approximately 5,525 crashes occurred on rural roads (KDOT 2014). The 2,011 crashes on rural roads accounted for 231 fatal crashes, or 70.6% of the total number of fatal crashes in Kansas (KDOT 2014).

Between 2005 and 2013, the total number of fatal crashes decreased from 276 to 231, respectively, while urban fatal crashes have remained relatively unchanged (KDOT 2014). The reduction in fatal rural crashes could be in part from the implemented safety programs, including a primary seat belt law, implementing FHWA Every Day Counts (EDC) programs, updating the Kansas Strategic Highway Safety Plan (SHSP), and identifying and improving high risk rural roads (HRRR).

The state of Kansas has a population of 2.85 million and a total of 714 cities (most under 5,000 population) over 82,278 square miles (United States Census 2010). Many rural Kansas residents use the state highway or paved secondary system to travel to larger communities. The Kansas road network comprises a significant amount of rural paved two-lane roads with posted speed limits of 55 mph. Due to the remote locations of rural roadways and minimal traffic, response time from emergency medical services (EMS) is often longer because crashes may go unnoticed for extended periods of time. Therefore, identification, prioritization for safety improvements, and implementation of roadway safety countermeasures before vehicle crashes occur is crucial to increasing rural roadway safety.

Identification of safety improvement locations on roadways have traditionally used hot spot or mass-action area determination from past crash data. However, crash data in rural settings tend to be sparse because of the low traffic volumes associated with rural roadways and crashes that may occur once every five years or more. To identify the locations of a probable crash location, a systemic and systematic approach that utilizes the roadway and intersection characteristics, opposed to crash data, should be used.

## LITERATURE REVIEW

Since the late 1980s, data about crashes and roadway characteristics have been collected and used by the Federal Highway Administration (FHWA) to help make policy decisions and by engineers researching highway safety (Tan 2011). One such database, in 1987, was the Highway Safety Information System (HSIS). HSIS collected crash, roadway, and traffic volume data from Illinois, Maine, Michigan, Minnesota, and Utah based on the availability, quantity, and quality of the data (Tan 2011).

With the creation of the databases, two different approaches have been traditionally used to determine safety concerns on roadways: crash mass action areas and systematic analysis of roadway characteristics. Crash hot spot analysis identifies locations that result in a high number of crashes based on previous crash data. Whereas, a systematic analysis of roadway characteristics identifies locations where crashes could potentially occur based on different variables associated with the roadway. SafetyAnalyst and FHWA geographical information system (GIS) using HSIS data are being used to identify crash hot spots, while road assessment programs and run-off-road models are used to identify safety concern locations.

### SafetyAnalyst

Harwood et al. (2010a) developed *SafetyAnalyst,* an analytical tool to assist in the decision-making process when identifying and managing site-specific, system-wide improvements. To determine where crash spot locations are, a network-screening tool uses traffic volumes and other roadway characteristics to identify sites with higher-than-expected and expected levels of crash frequencies. The tool can also identify sites with severe crashes and a high percentage of specific crash types. The network-screening tool focuses on identifying spot locations and short segments with potential for safety improvements. The network-screening tool can also identify large sections of roadway.

SafetyAnalyst closely refers to the Highway Safety Manual (HSM) and the FHWA's Interactive Highway Safety Design Model (IHSDM). All three tools extensively use safety performance functions (SPFs) and accident modification factors (AMFs) to predict crash frequency and severity (Hardwood et al. 2010a). SafetyAnalyst was created to improve effectiveness in decision-making and to strengthen support for the decisions made. Long-term viability of SafetyAnalyst is determined by continuous software enhancements to meet users' evolving needs (Hardwood et al. 2010a).

### FHWA GIS and HSIS

In 1999, the FHWA integrated GIS capabilities with the HSIS to create a crash analysis tool. The integrated system used traditional GIS features to spatially located crash locations and information using crash analysis tools. The tools allow engineers to evaluate crashes at a user designated spot, crashes along a segment, crashes near a certain roadway feature, and crashes along a specified corridor (FHWA 1999).

### Road Assessment Programs

In 1999, the road assessment program known as EuroRAP was created. The program analyzes specific information on roadway viewable physical characteristics. The characteristics range from vertical and horizontal alignment to objects near the roadway that could be struck by a motorist who leaves the roadway. Different values are assigned to the characteristics and used by the software to calculate a risk. Once the risks have been calculated, the software applies a benefit-cost ratio to different countermeasures and suggests countermeasures to be analyzed by an engineer (Harwood et al. 2010b).

### Run-Off-Road Model

Gao, Kan, Li, and Pang (2008) developed a run-off-road (ROR) prediction model using roadway geometry, traffic volume, crashes, roadside hardware, and features from 31 rural two-lane highways totaling 704 km. Road data were categorized into more than 900 sections in order to analyze the collected data. The model predicted ROR accident frequency, fatality, and injury using four statistical distributions: Poisson, negative binomial, zero-inflated Poisson, and zero-inflated negative binomial. Because ROR crashes occur infrequently, the researchers used zero-inflation distributions. They concluded that horizontal curves, vertical grade, traffic volume, and proportion of trucks were primary factors in ROR crashes. However, it was found additional research is needed to improve the ROR prediction models.

### Road Safety Audit

A roadway can also be analyzed using a road safety audit (RSA). An RSA is a formal safety evaluation of an existing road or intersection conducted by an independent team of highway engineers and traffic safety experts. The ideal team consists of a road safety specialist, a traffic operations engineer, a road design engineer, a local contact person, and additional experts depending on the size and complexity of the project.

Once an RSA team is formed, a formal meeting is conducted to set the context of the audit and review the project information. The RSA team must then conduct a field investigation. Two approaches are typical for the field review. For the first approach, each individual member of the RSA team independently conducts a review of the roadway and then come together as a team to review each identified issue. The second approach requires the RSA team to review the site as a group and note each issue the team encounters. After reviewing all issues, the RSA team finalizes the findings and develops possible solutions (FHWA 2006).

## RESEARCH OBJECTIVES

The primary objective of this research project was to demonstrate the effectiveness of the United States Road Assessment Program (usRAP) as a systemic safety tool for rural highways and paved secondary roads in Kansas. The goal was to determine if usRAP and its outputs beneficially help Kansas counties identify high-risk roadway segments without using historical crash data at each corridor. Secondary objectives included determining if usRAP was a viable tool to include in state and county level safety planning and seek feedback on the usRAP outputs by the local road engineer of the Kansas Association of Counties.

## EMPIRICAL SETTING

### Study Corridors

Three study corridors in Kansas were selected for evaluation in this study to represent three common roadways found in Kansas: a U.S. highway, a Kansas highway, and a rural secondary road. All three roads were two-lane undivided roadways outside of incorporated areas. The roadways were selected based on driving experience and visual investigation. Crash data were not used to identify roadways evaluated in this study

The first corridor selected was US-40 from Topeka to Lawrence. US-40 serves as a commuter route that has an annual average daily traffic (AADT) of 5,000 vehicles (KDOT n.d.). The study segment had a length of 19 miles and a posted speed limit of 60 mph. The research team conducted a speed study and found the average speed of vehicles was 61 mph with an 85$^{th}$ percentile speed of 64 mph. During the study, crash data from 2010 – 2014 were collected. There were a total of 236 crashes with one resulting in a fatality and six resulting in a disabling injury.

The second corridor selected was K-5 between Kansas City and Lansing. The corridor was unique because of several horizontal curves (left and right) and vertical curves (up and down) that produced multiple blind spots in both directions of travel. K-5 had an AADT of 2,500 vehicles with a posted speed limit of 55 mph. A speed study conducted by the research team found the average speed to be 51 mph with an $85^{th}$ percentile speed to be 57 mph. The study team hypothesized the average speed was lower because drivers on K-5 are aware of the constant changes in horizontal and vertical alignment. Crash data between 2010 and 2014 showed there was a total of 75 crashes with three resulting in a disabling injury crash.

The final corridor selected for this study was RS 20 and RS 25 between Lancaster and Effingham. At the intersection of RS 20 and RS 25, there is a horizontal curve that connects the two roads to bypass a four-way stop. RS 20 and RS 25 have an AADT of 750 and 850, respectively, and both roads have a posted speed limit of 55 mph. A speed study conducted by the research team found the average speed to be 57 mph with an $85^{th}$ percentile speed of 61 mph. To determine the number of crashes along the route, data were manually extracted from county crash records. From 2010 to 2014, there were a total of 35 crashes resulting in one disabling injury crash.

### usRAP Calibration

To achieve the most accurate results, a calibration using local data (crash costs/frequency and countermeasure costs) is required. In Kansas, the cost of a crash varies with the severity. A property damage only crash has an estimated cost of $3,200, while a fatal crash would have an estimated cost of $4,159,950. These values are used in estimating the benefit portion of the benefit-cost ratio.

To calibrate the crash frequency used by the software, crash information for U.S. highways in Kansas and Kansas highways was collected. For U.S. highways in Kansas, there were 21,305 crashes between 2010 and 2014 resulting in 264 fatal and 455 disabling injury crashes (KDOT 2014). Kansas highways had a total of 15,048 crashes between 2010 and 2014 resulting in 162 fatal and 353 disabling injury crashes (KDOT 2014). KDOT had limited crash data outside of incorporated areas. Therefore, for this study, default calibration parameters were used based on AADT, roadway type, and posted speed limit.

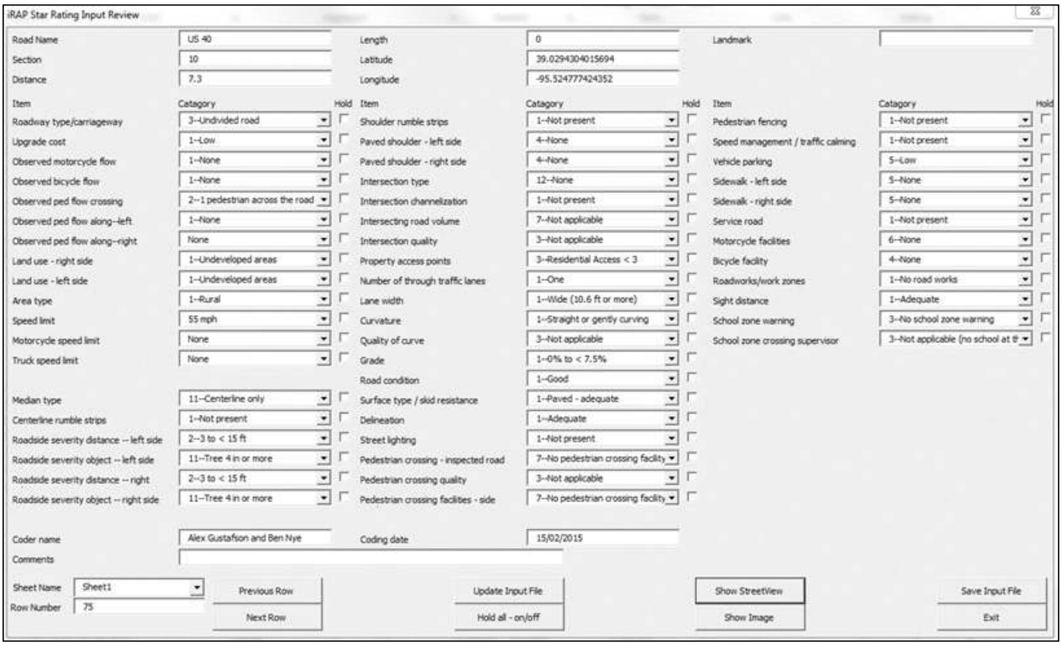
The usRAP software incorporates 192 built-in countermeasures for urban and rural environments. These countermeasures range from low cost to high cost, which may range from signs to large reconstruction projects, respectively. Each countermeasure has a low, medium, and high cost that can be adjusted prior to software coding. Of the 192 possible countermeasures, the research team selected 70 countermeasures that were applicable to Kansas rural environments. The research team then met with KDOT's Bureau of Local Projects to verify countermeasure costs. All countermeasure costs provided by KDOT were considered to be medium costs, and the low and high costs for each countermeasure were determined by a percentage decrease or increase, respectively.

## CODING METHODOLOGY

Prior to coding the three Kansas corridors, the research team participated in a two-day training administered by a private consulting firm. The private consulting firm team, consisting of experts in the development, testing, and implementation of usRAP and iRAP, presented a manual that explained each variable the research team was to code. The usRAP software relies on a visual inspection of the roadway and judgment by the research team, so examples presented by the private consulting firm team ranged from open space to dense vegetation. Based on previous studies, a coding time of 30 minutes per one mile was estimated for this project.

The coding environment for the usRAP software involved using two monitors displaying the coding screen and a view from Google Street View, as shown in Figure 1. The research team coded each variable based on a 100m segment of the roadway. For each variable, there was a drop-

**Figure 1: Example Display of Monitors During Coding Process**




down menu with options to best describe the roadway characteristics. For example, roadside object severity could range from a cliff or tree in the most severe case, to no object within range of a driver that has left the roadway. After all variables for a segment have been coded, the variables can be carried through to the next segment. This allowed the research team to cut down on the total time spent on each segment. For consistency in coding the roadway, the direction of coding was in the direction of increasing milepost markers.

To assure the highest quality results, three stages of quality assurance/quality control (QA/QC) were completed. The first stage took place during the initial coding of the variables. The research team worked in groups of two to discuss which variables would be the most appropriate for the given segment. After completion of a roadway, the code was sent to the principle investigator (PI) to verify the coded variables for half-mile intervals. If a disagreement was found between coded variables, the PI would adjust the segment and surrounding segments to better match the roadway segment's characteristics. Finally, the coded variables were sent to a private consulting firm to ensure each segment was coded accurately before data were uploaded to the usRAP website for analysis.

## RESULTS OF SELECTED KANSAS CORRIDORS

### usRAP

Using the coded data and operational characteristics for each corridor, the usRAP program determines a road protection score for each segment of the roadway using built-in modeling algorithms. The road protection score is based on coded variables having a known impact or relationship with crash occurrence and the probability a segment would have high risk of a serious injury or fatal crash. Determination of risk is translated into a star ranking (AAA 2012 and Knapp et al. 2014). The star ranking is a color coded and numerical ranking (1 to 5, with 1 being the highest risk) indicator of risk for a segment of roadway.

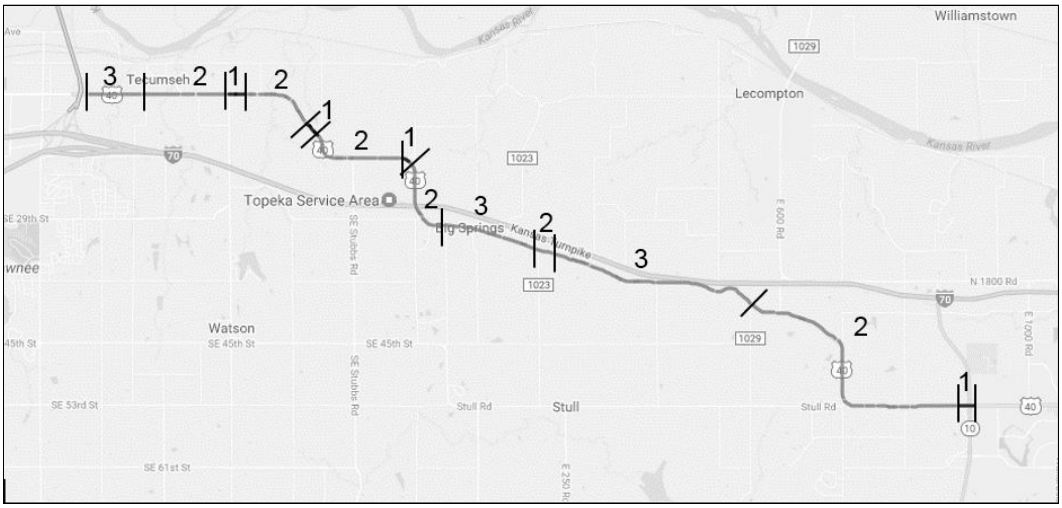
The usRAP program also generates a Safer Roads Investment Plan, which provides information on countermeasures previously selected that could be implemented to reduce the probability of there being a fatal or serious injury crash on a certain segment. The Safer Roads Investment Plan also provides a benefit cost ratio, location, and total length for each countermeasure selected, and a total benefit cost ratio if all countermeasures selected were implemented. Most countermeasures dictate which side of the road on which to implement the countermeasure using the terms driver side or passenger side. The driver side and passenger side are representative of the direction of coding of the roadway. For example, if the coding direction was east, the driver side would be on the north and passenger side would be on the south. For this study, the Safer Roads Investment Plan only showed countermeasures with a benefit cost ratio greater than 1.

### Star Rating and Safer Roads Investment Plan

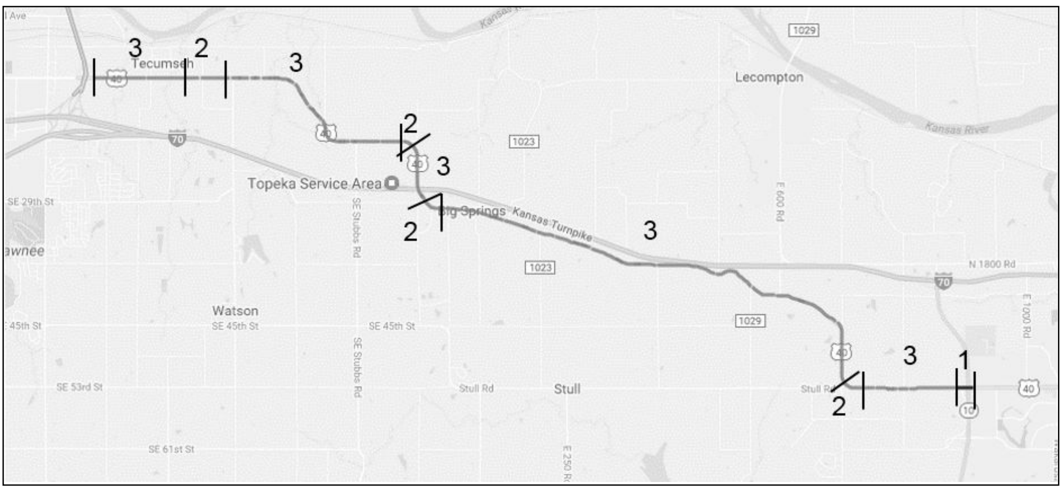
Figure 2 through 4 show the star ratings for the three corridors selected in this study. Each delineated segment shown has a number that corresponds with its star rating. The usRAP program generates a star rating map for vehicle occupants, motorcycles, bicycles, and pedestrians. However, the analysis showed minimum change in those areas. The usRAP website overlays the results on top of Google Maps, allowing users to zoom in to specific roadway segments and view attributes and nearby physical features.

Figures 2a and 2b show the star rating before and after countermeasure implementation, respectively, of US-40. As shown in Figure 2a, approximately 67% (19.4km) of the corridor was considered 2 stars or lower. Lower star ratings (labeled with the number 1) occurred around horizontal curves and on segments of roadways containing differing roadway geometry and entrances to businesses.

**Figure 2: Before and After Star-Rating for US-40**



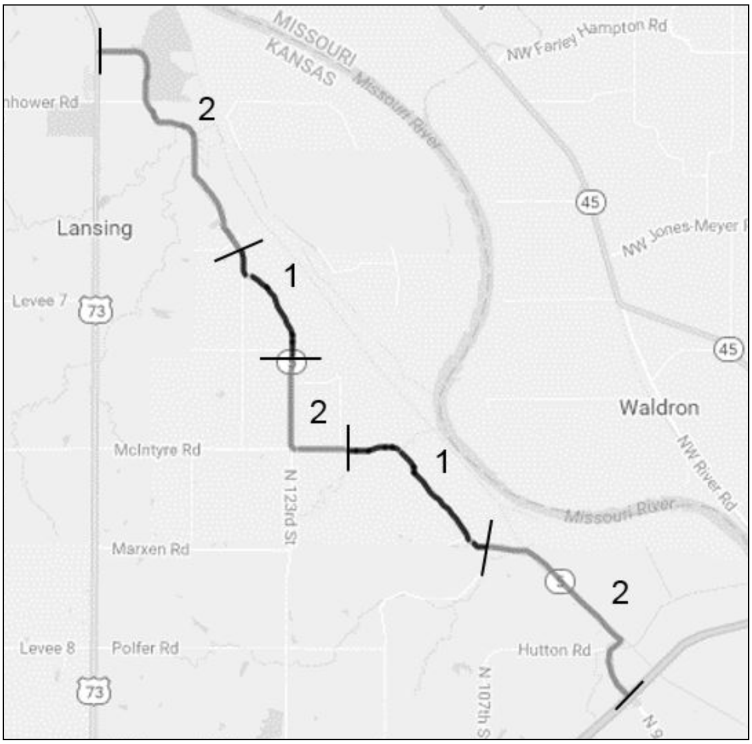

a) Before Countermeasures



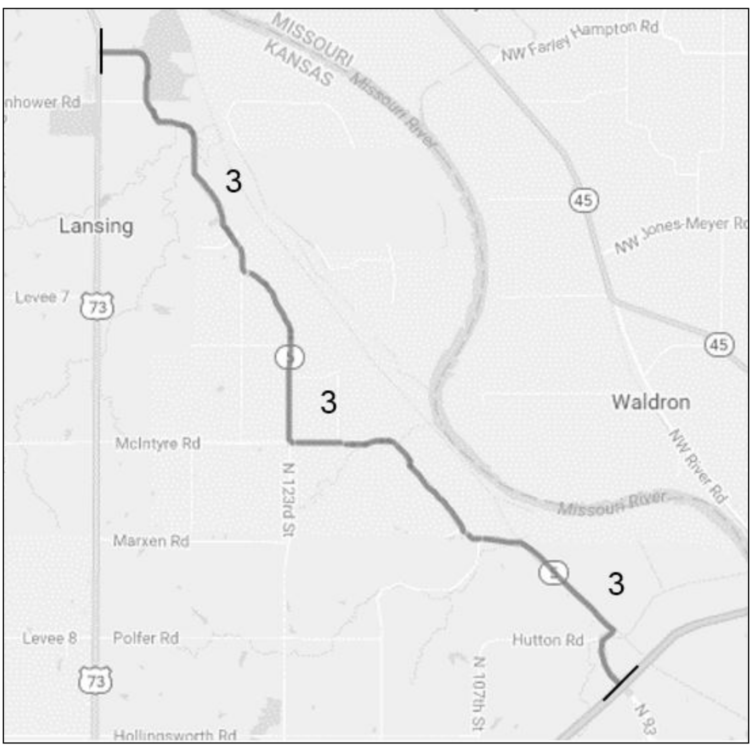

b) After Countermeasures

To increase the star rating and reduce the number of fatal and serious crashes on the corridor, the usRAP Safer Roads Investment Plan suggested 10 different countermeasures. Each countermeasure suggested shows the number of suggested sites (represented by length), total number of fatal or serious injury (FSI) crashes saved (over a 20-year period), benefit, estimated cost, cost per FSI crash saved, and total benefit cost ratio. For example, the countermeasure with the highest benefit cost ratio was to clear roadside hazards on the passenger side. The usRAP program estimated there was 13.60km (136 100-meter segments as shown in Figure 5) where implementation of the countermeasure would prevent five FSI crashes over a 20-year period. Figure 2b shows the star rating of US-40 if all countermeasures suggested by Safer Roads Investment Plan were implemented. After countermeasure implementation, approximately 12% (3.2km) of the corridor was considered 2 stars or lower. The usRAP program estimated the total cost to implement all suggested countermeasures to be $870,987; however, the total estimated benefit was $3,747,370 and a total benefit cost ratio of approximately 4.

**Figure 3: Before and After Star-Rating for K-5**

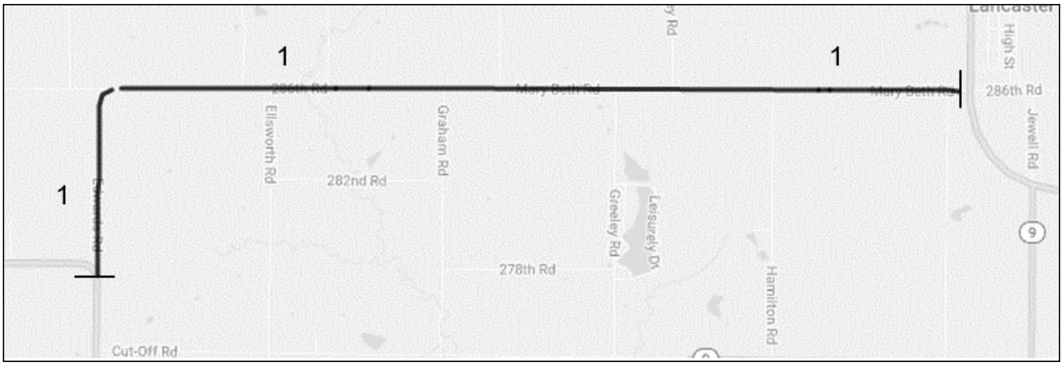



a) Before Countermeasures

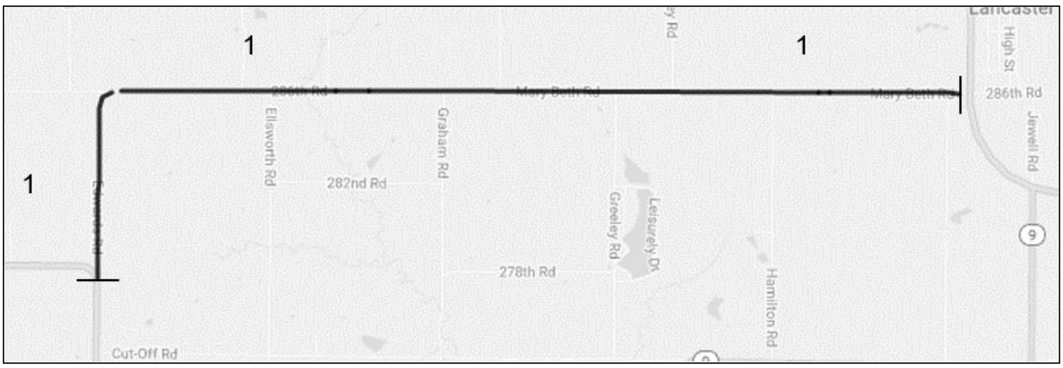



b) After Countermeasures

**Figure 4: Before and After Star Rating for RS 20 and RS 25**




a) Before Countermeasures




b) After Countermeasures

Figures 3a and 3b show the star rating before and after counter implementation, respectively, of K-5. As shown in Figure 3a, 100% (16.2km) of the corridor was considered 2 stars or lower (2 being second highest risk). A 1-star rating (1 on figures) represented areas with combined horizontal and vertical curves that produced areas with limited sight distance.

The Safer Roads Investment Plan for K-5 suggested 13 different countermeasures to reduce the total number of FSI crashes. The countermeasure with the highest benefit cost ratio was to improve roadway markings (delineation) on two curves. The usRAP software estimated the total cost to improve the delineation to be $6,046 but have a benefit of $76,040, resulting in a benefit cost ratio of approximately 13. One of the curves suggested for improved curve delineation had a slight vertical curve reducing sight distance as shown in Figure 6. Figure 3b shows the star rating of K-5 if all countermeasures suggested were implemented. If all countermeasures are implemented, 100% of the roadway would have a 3-star ranking and an estimated 11 FSI crashes would be prevented over a 20-year period. The implementation of all countermeasures would cost an estimated $1,182,692, but would have a total estimated benefit of $3,449,729 and have a benefit cost ratio of 3.

Figures 4a and 4b show the star rating before and after countermeasure implementation, respectively, of RS 20 and 25. As shown in Figure 4a, 100% (9.8km) of the corridor was considered to be 1-star. RS 20 and 25 is a rural secondary road with no delineation on the roadway and little to no shoulder before the drop off into the ditch along the roadway.

The Safer Roads Investment Plan for RS 20 and 25 suggested five different countermeasures. The countermeasure with the highest benefit cost ratio was improved curve delineation at the intersection of RS 20 and 25. However, on both RS 20 and 25, there were several large culverts

**Figure 5: Recommended Locations of "Clearing Roadside Hazard – Passenger Side" for US-40**

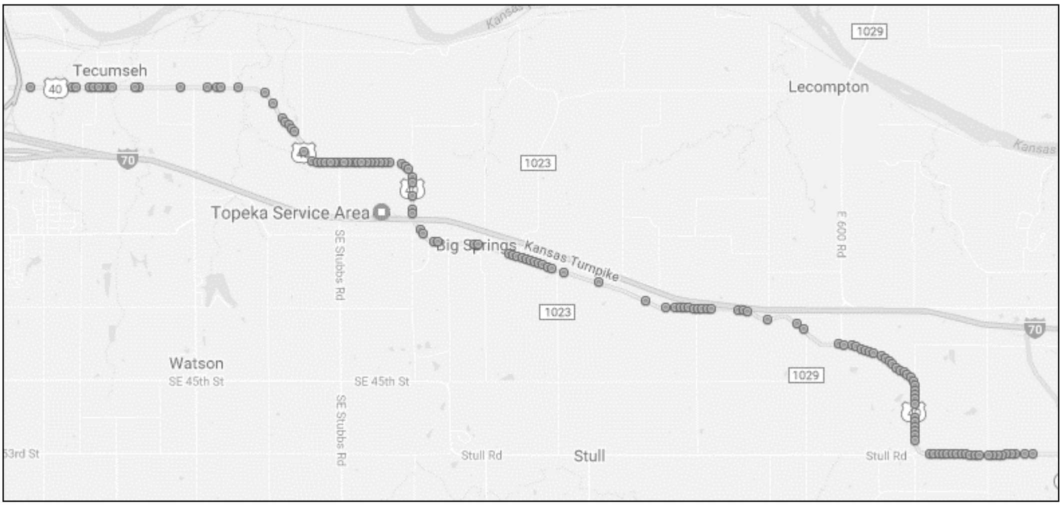
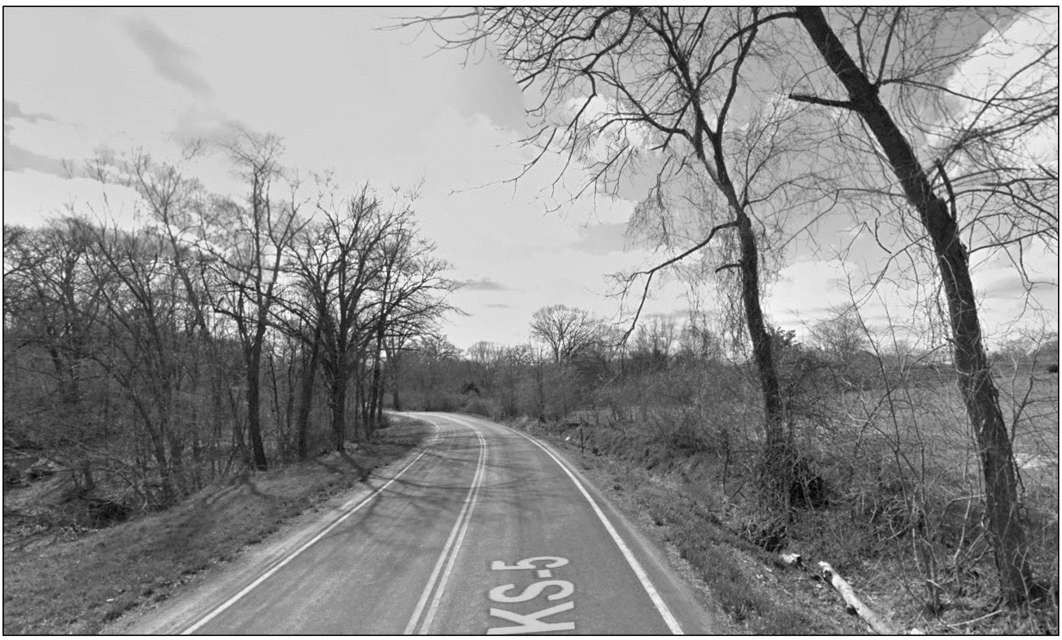



**Figure 6: Google Street View of the Curve Selected for Improved Delineation**




(greater than 10-feet tall) that did not have a barrier and had a drop-off less than three feet from the edge of the roadway. The usRAP's Safer Roads Investment Plan suggested implementing a roadside barrier on both sides of that roadway at the culverts. The roadside barriers would prevent an estimated two FSI crashes over a 20-year period. Figure 4b shows the star rating of RS 20 and 25. After implementation of all suggested countermeasures, 100% of the roadway remains a 1-star rating. However, the star rating for this particular roadway can be misleading. If all countermeasures were implemented, a total of three FSI crashes could be prevented with a total benefit cost ratio of 2. The star rating map suggests the roadway would need to be completely upgraded to the standards of a two-lane highway or higher to enhance the star ratings.

The usRAP results for RS 20 and 25 were validated by comparing the results to a road safety audit (RSA) conducted by KDOT on May 12, 2014. The RSA and usRAP software identified areas, including the need for improved curve delineation and a roadside barrier. However, the usRAP program was not able to identify specific areas found during the RSA. For example, a failed wing wall section on a box culvert was not identified. There are two significant factors for not identifying specific areas. The usRAP program is designed to identify potentially high-risk areas based on characteristics of the roadway such as geometry, markings, and roadside hazards such as fixed objects. The other factor is the limited field of view by Google's Street View camera and its field of vision.

## DISCUSSION

Understanding the safety risks of rural highways and paved secondary roadways is critical in Kansas because a significant percentage of roadways are rural centerline miles. However, allocation of funding for roadway improvements and determination of locations in need of improvements can be difficult due to limited data, limited expertise, and sometimes-unknown areas that pose a significant risk to drivers. A systematic tool that utilizes limited information (specifically historical crashes) to identify high risk areas can greatly benefit a local jurisdiction or the State of Kansas if even one life is saved or one serious injury is prevented.

The research team selected three corridors to test the usRAP software: A U.S. highway, a Kansas highway, and a paved rural secondary road. US-40 between Topeka and Lawrence, K-5 from Kansas City and Lansing, and RS 20 and 25 between Lancaster and Effingham, were selected based on previous driving experience and visual inspection from the research team. The amount of available data (crash or otherwise) were not used in the selection of the three corridors.

The usRAP program is a free software program that requires extensive data entry based on Google Street View or manual data collection for 100m intervals. Corridor baseline data are needed for system calibration (type of highway or roadway), including AADT, posted and 85$^{th}$ percentile speed, system-wide centerline miles for each roadway type, system-wide historical crash analysis for types of transportation modes, and typical countermeasure costs. A significant advantage of the usRAP program is that the program does not require historical crash data for the road segment or corridor of interest. The usRAP software analysis is based on roadway characteristics directly related to crashes.

The usRAP software outputs provide valuable information that can be easily interpreted for most levels of roadway design and/or supervision. Outputs include a star rating for each corridor every 100m and a Safer Roads Investment Plan for each corridor. The usRAP software is not designed to replace a required engineering study before implementation of any major roadway countermeasure or geometric change. Rather, the usRAP software output identifies potentially risky areas of a corridor to help guide a transportation study.

The star ratings developed for the three corridors provide a visualization of potential risky areas for each corridor. Each of the three corridors selected had 3-star or lower segments for the entirety of the corridor because the roads were not interstates or divided highways. The three corridors also exhibited vast differences in horizontal and vertical alignments, in which these corridors were narrow with fixed objects near the roadways. This led to different star ratings for the three roadways.

The Safer Roads Investment Plan shows different countermeasures that can be implemented along with the estimated cost, the estimated benefit, the benefit-cost ratio, and an estimate of the number of fatal or serious crashes prevented over a 20-year period for each countermeasure. The usRAP software benefits counties with limited resources to invest in a countermeasure because it narrows down the location of countermeasure implementation and reduces the time, money, and initial investigations required for engineering studies.

Finally, the usRAP software predicted a star rating for each corridor if all countermeasures above a benefit-cost ratio of 1 were implemented. Although substantial improvements were predicted for US-40 and K-5, RS 20 and RS 25 were predicted to remain constant because substantial reconstruction was needed to upgrade the safety of the corridor. However, upgrading certain areas on the corridor may not bring the segment to a 2-star or higher rating, it could save a life or prevent a serious injury.

**References**

American Automobile Association (AAA) Foundation for Traffic Safety. *Guide to Using usRAP Star Ratings and Safer Roads Investment Plans.* Washington, D.C.: Federal Highway Administration, 2012.

Federal Highway Administration. *FHWA Road Safety Audit Guidelines.* Washington, D.C.: Federal Highway Administration, 2006.

Federal Highway Administration. *GIS-Based Crash Referencing and Analysis System.* McLean, VA: Turner-Fairbanks Highway Research Center, 1999.

Gao, H., W. Kan, C. Li, and C. Pang. "Run-Off-Road Accident Prediction Model for Two-Lane Highway." *Journal of Highway and Transportation Research and Development* 3(1), (2008): 110-115.

Harwood, D.W., D.J. Torbic, K.R. Richard, and M.M. Meyer. *Safety Analysis: Software Tools for Safety Management of Specific Highway Sites.* Washington, D.C.: Federal Highway Administration, 2010a.

Harwood, D.W., D.K. Gilmore, K.M. Bauer, R.R. Souleyrette, and Z.N. Hans. *U.S. Road Assessment Program (usRAP) Pilot Program – Phase III.* Washington, D.C.: American Automobile Association Foundation for Traffic Safety, 2010b.

Kansas Department of Transportation (KDOT). *Kansas Traffic Accident Facts Book.* Topeka, KS: Kansas Department of Transportation, 2014.

Kansas Department of Transportation (KDOT). *District Traffic Count Maps,* n.d. Accessed November 2, 2015 ksdot.org/burtransplan/maps/MapsTrafficDist.asp.

Knapp, K.K., S. Hallmark, and G. Bou-Saab. *Systemic Safety Improvement Risk Factor Evaluation and Countermeasure Summary* (Report No. WBS: 25-1121-0003-140). Lincoln, NE: Mid-America Transportation Center, 2014.

National Highway Traffic Safety Administration (NHTSA). *Traffic Safety Facts: 2012 Data Rural/Urban Comparison.* Washington, D.C.: United States Department of Transportation, 2014.

Tan, C.H. *Highway Safety Information System (HSIS): The Essential Information System for Making Informed Decision about Highway Safety.* Washington, D.C.: Federal Highway Administration, 2011.

United States Census. *2010 United States Census. Population, Housing Units, Area, and Density: 2010 – State – Place and (in Selected States) County and Subdivision, 2010.*

***Benjamin Nye*** *is a graduate research assistant in the department of civil engineering where he is pursuing a master of science degree in civil engineering. He received his bachelor's degree in civil engineering in 2016. His research interests are highway safety and capacity, railroad engineering, and roadway geometrics.*

***Eric Fitzsimmons****' research interests include highway safety and operations in both rural and urban environments. His research has been funded by state departments of transportation, the Federal Highway Administration, NCHRP, and university transportation centers. Some research examples he has conducted or are in progress include development and analysis of vehicle trajectory along horizontal curves, wrong-way driving crashes, usRAP demonstration in Kansas, traffic calming applications, micro-simulation of access management, automated enforcement, work zone applications including temporary traffic signals and transportation management plan (TMP) strategies, vehicle data collection, big data applications in highway operations, railroad engineering, and engineering education.*

*Dr. Fitzsimmons has authored and/or co-authored 15 journal papers, 26 research reports, and over 30 conference manuscripts, and holds one patent pending of a self-deicing traffic signal he co-invented with two of his colleagues at the University of Kansas. He is highly active in professional activities and is an associate member of American Society of Civil Engineers, a member of the Institute of Transportation Engineers, and a member of the American Society of Engineering Education. Fitzsimmons currently serves as a member of multiple Transportation Research Board standing committees including: Operational Effects of Geometrics (AHB65), Access Management (AHB70), and Traffic Law Enforcement (ANB40).*

***Sunanda Dissanayake*** *is a professor and graduate program director of civil engineering at Kansas State University (KSU), specializing in the area of transportation engineering. She obtained her bachelor's degree in civil engineering from the University of Moratuwa, Sri Lanka; a master's degree in transportation engineering from the Asian Institute of Technology, Thailand; and a doctorate degree in civil engineering from the University of South Florida. Her research focuses on studies related to solving applied and practical problems related to transportation engineering, with particular emphasis on traffic operations and safety of the highway mode. She has been a Fulbright scholar and was recently appointed as a high-end foreign expert in traffic safety and as a member of the First Advisory Board for Joint International Research Lab of Transportation Safety at Tongji University in Shanghai, China.*

*She has authored and co-authored more than 40 journal papers and presented more than 135 papers at national, international, and regional conferences, most of which are proceedings papers. She is highly active in several professional societies, a member of two journal editorial boards, a member of two TRB technical committees, and the chair of the Transportation Safety Committee of ASCE/T&DI. She has won the Outstanding University and Professional Service Award, Advisor of the Year Award, Outstanding Teacher Award, and Outstanding Researcher Award at KSU civil engineering department several times. She has successfully completed numerous externally funded research projects in the area of transportation engineering and teaches courses related to those topics at KSU, preparing the future generation of civil engineers ready for the real world.*

# Impacts of Mobility Management and Human Service Transportation Coordination Efforts and End-User Quality of Life

**by Jeremy Mattson, James Miller, Jay Goodwill, P.S. Sriraj, and Jill Hough**

*This study developed an evaluation method to examine the effectiveness of mobility management and coordination programs in a community. A series of surveys were conducted of both transit users and stakeholders in communities across the country. Results from these surveys suggest improvements have occurred in efficiencies, ease of access, and quality of service. Most respondents to the stakeholder survey reported benefits that have been realized. Results from an ordered probit model demonstrate the positive impacts that improved mobility has on life satisfaction.*

## INTRODUCTION

The Federal Transit Administration (FTA) has been engaged, as part of its livability goals, in helping people with disabilities, older adults, low-income individuals, and other transportation-disadvantaged populations to be active and engaged in their communities by having access to the mobility options that make it possible to connect to employment, community services, and activities. To pursue this objective of community connectivity through mobility, the Secretary of Transportation chairs a Federal Interagency Council on Access and Mobility (CCAM) that strives to coordinate federal programs funding transportation to improve community mobility options. The FTA and its council partners have worked to build a transportation coordination infrastructure that includes establishing coordinated transportation planning processes, mobility management coordination practices, one call/one click transportation management centers, and state leadership activities, including the development of state and regional transportation coordinating councils.

However, a 2011 Government Accountability Office (GAO) (2011) report suggests duplication still exists and many improvements could be made to the coordination efforts. The GAO did recognize that improvements had occurred, specifically at the state and local levels, but suggested Congress may want to consider requiring federal funding programs to participate in coordinated planning. A 2012 GAO report further analyzed the issue by examining federal programs that may fund transportation services for the transportation-disadvantaged (including 80 federal programs), federal coordination efforts undertaken since 2003, and coordination at the state and local levels.

These and other studies have conducted interviews of federal, state, and local officials (GAO 2012, National Conference of State Legislators 2010), but less research is available regarding the impacts of these programs on end-users. The effectiveness of these programs can ultimately be evaluated based on the economic and quality of life impacts they have on their users. Mobility management and coordination efforts need to be evaluated further to determine their impacts on users and their impacts on improving quality of service, ease of access, and efficiency.

This study developed an evaluation method that can be used in communities across the country to examine the effectiveness of their programs. Results examine the impacts of services on meeting the needs of transportation-disadvantaged populations, the impacts of improved mobility on quality of life, and the impacts of mobility management and coordination efforts on meeting the goals of quality of service, ease of access, and efficiency. The evaluation method developed for the study consisted of a series of surveys of both transit users and stakeholders in communities across the country.

## BACKGROUND

Human service transportation has evolved over the past several years to focus more on meeting customer needs. While the focus has evolved, non-traditional measures of performance also need to be adopted to properly evaluate how well these programs are meeting their goals.

### Evolution of Human Service Transportation Coordination and Mobility Management

In the past 40 years, many public sector and non-profit organizations have been created to respond to specific human service needs of children, low-income individuals, older adults, and people with disabilities. Early on, these organizations realized that lack of transportation prevented potential customers from accessing the agency's services. In response, many human service agencies set up their own transportation services to directly provide rides for their clients. This fragmented response to mobility needs led to a proliferation of providers and often resulted in duplicative, inefficient services. Further, agency efforts to operate a transportation system diverted attention from the agency's primary purpose. By the late 1970s, primarily due to local initiative, these fragmented systems combined to offer region-wide transportation to the clients of many agencies and in some cases, especially in rural areas, to the public.

These early efforts to coordinate human service transportation focused on the supply or provider side of the enterprise with the goal of creating cost-effective organizations that could provide more rides and a lower per-unit cost. More recently, especially in the past 10 years, the vision for coordinated transportation has been expanded to one of mobility management that focuses on customers and meeting their needs, and using the assets of a number of organizations, rather than on the production of transportation services.

Nearly all of the earliest examples of coordinated transportation systems resulted from local initiatives. One of the key ingredients to the success of these efforts of the 1970s and 1980s was the leadership of a particular individual who believed in the value of coordination and worked to make it a reality (TranSystems Corporation 2004). Along with the local champion, access to funding for planning, startup, and operations was a key to continued development of coordinated systems.

Federal interagency efforts to encourage coordination date from the mid-1980s and are chronicled and evaluated in a series of reports produced by the GAO, then known as the General Accounting Office, (1999, 2003). A significant change and boost to coordination efforts occurred in 2004 with the signing of Executive Order 13330 (2004) that established the CCAM chaired by the secretary of transportation.

One of the first actions of the CCAM was to establish the United We Ride interagency initiative aimed at improving the availability, quality, and efficient delivery of services for older adults, people with disabilities, and low-income individuals (United We Ride 2014). This FTA-funded activity provided a range of resources to assist state and local officials to enhance coordination efforts, and it provided technical assistance and training. United We Ride adopted a mobility management vision as an expanded view of coordination that emphasized service quality and advocacy for access. They explained this vision with a definition for mobility management: "Mobility management focuses on meeting individual customer needs through a wide range of transportation options and service providers. It also focuses on coordinating these services and providers in order to achieve a more efficient service delivery." (United We Ride 2007a) In addition to this vision, which is similar in scope to earlier coordination efforts, the new vision of mobility management proposes that mobility managers serve as policy coordinators, operations service brokers, and customer travel navigators. The policy coordination role is one of the key differences between previous coordination efforts and mobility management in that the mobility manager now helps communities develop coordination plans, programs, policies, and local partnerships.

A 2011 report by the GAO recognized that improvements had occurred, specifically at the state and local levels, but duplication still existed and many improvements could be made to the coordination efforts. In a later report, the GAO (2012) found an apparent lack of activity at the leadership level of the CCAM. The failure of non-FTA programs to encourage coordination was one of the major shortcomings of federal leadership reported by state and local officials interviewed as part of the GAO's performance audit. Other obstacles to coordination reported by the interviewed officials were changes in state legislation and policies, limited financial resources, and growing unmet needs. Nevertheless, the report catalogued six coordination activities underway at the state and local level: state coordinating councils, regional and local planning processes, one-call centers, mobility managers, vehicle sharing, and outreach and communication activities.

Since the 2004 executive order, a major focus of both the CCAM and the United We Ride program has been to encourage and facilitate state and local coordination efforts. This focus was in part due to a lack of success in coordinating the many federal programs and agencies with a stake in human service transportation, but perhaps more significantly, a recognition that local leadership and energy are required to achieve coordinated systems. Such leadership can best be encouraged by state and regional planning, policy, and funding efforts.

Some states, such as Florida, have for many years (since 1989) had state-level coordinating bodies that were created legislatively or by regulation to promote coordination or to directly control the distribution of state-managed program funds in a coordinated manner. Within the past decade, many other states have taken steps to foster coordinated human service transportation. A report prepared by the National Conference of State Legislatures (NCSL) (2010) documented the progress in building the state-level infrastructure to support coordination and mobility management efforts.

**Evaluation Techniques**

The most common form of evaluation of coordination programs has been a qualitative judgment on whether federal and state agencies met targets or completed tasks that they agreed to accomplish. The evaluations focused on process and on delivery of products such as technical assistance, training, policy clarifications, etc. The implied assumption was that completion of these tasks would result in increased coordination and the related service and efficiency benefits.

Within the past few years, two changes are evident from the review of the literature. First, the strategic and annual plans of CCAM and related programs such as United We Ride explicitly contain performance measures to assist in the evaluation of program successes. Recent research and reports have examined the use of performance measures (Sen et al. 2011, Burkhardt and Yum 2010, United We Ride 2007b). Second, as an integral part of the mobility management philosophy, evaluation of the success of the federal and state programs has taken on a customer focus in addition to continued concern for the performance of the federal and state initiatives.

Performance measurement is nothing new for public transit and human service transportation agencies. Funding agencies often require that certain performance metrics be reported. In addition, many providers have adopted evaluation criteria and measures as part of their internal strategic and business plans. Because of readily available financial and operating data, most measures focus on efficiency criteria. Effectiveness measures, such as customer satisfaction or measures of access to service, are more difficult to quantify than measures such as expense per vehicle hour or one-way passenger trips per hour, so they are not as readily reported. In TCRP Report 53, Cambridge Systematics, Inc. (1999) argued that while traditional measures remain important, it has become increasingly necessary to measure the success of transit investments in broader terms that reflect community goals and expectations. They further argued that measures should shift from those of efficiency and output to measures of impact and outcome.

Mobility management in practice is broader than traditional transit; therefore, conventional performance evaluation schemes need to be adapted to mobility management programs. Recognizing the need for a more robust evaluation framework, the FTA sponsored a study of the state of the art and practice to examine how existing U.S. mobility management programs incorporate performance evaluation. The report presented the results of surveys and case studies of state and local entities that received FTA or Texas DOT funding for mobility management activities (Sen et al. 2011). The study reported on key measures used by each case study system. These measures were found to vary significantly but were still primarily focused on measuring traditional transit service objectives.

Sen et al. (2011) found that most mobility management programs used traditional transit performance measures, such as rides or trips per revenue hour, total passengers, operating expense per passenger trip or per vehicle mile or hour, and on-time performance. Some organizations, primarily in urban areas, did report using unique performance measures considered critical to the success of their programs. However, these non-traditional measures often require data that may not be readily available and therefore require additional effort and expense to collect. Also, since the terminology used for some of these measures may be new, terms and methods of calculation need to be defined. Designing an evaluation framework that goes beyond traditional transit measures and captures the intended outcomes of a mobility management strategy is needed to determine if an agency's program actually works.

Previous reports have developed recommendations for measuring the performance of mobility management programs. Sen et al. (2011) presented a detailed framework suggesting seven program goals along with a series of objectives, possible performance measures, and outcomes. Equally important, the recommended framework also specifies how the outcome is measured, who does the measurement, and finally, the type of service environment (rural, small regional, metro) for which the measures might be appropriate. Burkhardt and Yum (2010) developed recommendations for measuring the performance of human service transportation programs at the national, state, and local levels, though the measures are focused more on inputs and processes than outcomes and impact measures.

A general design and evaluation of a coordinated transportation program was promoted as part of the United We Ride technical assistance effort (United We Ride 2007). This design is a customized version of a technique called the Logic Model and Measures, which provides a representation of the theory of change behind a program or initiative. Some of the key concepts are: a description of the situation, a discussion of the inputs and outputs of the process, and indicators that are initial markers of success, outcomes, and results.

Akoto (2016) explored the use of non-traditional performance indicators, as well as traditional measures, for evaluating rural transit operators whose goals are similar to those of mobility management programs. The results showed that the non-traditional mobility indicators communicated positive outcomes when the traditional measures did not, suggesting that these measures are needed in conjunction with the traditional indicators to better evaluate how well the agency is meeting its goals.

**Impacts of Mobility on Quality of Life**

The ultimate goal of mobility management is to improve end-user quality of life through enhanced mobility. A number of studies have evaluated the link between mobility and quality of life. For example, Banister and Bowling (2004) found that engaging in a large number of social activities was an important component of what constitutes quality of life for older adults; Delbosc (2012) proposed a model, based on a review of literature, that transportation influences life satisfaction indirectly by facilitating access to important activities and directly through physical mobility and externalities; Stanley et al. (2011) showed that trip making indirectly influences well-being by impacting the risk of social exclusion; Delbosc and Currie (2011) found that a combined effect of transportation disadvantage and social exclusion had a significant negative effect on well-being; and Spinney et al. (2009) found a significant association between transportation mobility benefits and quality of life in a study of elderly Canadians. This study contributes to the literature by providing further evidence on the impacts of mobility measures on life satisfaction

## METHODS

This study builds upon previous research by developing and testing an evaluation method using non-traditional measures that can be used by communities to examine the effectiveness of their mobility management and coordination programs. The evaluation method developed consisted of two survey instruments that were administered at locations across the country. The first was a mail survey of riders, and the second was an online survey of stakeholders. Participating stakeholders included transportation providers, human service agencies, and other interested organizations. Results from the rider survey were used to examine the relationship between mobility and life satisfaction.

### End-User and Stakeholder Surveys

The intent of the transit user survey was to evaluate the impacts that transit services have on the lives of users and to assess the importance and effectiveness of mobility management and coordination programs. The goal of the stakeholder survey was to learn more about the types of mobility management and coordination activities being conducted, barriers and challenges that exist, successes that have been achieved, and the degree to which the needs of users are being met. The development of the stakeholder survey built upon previous surveys conducted by Sen et al. (2011) and the Virginia Department of Rail and Public Transportation (2005). By evaluating results from both surveys, the goal was to assess the impacts of mobility management and coordination activities on quality of service, ease of access, trip creation, efficiency, and quality of life impacts on users.

The surveys were developed so they would not be specific to any community and could be used over time to assess progress. Therefore, the survey instruments provide an evaluation model that could be applied to other communities across the country and could be repeated over time. The complete survey instrument is provided by Mattson et al. (2014).

Agencies were identified as potential participants if they were actively engaged in mobility management or transportation coordination activities. Potential participants were sent invitations to participate in both the end-user and stakeholder surveys. The intent was for each participating community to conduct both of these surveys. The end-user survey would be conducted of riders for one of the transportation providers in the community, and the stakeholder survey would be completed by the participating transportation provider as well as other transportation providers, human services agencies, and interested stakeholders within that community. Some of the agencies that were contacted, however, were only interested in participating in the stakeholder survey.

Responses were received from a number of different locations across the country, including a mix of urban, suburban, and rural. End-user surveys were completed by riders from six different transportation providers from five different communities and five FTA regions, and stakeholder surveys were obtained from each of the 10 FTA regions (Table 1).

**Table 1: Participating Agencies**

| FTA Region | Participating Agency | Location | Rider Survey: Responses | Rider Survey: Response Rate | Stakeholder Survey Responses |
|---|---|---|---|---|---|
| 1 | Way to Go CT | North Central Connecticut | -[a] | -[a] | 7 |
| | Eastern CT Transportation Consortium, Inc. | Eastern Connecticut | -[a] | -[a] | 1 |
| 2 | Tompkins County Dept. of Social Services | Tompkins County, NY | -[a] | -[a] | 2 |
| 3 | JAUNT, Inc. | Charlottesville, VA | 19 | 19% | 11 |
| 4 | St. Johns County COA | St. Johns County, FL | 32 | 24% | 4 |
| 5 | Dane County Dept. of Human Services | Dane County, WI | -[a] | -[a] | 4 |
| 6 | Harris County RIDES | Harris County, TX | -[a] | -[a] | 13 |
| 7 | Neighborhood Transportation Service (NTS) | Cedar Rapids, IA | 42 | 21% | 21 |
| | Linn County LIFTS | | 75 | 30% | |
| | Heart of Iowa Regional Transit Agency (HIRTA) | Central Iowa | -[a] | -[a] | 39 |
| 8 | Seniors' Resource Center (SRC) | Denver, CO | 232 | 31% | 3 |
| 9 | Valley Metro | Phoenix, AZ | 101 | 13% | 1 |
| 10 | Community Transportation Association of Idaho (CTAI) | Idaho | -[a] | -[a] | 4 |
| | Ride Connection | Portland, OR | -[a] | -[a] | 1 |
| | **Total** | | **501** | **23%** | **111** |

[a]Did not participate in rider survey.

Rider surveys were administered by mail to a random sample of riders (with the exception of JAUNT, which had their drivers hand out surveys to riders), and surveys were conducted from May-September 2013. A total of 2,181 surveys were distributed, and 501 responses were received.

Stakeholder surveys were administered online. A link to the survey was sent to individuals from each of the participating agencies. The intent was to receive a variety of responses from different organizations in each community. Therefore, each recipient was asked to complete the survey and also pass it on to organizations they partner with or other interested stakeholders within the area, or they were asked to provide names of other organizations and individuals in the area to whom the survey could be sent. A total of 111 responses were received. The greatest concentration of responses was received from participating agencies in Iowa, but responses were received from each of the 10 FTA regions.

Of the respondents to the rider survey, 72% were female; 44% were aged 75 or older, and nearly two-thirds were 65 or older; 40% had a valid driver's license while just less than one-fourth had access to a vehicle; 70% had a medical condition or disability that made it difficult to travel; and 72% had household income of less than $20,000. These results suggest many of the respondents have limited transportation options. Nearly all respondents answered that the service is important to them, including 90% who said it is very important.

The respondents included a mix of frequent (15% use the service five or more days per week) and infrequent (10% use it less than once a month) users. About one-third of respondents had been using the service for more than five years, and more than half had been using it for at least three years, while 10% just began using the service within the previous six months

Representatives from a number of different types of organizations completed the stakeholder survey. Approximately one-third of respondents identified themselves as belonging to a multi-purpose human service agency, 15% were from a public transit agency, and the remainder were from a variety of different types of human service organizations serving a number of different populations.

Half of the stakeholders were from organizations that directly provide transportation services to their clients. Among these, about two-thirds identified themselves as specialized transportation providers that receive FTA Section 5310, 5316, or 5317 funding. The remainder included both urban and rural transit agencies and lead agencies for regional service coordination. These transportation providers most commonly provide a door-to-door or curb-to-curb demand-response service, but some also provide fixed-route service or other services.

### Impacts of Mobility on Quality of Life

Results from the rider survey were used to examine the relationship between mobility and life satisfaction. It is expected that life satisfaction could be influenced by a number of factors, including age, disability, health status, and income, as well as mobility. Data for all of these variables, as well as life satisfaction and different measures of mobility, were collected in the rider survey. Using these data, an ordered probit model was developed that estimated life satisfaction as a function of age, disability, health status, income, and two measures of mobility. Responses from 344 survey respondents were used to estimate the model.

The rider survey collected information on life satisfaction by asking the following question: "All things considered, how satisfied are you with your life as a whole these days? Use a 1 to 10 scale, where 1 is completely dissatisfied and 10 is completely satisfied." This question has been used in previous surveys as a measure of life satisfaction (Kahneman and Krueger 2006).

An ordered probit model was used because the dependent variable was measured using a scale where there is a natural order to the choice categories. Ordered probit and logit models are commonly used when the dependent variable is a ranking. The explanatory variables were also measured using a scale or with a dummy variable. Age was measured with a 1-6 scale (where 1=18-24, 2=25-34, 3=35-49, 4=50-64, 5=65-74, and 6=75 or older), disability was measured using a dummy variable equal to 1 if the individual reported having a disability or medical condition that made it difficult to travel and 0 if not, health status was measured with a 1-3 scale (where 1=poor, 2=fair, and 3=good), and income was measured with a 1-5 scale (where 1=less than $20,000, 2=$20,000-$39,999, 3=$40,000-$59,999, 4=$60,000-$79,999, and 5=$80,000 or more). It is expected that increases in income and improvements in health status will have positive effects on life satisfaction, while it is hypothesized that those with disabilities will have lower life satisfaction. The expected effect of age on life satisfaction was uncertain.

Finally, mobility was measured using two variables. The first was a dummy variable equal to 1 if the respondent had missed a trip during the previous week because of lack of transportation and 0 otherwise. The second was the response regarding how difficult it is to travel to the places they want or need to go to, considering all forms of transportation available. The variable was measured with a 1-6 scale, where 1=very easy and 6=very difficult.

## MOBILITY MANAGEMENT AND COORDINATION ACTIVITIES AND CHALLENGES

Close to 80% of the stakeholders surveyed indicated they have been involved with efforts to coordinate transportation services in their service area, and most have been taking an active role in coordination. Seventy-five percent of organizations involved with coordination said that high unmet transportation needs contributed to the initiation of coordination efforts, while a number cited interest from local leaders and potential financial opportunities. Other factors cited by respondents included state or federal mandates and desires to reduce duplication of services and improve current services.

As part of their coordination efforts, these agencies most commonly attend communication coordination meetings that specifically deal in part with transportation. Many provide services to human service agencies by contract, transport clients of other agencies, share or have compatible transportation software, or engage in a number of different activities.

Lack of funding was the most common barrier these organizations faced when initiating these transportation coordination efforts. Other common barriers included lack of communication, fear of responsibility shifting, and lack of time. Comments from respondents also mentioned turf issues and other barriers. Most respondents indicated there is a need for more coordination of transportation in their region, and the greatest barriers hindering more coordination include the unique needs of various client populations, conflicts in hours of needed service, and lack of communication across agencies. These barriers are similar to those identified in previous research (Burkhardt et al. 2003, Burkhardt et al. 2004, GAO 2012). Respondents often commented that working through these barriers required attention to communication efforts, education, bringing together stakeholders, building relationships, and continually searching for funding.

Twenty-nine percent of the responding agencies receive funds specifically for mobility management, and an additional 23% provide services they consider to be mobility management, while 13% currently do not provide mobility management but would like to in the future. The agencies involved with mobility management most commonly participate in outreach regarding public transit access, provide agencies and individuals with information and training materials on how to use local transportation, conduct needs assessments, or employ agency staff to plan and manage activities to improve coordination among public transportation providers, other transportation service providers, and agencies that serve people who need transportation services. Challenges identified with implementing these programs were lack of funding, limited time and resources, turf issues, and lack of leadership.

## IMPACTS ON MEETING THE NEEDS OF THE TRANSPORTATION-DISADVANTAGED AND ACHIEVING GOALS

Results from the rider and stakeholder surveys were used to evaluate the impacts of mobility management and coordination programs on meeting the needs of the transportation-disadvantaged and achieving the goals of improved quality of service, ease of access, and efficiency. As noted by Majumdar et al. (2013), the evaluation of these programs is difficult due to a lack of national guidelines, and little research currently exists.

### Results from Rider Survey

The rider survey specifically examined the types of trips taken, other transportation options available to riders, ability for riders to make trips, rider satisfaction with the service, and perceived changes in quality of service.

**Travel Destinations, Transportation Options, and Ability to Make Trips.** Riders from the participating agencies were found to most commonly use these services for health care trips, but the responses differ between agencies. For example, NTS primarily provides work trips, and SRC, serving older riders, provides a high percentage of medical trips. The results show that while agencies may focus on medical or work trips, riders use the services for a number of different purposes.

The impact of the transportation service can be demonstrated by how riders would respond if the service was no longer available. The survey found that only 38% of respondents would continue to make the same number of trips if the service was not available. The remainder would either make somewhat fewer trips (13%), a lot fewer trips (26%), or no trips at all (22%) for the activities they currently use the service for. These results show the significant impact the services have on increasing the ability of riders to make trips, and the results are especially important considering the percentage of trips that are for health care purposes.

When asked what mobility options were available if this service was no longer available, only 7% of respondents said that they can drive themselves. Nearly one-fourth answered that they have no options other than the transit service they are using. When asked to identify how they most often would get to where they are going if the service was not available, 32% said they would get a ride from a family member or friend, 12% would get a ride from a volunteer driver, 11% would use a taxi, and very few would use some other option. Only 4% would drive, and 29% would not make the trip.

Responses varied regarding how easy it is to make trips with the current availability of transportation services, as 20% said it is very easy to travel to the places they want or need to go, and the same percentage said it is very difficult. Half of respondents said they always, or almost always, are able to get the transportation they need so they can go where they want to go, while 20% are often able to get transportation, 23% are only sometimes able to get transportation, and 8% are rarely able to get transportation. Meanwhile, 20% said there was a destination they wanted to travel to during the previous week but could not due to lack of transportation.

**Satisfaction with Transportation Service.** Most respondents were satisfied with the quality of service they are receiving from their transportation provider. Respondents were specifically asked about their satisfaction with how the service serves their needs, number of trips offered, weekend hours, service coverage, ease of use, scheduling procedures, access to information, door-to-door availability, cost, and comfort. Regarding each aspect of service quality, the number of respondents satisfied was greater than the number not satisfied, and with the exception of weekend hours, the difference was statistically significant at the 1% level. For example, 72% were very satisfied with how the service served their needs, 73% were very satisfied with ease of use, and 69% were very satisfied with available travel destinations.

An important measure of the success of mobility management and coordination efforts is the degree to which service quality is improving for the transit user. A majority of respondents answered that since they have been using the service, service quality had stayed about the same, but a number also reported improvements in service and fewer noted declines in service (Table 2). For example, 31% of respondents reported that ease of use has improved, while only 3% answered that it is getting worse. Similarly, 28% reported that the service is doing a better job of serving their needs, while only 4% answered that the service is doing worse. The difference between those who reported improvements and those who reported service is getting worse is statistically significant in each case, with the exception of weekend hours. These results show general improvements in quality of service, as perceived by the riders.

**Table 2: Transit-User Perceptions on Changes in Quality of Service**

| | Has gotten better | | Has stayed the same | | Has gotten worse | |
|---|---|---|---|---|---|---|
| | % | Count | % | Count | % | Count |
| Serves your needs | 28** | 123 | 68 | 303 | 4** | 19 |
| Number of trips offered | 20** | 81 | 75 | 306 | 5** | 20 |
| Weekend hours | 15 | 43 | 73 | 209 | 12 | 34 |
| Goes where you want to go | 27** | 114 | 70 | 294 | 4** | 15 |
| Ease of use | 31** | 129 | 66 | 277 | 3** | 12 |
| Scheduling procedures | 26** | 114 | 67 | 289 | 7** | 29 |
| Access to information | 26** | 103 | 71 | 281 | 4** | 14 |
| Door-to-door service availability | 33** | 141 | 64 | 273 | 3** | 11 |
| Cost of the service | 24** | 100 | 68 | 278 | 8** | 32 |
| Comfort | 31** | 132 | 67 | 287 | 2** | 9 |

**Difference between "Has gotten better" and "Has gotten worse" is statistically significant, $p < .01$

**Results from Stakeholder Survey**

The stakeholder survey documented benefits that have been achieved and the perceived impacts on quality of service.

**Benefits of Mobility Management and Coordination.** Many respondents to the stakeholder survey reported that mobility management and coordination activities have yielded positive results (Table 3). Nearly two-thirds have recognized simplified access to transportation services for riders, and a majority also identified an increase in the range of transportation options and service providers available to riders, increased awareness of transportation services, and increased ridership. A number of other benefits have also been observed by a smaller percentage of respondents.

**Table 3: Percentage of Agencies Involved with Coordination or Mobility Management that have Realized Specific Benefits (n=60)**

| Answer Options | Response Percent |
|---|---|
| Simplified access to transportation services for riders | 65% |
| Increase in the range of transportation options and service providers available to riders | 63% |
| Increased awareness of transportation services | 63% |
| Increased ridership | 57% |
| Reduction in service gaps | 48% |
| Expanded transit service area to include new destinations where individuals need to go | 43% |
| Expanded span of service (provide transit service earlier or later) | 37% |
| Reduction in service duplication or overlap | 35% |
| Increased service days per week (provide transit service more days of the week) | 32% |
| Increased frequency of service | 32% |
| Reduced cost per ride | 30% |
| Expanded transit service days to include weekends | 23% |

Many respondents commented on the benefits of partnership and increased communications, including increased awareness of existing transportation resources and greater capacity to identify and address unmet transportation needs. Some respondents provided specifics about new services that have been implemented, and others commented on how the programs have improved efficiencies by combining routes and co-mingling trips. In addition to the increased availability of transportation options and improved efficiencies, some respondents commented on how the programs have improved quality of life for the users and their families by providing a more personal connection for riders, relieving family members of numerous stressful trips, and allowing users to be more independent. Most respondents indicated that these efforts have resulted in improved access to transportation services for older adults and people with disabilities.

**Needs of End-Users and Impacts on Quality of Service.** Stakeholders were asked the degree to which they agree or disagree with whether the transportation needs of their clients are being met and whether the transportation services are easy for their clients to access. Opinions were mixed. Among respondents, 44% either strongly agreed (11%) or somewhat agreed (33%) that the transportation needs of their clients are being met, while 42% either strongly (13%) or somewhat (29%) disagreed. Similarly, 46% agreed that transportation services are easy for their clients to access, and 41% disagreed. In both cases, the difference between the number who agreed and the number who disagreed was statistically insignificant.

A majority of respondents agreed that these efforts have led to improvements. For example, 66% agreed that mobility management and coordination programs have resulted in more transportation options available to their clients; 65% agreed it has resulted in simplified access to transportation services; and a majority also agreed that there has been increased awareness of transportation services and expanded service areas. In each of these cases, the difference between the number who agreed and the number who disagreed was statistically significant at the 1% level.

## MOBILITY AND QUALITY OF LIFE

Table 4 shows the results from the ordered probit model estimating the impacts of age, disability, health status, income, and mobility on life satisfaction. The statistically significant variables are noted, and the calculated odds ratios are shown. An odds ratio greater than 1 indicates an increased probability of the respondent giving a higher life satisfaction score as the value of the independent variable increases, and a value less than 1 indicates a decreased probability.

The impacts of age, disability, and income were all statistically insignificant, while the other three variables had significant impacts. As expected, health status was found to have a significant impact on life satisfaction. Increases in health status were associated with higher life satisfaction ratings. The results show that the odds of giving a higher life satisfaction score increase by 88% as health status increased from poor to fair or from fair to good.

**Table 4: Factors Affecting Life Satisfaction: Results from Ordered Probit Model (n=344)**

| Variable | Estimate | Odds Ratio |
|---|---|---|
| Age (1-6 scale) | 0.012 | 1.01 |
| Disability (0-1) | -0.023 | 0.98 |
| Health Status (1-3 scale) | 0.633** | 1.88** |
| Income (1-5 scale) | 0.0148 | 1.01 |
| Missed Trip (0-1) | -0.4067** | 0.67** |
| Travel Difficulty (1-5 scale) | -0.1138** | 0.89** |

*$p < .05$, **$p < .01$

The results demonstrate the importance of mobility on life satisfaction, supporting findings from previous research. Those who had reported missing a trip during the previous week because of lack of transportation and those who reported greater difficulty in making trips gave significantly lower life satisfaction ratings. The odds ratios for these two variables were 0.67 and 0.89, respectively, indicating decreases in the odds of a respondent giving higher life satisfaction scores if they missed a trip or if travel became more difficult. The impacts of mobility on life satisfaction were found after controlling for other factors such as age, disability, health status, and income.

These results demonstrate the impacts that mobility management programs can have on the lives of the users. When these efforts result in new transportation options, new trips that can be made, and simplified access to service, quality of life for the users of these services is shown to improve significantly.

## CONCLUSIONS

A diversity of performance measures, with the inclusion of non-traditional mobility indicators, is beneficial for evaluating how well programs focused on mobility and accessibility are meeting their goals (Akoto 2016). This study developed non-traditional measures and collected data through end-user and stakeholder surveys across the country. Results suggest improvements in efficiencies, ease of access, and quality of service. Most respondents to the stakeholder survey reported benefits that have been realized.

The general perspective of the stakeholders is that 1) there are a number of challenges to implementing coordination and mobility management, such as lack of funding, lack of communication, unique needs of various client populations, and many other issues; 2) there is a need for more coordination of existing human service transportation programs; and 3) the programs that have been implemented have had a positive impact on quality of service, ease of access, and, to a lesser extent, efficiency.

Results from the stakeholder survey were somewhat mixed regarding how well services are meeting the needs of end-users. Most indicated some need for more service, such as longer hours, weekend service, or an increase in the scale of services currently available. Results were positive regarding the impact that mobility management and coordination programs have had on quality of service.

Most respondents to the end-user survey were satisfied with the quality of service they receive from their transportation provider, and the results show general improvements in quality of service, as perceived by the riders. The results show that these transportation programs have significant impacts on the lives of their users. Many respondents reported that they would not be able to make these trips if the service they use was not available.

Results from an ordered probit model show how improving mobility and increasing the number of trips an individual can make improves quality of life. These results demonstrate the impacts that mobility management programs can have on the lives of the users. When these efforts result in new transportation options, new trips that can be made, and simplified access to service, quality of life for the users of these services is shown to improve significantly.

These surveys were conducted in different locations across the country, including a mix of urban, suburban, and rural areas. Key for such an evaluation is to collect information from a variety of perspectives, including the end-users, transportation providers, human service agencies, and other stakeholders. While the surveys provide enough information to evaluate mobility management and coordination efforts, more specific data for performance measures would provide more precise results. Future evaluation methods could investigate the possibility of collecting more specific data on performance measures. Individual communities need to ensure a large enough response from both stakeholders and end-users to ensure a proper evaluation. Because of the limited number of responses received from some communities, this study did not attempt to draw conclusions about individual jurisdictions. The results presented were based on the collection of responses from all communities surveyed.

The survey method can be useful for tracking progress over time. Results from end-user responses on ability to make trips and satisfaction with transportation service, as well as stakeholder responses on benefits, needs of end-users, and quality of service could be used to track progress. Overall, the results suggest that some progress has been made and that the mobility management programs should continue.

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**References**

Akoto, Eunice V. "Exploring Diversified Performance Indicators for Evaluating Non-Urbanized Transit Program Outcomes." *Journal of Public Transportation* 19 (1), (2016): 28-48.

Banister, David, and Ann Bowling. "Quality of Life for the Elderly: The Transport Dimension." *Transport Policy* 11, (2004): 105-115.

Burkhardt, Jon E., and Joohee Yum. "Performance Measures for Mobility Management Programs." American Public Transportation Association, 2010.

Burkhardt, Jon E., David Koffman, and Gail Murray. *TCRP Report 91: Economic Benefits of Coordinating Human Service Transportation and Transit Services*. Transit Cooperative Research Program. Washington, DC: Transportation Research Board, 2003.

Burkhardt, Jon E., Charles A. Nelson, Gail Murray, and David Koffman. *TCRP Report 101: Toolkit for Rural Community Coordinated Transportation Services*. Transit Cooperative Research Program. Washington, D.C.: Transportation Research Board of the National Academies, 2004.

Cambridge Systematics, Inc. *TCRP Report 53: New Paradigms for Local Public Transportation Organizations Task 1 Report: Forces and Factors that Require Consideration of New Paradigms*. Transit Cooperative Research Program. Washington, D.C.: Transportation Research Board of the National Academies, 1999.

Delbosc, Alexa, and Graham Currie. "Exploring the Relative Influences of Transport Disadvantage and Social Exclusion on Well-Being." *Transport Policy* 18, (2011): 555-562.

Delbosc, Alexa. "The Role of Well-Being in Transport Policy." *Transport Policy* 23, (2012): 25-33.

Executive Order 13330. "Human Service Coordination." *Federal Register*. Vol. 69. no. 38. February 26, 2004.

General Accounting Office. *Transportation Coordination: Benefits and Barriers Exist, and Planning Efforts Progress Slowly*. GAO/RCED-00-1. Washington, D.C., 1999.

General Accounting Office. *Transportation Disadvantaged Populations: Some Coordination Efforts Among Programs Providing Transportation Services, but Obstacles Persist*. GAO-03-697. Washington, D.C., 2003.

Government Accountability Office. *Opportunities to Reduce Potential Duplication of Government Programs, Save Tax Dollars, and Enhance Revenue*. GAO-11-318SP. Washington, D.C., 2011.

Government Accountability Office. *Transportation-Disadvantaged Populations: Federal Coordination Efforts Could be Further Strengthened*. GAO-12-647. Washington, D.C., 2012.

Kahneman, Daniel, and Alan B. Krueger. "Developments in the Measurement of Subjective Well-Being." *Journal of Economic Perspectives* 20 (1), (2006): 3-24.

Majumdar, Sarmistha R., Lalita Sen, Meredith K. Highsmith, and Linda Cherrington. "The Case of Performance Measurement in Mobility Management Programs." *Public Performance & Management Review* 37, (2013): 280-301.

Mattson, Jeremy, James Miller, Jill Hough, Jay Goodwill, and P.S. Sriraj. "Evaluating the State of Mobility Management and Human Service Transportation Coordination." National Center for Transit Research, 2014.

National Conference of State Legislators (NCSL) for the Federal Transit Administration and Department of Labor. "State Human Service Transportation Coordinating Councils: An Overview and State Profile," 2010.

Sen, Lalita, Sarmistha Rina Majumdar, Meredith Highsmith, Linda Cherrington, and Cinde Weatherby. *Performance Measures for Public Transit Mobility Management.* Texas Transportation Institute, 2011.

Spinney, James E.L., Darren M. Scott, and K. Bruce Newbold. "Transport Mobility Benefits and Quality of Life: A Time-Use Perspective of Elderly Canadians." *Transport Policy* 16, (2009): 1-11.

Stanley, John K., David A. Hensher, Janet R. Stanley, and Dianne Vella-Brodrick. "Mobility, Social Exclusion and Well-Being: Exploring the Links." *Transportation Research Part A* 45, (2011): 789-801.

TranSystems Corporation, Center for Urban Transportation Research, Institute for Transportation Research and Education, and Planners Collaborative. *TCRP Report 105: Strategies to Increase Coordination of Transportation Services for the Transportation Disadvantaged*. Transit Cooperative Research Program. Washington, D.C.: Transportation Research Board of the National Academies, 2004.

United We Ride. *About United We Ride and the Coordinating Council*, 2014. Accessed May 2014. http://www.unitedweride.gov/1_3_ENG_HTML.htm.

United We Ride. "Mobility Management," 2007a. Accessed May 2014. http://www.unitedweride.gov/Mobility_Management_Brochure.pdf.

United We Ride. "United We Ride Logic Model and Measures," 2007b. Accessed May 2014. http://www.unitedweride.gov/FINALUWRlogicmodel_perfmeasure_1_2007.pdf.

Virginia Department of Rail and Public Transportation. "2005 United We Ride Inventory: Coordination Efforts in Human Service Transportation in the Commonwealth of Virginia," 2006.

***Jeremy Mattson*** *is an associate research fellow with the Small Urban and Rural Transit Center, a program of the Upper Great Plains Transportation Institute at North Dakota State University. He is also a Ph.D. candidate in transportation and logistics at North Dakota State University.*

***James Miller*** *is a faculty affiliate with the Small Urban and Rural Transit Center at North Dakota State University. Previously, he was a faculty member in Penn State University's Smeal College of Business Administration from 1976 until his retirement in 2003. He directed the Mid-Atlantic Universities Transportation Center from its founding in 1988 until 2002. He earned a Ph.D. from Penn State University.*

***Jay Goodwill*** *is a senior research associate at the Center for Urban Transportation Research at the University of South Florida. He previously served as the general manager of the Sarasota County Area Transit System in Florida and was executive director of the Sarasota/Manatee Metropolitan Planning Organization.*

***P.S. Sriraj*** *is the director of the Metropolitan Transportation Support Initiative (METSI) and research associate professor at the Urban Transportation Center at the University of Illinois at Chicago. He earned a Ph.D. in civil engineering from the Illinois Institute of Technology.*

***Jill Hough*** *is the director of the Small Urban and Rural Transit Center within the Upper Great Plains Transportation Institute at North Dakota State University. She is an adjunct professor for agribusiness and applied economics and a professor for the Transportation and Logistics Ph.D. program at North Dakota State University, where she teaches a course on public transportation. She earned a Ph.D. in transportation technology and policy from the University of California, Davis.*

# Export Spread, Farmer Revenue and Grain Export Capacity in Western Canada

**by Mohammad Torshizi and Richard Gray**

*Starting in the 2013-14 crop year, a lack of export capacity resulted in substantial increases in the spread between farm and port FOB prices in western Canada. This created a very difficult situation for the farming community. We calculate that this situation reduced grain farmers' income over the 2013-14 and 2014-15 crop years by approximately C$6.7 billion. Clearly, the grain handling and transportation system has problems and capacity to move grain is one of them. To evaluate the need for grain export capacity expansion, we forecast future grain production using a rational expectations model to estimate future export spreads and subsequent rents. We find that without capacity improvements, the expected cost of limited grain export capacity could exceed C$5.6 billion over the next decade. Capacity improvements on the order of a 25% increase will likely mitigate this issue in the future.*

## INTRODUCTION

Capacity constraints in transportation can have a significant impact on spatial price relationships within commodity markets. To this end, the law of one price suggests that if a commodity can be moved from point A to B, then any difference in the price of the commodity at the two points should reflect only transportation costs. However, when commodity arbitrage is capacity constrained, spatial price spreads in the market must increase so as to ration the available transportation capacity. Any such price adjustments can have very significant economic and distributional impacts.

Transportation markets can become capacity constrained from both supply and demand shocks. For example, commodity analysts continually monitor labor strikes, natural disasters, and wars that disrupt transportation and/or reduce capacity. Given its importance in commodity market arbitrage, investment in transportation infrastructure is often perceived as a prerequisite for economic development.

In the 2013 crop year, record Canadian grain production levels combined with a later start to harvest, an unexpectedly early and cold winter, poor production forecasts, and a low carryover of grain from the previous year resulted in a slower than normal movement of grain, creating a transitional grain transportation crisis in western Canada.[1] As grain companies lowered their cash bids for grain to ration available capacity, the price spread between FOB port and country elevator cash bid (the so-called export spread) levels in western Canada increased significantly, peaking at up to three times above normal, or historical levels. In March 2014, the Canadian government responded with new regulations, one of which enforced a level of minimum weekly grain movements by both railways. Effectively, it took until July 2015 for ending stocks and export spread levels to return to historical levels. These two years of elevated export spread levels came at a cost to Canadian prairie grain farmers.

One may argue that the grain transportation crisis buttressed by the record 2013 crop yield was an isolated incident that is not likely to be repeated again, rendering any efforts to improve grain export capacity as unnecessary. However, we believe this to be an empirical issue that will be governed by future export demand as well as future grain transportation capacity.

Using price and quantity data for the 2012-13, 2013-14, and 2014-15 crop years, we estimate ex post impacts of limited grain export capacity. Looking forward, the ex ante component of our study addresses the need for future grain export capacity, a task that begins with forecasting grain production over the 2016-2026 period. We develop a model that incorporates the derived demand for grain exports within a spatial market, consisting of three major Canadian production regions and four export points for grain. As a benchmark in this section, we first estimate farmers' potential losses assuming no grain export capacity improvements. We then examine how this loss might be mitigated with additional export capacity.

The remainder of this study is organized as follows. The next section provides a short review of the relevant literature. The third section presents the analytic background on demand for grain handling and transportation in Canada (GH&T). The fourth and fifth sections present our ex post and ex ante analyses, respectively. The last section provides a conclusion along with some policy implications.

## LITERATURE REVIEW

This study borrows its foundations from two related streams in the economics literature. The first investigates arbitrage and spatial price spreads, while the other studies storage and temporal price differentials or basis.

To start, the work of Samuelson (1952) and Takayama and Judge (1964) developed spatial price equilibria in linear and quadratic programming frameworks, respectively. Subsequently, Richardson (1978) examined commodity arbitrage between the U.S. and Canada, while later work saw Ardeni (1989) and Goodwin et al. (1990) examine the law of one price for international wheat markets. In turn, various aspects of goods arbitrage, spatial price differentials and equilibrium related to agricultural markets were examined in the work of Spiller and Wood (1988), Sexton et al. (1991), Goodwin and Schroder (1991), Faminow and Benson (1990), Baulch (1994, 1997), and Fackler (1996).

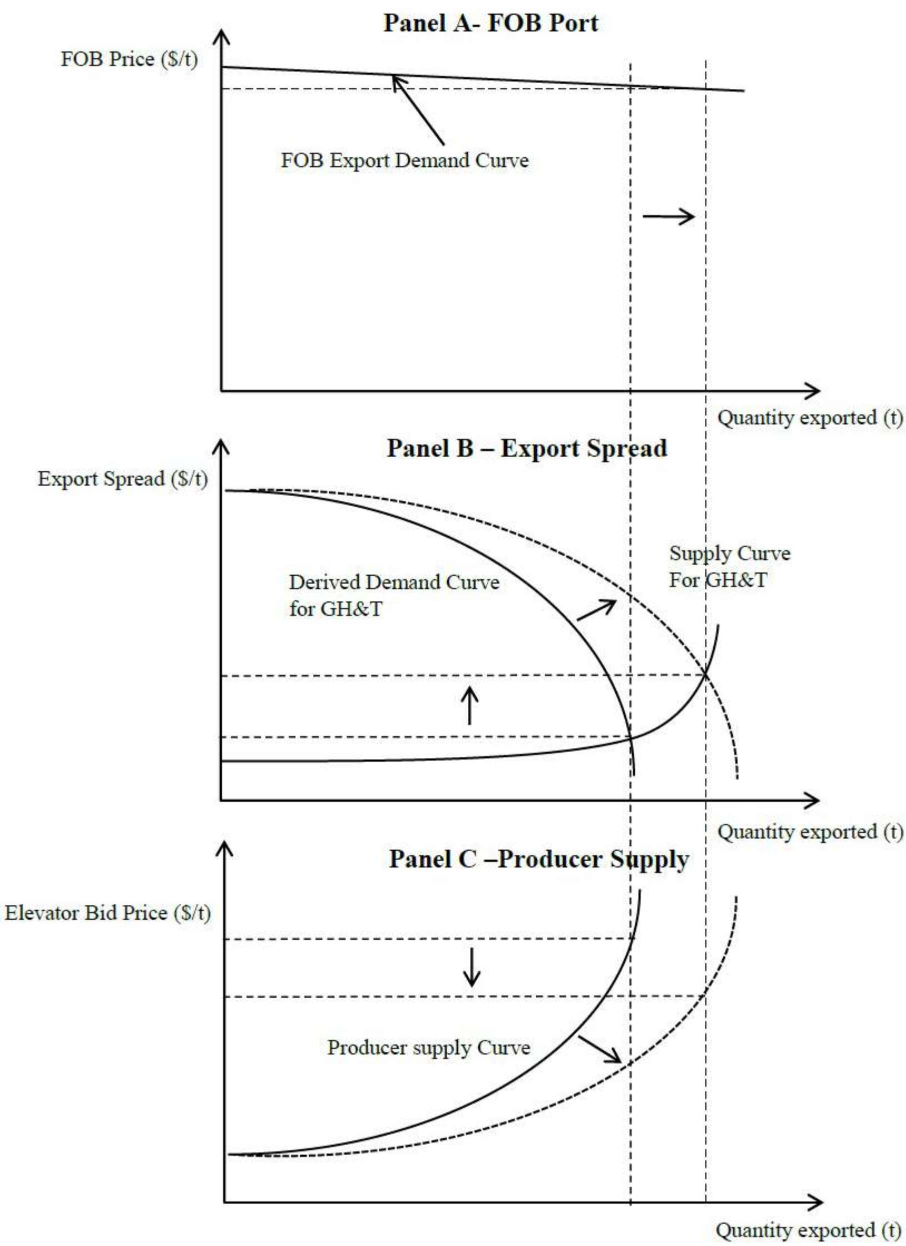
Research inspired by Working's (1949) "theory of the price of storage" explored various aspects of storage and temporal price differentials. The subsequent related literature on agricultural markets is vast. For example, Brennan (1958) is widely cited for his work on the supply of storage, while Williams and Wright (1991) modeled storage in commodity markets. Other relevant studies in this area include Weymar (1966), Ehrich (1969), Tilley and Campbell (1988), Sarwar and Anderson (1989), and McKenzie (2005). Most recently, Tadasse et al. (2016) explored the causes of food price spikes, while Caves et al. (2000) and von Braun (2009) discussed mitigating price spikes in wholesale and food markets, respectively. Collectively these studies highlight that disruptions in commodity transportation that limits its arbitrage can have significant impacts on both spatial price spreads and relative price levels.

## DERIVED DEMAND FOR GRAIN HANDLING AND TRANSPORTATION AND THE ROLE OF STORAGE

Here, we define the export spread as the difference between country elevator cash bids in Saskatchewan and FOB port prices in Vancouver.[2] We offer that this is an approximate measure of the per (metric) tonne (MT) revenue or gross margin earned by grain companies to purchase grain from farmers on the prairies and load it onto a vessel at port.[3] To earn this gross margin, the grain companies must incur the cost of primary elevation, cleaning and storage, rail freight, terminal elevation, and fobbing. Given this, we also offer that an opportunity for profitable arbitrage by a grain company occurs when export capacity is constrained.

To provide better understanding of the impact of an export capacity constraint in this context, GH&T services are modeled in a derived demand framework, as illustrated in Figure 1. Here, the FOB Vancouver demand has minimal slope, reflecting the fact that Canada is largely a price taker in world grain markets (Schmitz and Furtan 2000).

**Figure 1: The Impact of Large Capacity Constrained Supply on Export Spread Levels and Producer Prices**



Examining this diagram, the producer supply curve (Panel C) is the price at which farmers on aggregate are willing to sell any specific quantity of grain to elevators (in Saskatchewan) for export. Intuitively, the price intercept of the supply curve indicates the cash price that the most desperate producer would accept if exports were limited to just a single tonne for the region. As the quantity purchased for export increases, the producers' offer price also increases. As this quantity approaches the total available grain, higher prices cannot attract additional deliveries and, thus, the producers' supply curve becomes vertical.

The derived demand for GH&T services (Panel B), which is the vertical difference between the FOB demand curve (Panel A) and the producer supply curve (Panel C), represents the maximum willingness of a broker to have grain handled and transported from producer delivery to FOB port (Vancouver) position. Further, the supply of GH&T services is shown in Panel B. Once again, the price intercept of the supply curve represents the minimum export spread charge by any grain company to export the first tonne offered. The long and nearly horizontal portion of the GH&T supply curve represents the quantity that is moved at posted tariff rates. As the quantity moved approaches GH&T export capacity, the GH&T supply curve slopes upward since the exporter must incur additional costs to secure additional export capacity. This supply curve becomes nearly vertical as short-term options to increase export capacity are exhausted.

The export spread charges or price for GH&T services is determined by where the demand and supply curves for GH&T intersect (Panel B). If this intersection occurs where capacity constraints are not binding, the export spread charges are at normal or historical levels. In this case, bid prices in the province of Saskatchewan for example, reflect the Vancouver FOB price minus GH&T costs, so that grain companies earn normal profits from exporting grain.

When there is a large producer supply, GH&T capacity constraints become binding and the situation changes dramatically. This is illustrated by the dashed supply curve in Panel C. In this case, the intersection of derived demand and the supply of GH&T occurs in the more vertical portion of the GH&T supply curve, where the export spread is far higher than normal and the cash bids are reduced relative to Vancouver FOB prices.

The GH&T rents, which are the differences between the average cost of GH&T and the export spread charges, accrue to grain companies or contract holders that have secured access at lower (tariff based) rates. Average freight rates in Canada are currently constrained by the maximum revenue entitlement policy, known as the MRE (Nolan and Peterson 2015). Due to this constraint, railways cannot capture additional system revenue by increasing their freight rates.[4] Producers who do not contract sales face lower prices for the grain they export or sell locally, incurring a cost equal to the increase in export spread multiplied by the quantity of their sales.

Several forms of arbitrage related to the law of one price[5] contribute to higher export spread impacts across markets. First, as long as some of the product is exported at elevated export spread levels, the price at which producers are willing to sell to local processors also reflects the same lower cash bids. Second, grain companies have an incentive to purchase grain types and grades with higher export spread levels. This grain company arbitrage occurs until all grades and commodities earn similar export spreads per tonne. Finally, producers have a choice between selling grain at the current export spread versus storing and selling grain at some future date, with the expected return from current and future sales differing by storage costs. When export spread levels increase, both current and future contract prices are affected.

Given these various forms of arbitrage that characterize efficient markets, increased export spreads tend to be pervasive, affecting nearly all sales within the export area equally. Nevertheless, some producers should be able to avoid the effects of lower cash bids by contracting prior to export spread increases or finding alternative markets for delivery. We note that in the 2013-14 crop year, some Canadian producers near the U.S. border were able to limit the effects of increased export spreads by instead trucking their grain to less congested U.S. shipping points. However, CGC delivery statistics suggest that at that time, the vast majority of Canadian grain was still delivered to local grain elevators for export (CGC 2015). If a similar situation occurs in the future, it remains to be seen whether or not Canadian farmers will use this potential outlet to try to further alleviate these effects. Therefore, we conduct this analysis assuming that Canadian farmers in the foreseeable future will not suddenly start transporting vast quantities of export bound grain south of the border in response to increased export spreads at Canadian ports.

The theory presented in this section is the primary framework we use to measure the effects of GH&T capacity constraints. To further illustrate what occurred in this market, the next section calculates export spread levels and foregone revenues over 2012-13, 2013-14, and 2014-15 crop years. The basis for these calculations is the work done by Gray (2015).

## EX POST ANALYSIS: FOREGONE GRAIN PRODUCER REVENUE

Actual excess export spread levels are used to estimate the income effects of the 2013-14 transportation situation for western Canadian grain producers. The export spread levels are presented in Figure 2. As reported in Table 1, losses to producers are calculated based on the deliveries of grain in western Canada during the periods of August 1 to December 31, January 1 to March 31, and April to July 1 for both the 2013-14 and 2014-15 crop years.[6] Wheat, barley, canola, peas, and oats are the only grains included in these calculations.

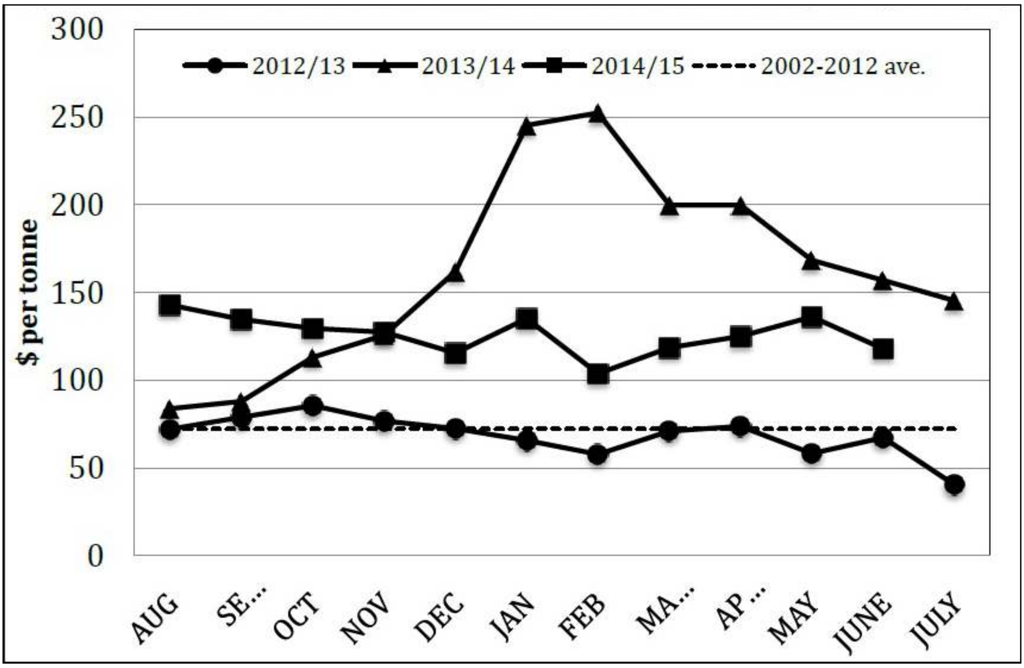
Farmer deliveries are multiplied by our estimates of excess export spread levels in order to quantify the overall impacts. In our first calculation, the export spread levels that existed at the time of delivery are assumed to apply to all grain delivered during the period. This metric describes the total export rents generated because of limited export capacity. Given our assumptions, this amount is estimated to be C$6.7 billion. However, we caution that this amount should be considered an upper bound because many producers were able to avoid paying the above normal export spread by using other means, including delivering to U.S. points, or using forward-price and forward-contract deliveries.

In our second calculation, we assume that all grain delivered reflects the export spread which existed 12 weeks earlier. Here, the loss to Canadian producers is estimated to be C$6.3 billion. While this calculation represents an extreme amount of forward contracting in the market, it illustrates the idea that the export spread effect only becomes slightly smaller when forward contracting is formally taken into account.

In our third sample calculation, we assume that 20% of all grain deliveries reported were able to escape the effect of a higher export spread. This means all grain sales had their export spread set a full three months in advance. Even in this very conservative case, the estimated losses to Canadian grain producers still exceeded C$5.05 billion.

The figures reported in Table 1 are based on several simplifying assumptions. First, we assume that the increase in export spread is solely due to lack of export capacity. Given a clear comparison to the C$72 export spread that existed in the 2012-13 crop year when there was adequate export capacity, we offer that any excess over C$72 can be reasonably attributed to a lack of export capacity. The return toward a more normal export spread level by June 2015, as delivery pressures decreased, also supports our assumption.

**Figure 2: Estimated Vancouver FOB – Saskatchewan Cash Bid Export Spread (C$/T)**




*Notes:* Export spread is calculated as the difference between Vancouver FOB prices and Saskatchewan cash bid prices.

*Source*: Vancouver FOB prices: AAFC (2014), Saskatchewan cash bid prices: Saskatchewan Ministry of Agriculture (2014).

Second, we assume that the FOB price is fixed and not positively affected by reduced exports. Demand factors suggest that buyers pay more for Canadian grains when export volumes are reduced, particularly for types and classes of grain where Canada is a major supplier. However, when export flows are reduced, the deferred export quantities are additional grain for future sale, so the net price effect is likely to be limited. Looking at the price data for example, the FOB prices for Canadian western red spring wheat atypically traded at a significant discount to the equivalent quality dark northern spring wheat out of Portland, C$25/tonne in 2013-14 and C$42/tonne in the 2014-15 crop year (Gray 2015). This suggests buyers pay less for grain with an insecure delivery schedule, which we assume just offsets any increase in the world price, due to the increased export spread. However, if there were some short-term net positive effects on FOB prices, then our estimated producer losses would be overestimations of actual producer losses.

**Table 1: Estimated Grain Producer Income Impact of Congestion Related Excess Export Spread in Western Canada, 2013-14 and 2014-15**

| | 2013-2014 Crop year | | | 2014-2015 Crop year | | | |
|---|---|---|---|---|---|---|---|
| | Aug-Dec | Jan-Mar | Apr-Jul | Aug-Dec | Jan-Mar | Apr-Jul | Total |
| Farm Deliveries (000T) * | 21.80 | 11.86 | 18.92 | 22.85 | 12.72 | 15.00 | 103.15 |
| **All Sold at Prevailing Export Spread**** | | | | | | | |
| Ave Excess Export Spread($/MT) | $51.49 | $143.53 | $77.67 | 48.63 | 59.97 | 34.94 | 64.88 |
| **Total Export Rents ($Million)** | $1,123 | $1,702 | $1,470 | $1,111 | $763 | $524 | **$6,692** |
| **All sold at Export Spread 12 weeks prior^** | | | | | | | |
| Excess Export Spread (t - 12weeks)($/MT) | $6.02 | $75.78 | $130.82 | 58.62 | 48.48 | 56.82 | 61.21 |
| **Producer Losses** ($Million) | $131 | $899 | $2,475 | $1,339 | $617 | $852 | **$6,314** |
| **80% sold at export spread 12 weeks prior^^** | | | | | | | |
| Excess Spread (t - 12weeks)($/MT) | $6.02 | $75.78 | $130.82 | $58.62 | $48.48 | $56.82 | 0.75 |
| **Producer Losses** ($Million) | $105 | $719 | $1,980 | $1,071 | $493 | $682 | **$5,051** |

*Source*: Authors Calculation, Figure 3, and CANSIM Table 0010043 (Statistics Canada 2015b).
* Farm Deliveries of wheat, oats, barley, canola, peas, western Canada.
**Excess export spread is estimated to be Vancouver FOB – Sask. Cash bids for wheat - $72/MT see Figure 1 for calculation and sources.
^ Excess export spread reported for 12 weeks prior to delivery is used to estimate impact.
^^ This lower bound estimate assumes that only 80% of producer deliveries are impacted and all export spread is priced 12 weeks prior to delivery.

Finally, these calculations assume that the wheat export spread is reflected in other grains (barley, canola, oats and peas). From an arbitrage perspective, this is a reasonable assumption because if the export spread on another grain is significantly higher than wheat, a company should move more of that product until the export spread becomes equal among the grains. Similarly, if the export spread was lower on some other grain, a grain company would use its available capacity to ship wheat.

## EX ANTE ANALYSIS

Our ex ante analysis first estimates prairie farmers' potential losses from limited export capacity, and then estimates the cost savings available through capacity improvement.

### Methodology

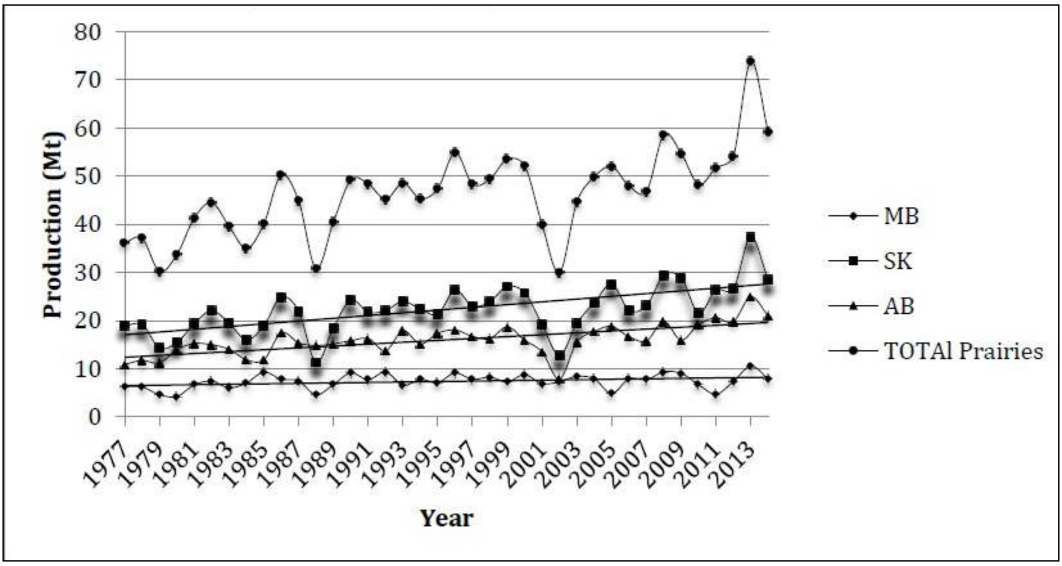
To find the effect of limited export capacity on export spread levels and farmers' revenue, we must first forecast future production. Production forecasts, along with their computed probability distribution functions (PDFs) are then used in a rational expectations storage model to calculate future expected export spread levels as well as farmers' expected losses due to limited export capacity. The rational expectations storage model is founded upon the literature on storage theory in commodity markets (Williams and Wright 1991). The next section illustrates the methodology.

## Future Production

This analysis uses historical data to forecast future crop production in western Canada. Crops used in the analysis include spring wheat, winter wheat, durum wheat, barley, canola, soybeans, oats, rye, flaxseed, chick peas, lentils, and dry peas.

As presented in Figure 3, production levels in the three Canadian Prairie provinces are highly correlated. Therefore, the aggregate data from Alberta, Saskatchewan, and Manitoba are used to forecast future production.

**Figure 3: Production of Grains, Oilseeds, and Pulses in Manitoba (MB), Saskatchewan (SK) and Alberta (AB), 1977-2014**




*Source*: Statistics Canada (2014).

An autoregressive (AR) time series model is used to estimate the magnitude and length of autocorrelation in our data, along with the importance of a time trend in our crop production time series (Allen 1994; Greene 2002, Chapter 19; Campbel et al. 2002). The AR forecasting model used here takes the following form:

(1) $Y_t = \beta_0 + \beta_1 Y_{t\text{-}1} + \beta_2 Y_{t\text{-}2} + \beta_3 T + \beta_4 D_{1988} + \beta_5 D_{2002} + \beta_6 D_{2013} + \epsilon_t$

where $Y_t$, $Y_{t\text{-}1}$, and $Y_{t\text{-}2}$ are the current, first lag, and second lag of production levels, respectively; $T$ represents time trend; $D_{1988}$, $D_{2002}$, and $D_{2013}$ are dummy variables for years with significantly lower or higher than average production levels; and $\epsilon_t$ represents the error term.

Schwarz Criterion suggests an optimal lag length of two for our production data. The time trend variable, $T$, is critical for estimating the rate of yield improvement over time. To ensure that abnormally high or low production levels do not affect the estimated parameter on the time trend variable, dummy variables are incorporated for the extreme prairie crop years 1988, 2002, and 2013. The observations for these three years are included when calculating the variance for the PDFs to ensure that our estimates do not ignore the possibility of the occurrence of extraordinarily good or bad crop years, also meaning there are fewer concerns about under-representing risk in the model.

**Probability Distribution Functions for Grain Production**

Production forecasts do not provide us with the probability of running into a limited export capacity problem given the storage levels of previous years and current production levels. A simulation model is developed to produce PDFs for both current and future production of Canadian grain (Billingsley 1979). A Jarque-Bera test cannot reject the null hypothesis of normal distribution. Therefore, the PDFs are assumed to be normally distributed and are computed in the following manner:

a. Calculate the parameters (i.e., mean and variance) of the de-trended historical production data, from 1977 to 2014.
b. Produce random draws within a normal distribution with the parameters calculated in part *A*.
c. Add the first lag parameter, $\beta_1$, estimated in Equation 1 to the random draws calculated in part *B*.
d. Add the second lag parameter, $\beta_2$, estimated in Equation 1 to the result of part *C*.
e. Add the time trend variable parameter, $\beta_3$, estimated in Equation 1 to the result of part *D*.

The first two steps of our simulation approach resemble a bootstrapping method as they use a known sample to generate random draws (Efron and Tibshirani 1993). However, our approach also incorporates the time trend and any potential serial correlation estimated in Equation 1 into the PDFs - parameters $\beta_1$, $\beta_2$, and $\beta_3$ shift the PDFs. Thus, PDF of grain production in any given year has a random component (generated in steps a and b) and a deterministic component (added in steps c, d, and e). The merit of the approach described above is that it allows us to easily calculate the conditional probability of having to store grain in any given year given the production and storage levels of previous years. This is explained further in the next section.

**Expected Export Spread with Rational Expectations**

Storage theory in commodity markets developed by Williams and Wright (1991) is used as the basis of the rational expectations storage model developed in this section. We assume that total export capacity is also constrained by current railway capacity. Therefore, we presume that exportable supply levels that are higher than export capacity result in storage. The existence of storage costs, which are incurred by farmers, also creates an opportunity for grain companies to increase export spread levels. For instance, in year *t,* farmers have no choice but to either accept a cash price $P_t^f$ or pay a storage cost $SC_t$ and sell their crop the next year at the price $P_{t+1}^f$ of .[7] Therefore, in year *t,* farmers are indifferent between $P_t^f$ and $P_{t+1}^f$- $SC_t$. Therefore, farm price (i.e., farmers' received price) in year *t* can be derived from the following condition:

(2) $$P_t^f = P_{t+1}^f - SC_t$$

Thus, equation 2 links farm price in year *t* to farm price in year *t*+1 and is valid if and only if there is storage in year *t*. However, farm price in year *t*+1 depends on farm price in year *t*+2 and storage cost in year *t*+1. Therefore, farm price in year *t*+1 can be found with the following:

(3) $$P_{t+1}^f = P_{t+2}^f - SC_{t+1}$$

Therefore, assuming storage continuously occurs for *n* consecutive years, the price in year *n* is found as follows:

(4) $$P_{t+n}^f = P_{t+n+1}^f - SC_{t+n}$$

Furthermore, Equation 2 can be rewritten as follows:

(5) $P_t^f = P_{t+n+1}^f - \sum_{i=t}^{t+n} SC_i$

Given that the cash price in any year is equal to a constant world price, $P^w$ minus export spread, and assuming that the export spread returns to the normal level after $n$ years, equation 5 can be rearranged as:

(6) $P^W - B_t = P^W - \bar{B} - \sum_{i=t}^{t+n} SC_i$

where $B_t$ is the export spread level in year $t$ and is $\bar{B}$ the normal export spread level. Equation 6 can also be rewritten to find the export spread level in year $t$:

(7) $B_t = \bar{B} + \sum_{i=t}^{t+n} SC_i$

Equation 7 states that the export spread level in any given year is equal to the normal or average export spread plus all storage costs that farmers incur for the crop produced in that year. However, farmers cannot be certain about how many consecutive years there will be positive storage from the crop produced in year $t$. The number of years with positive storage from crops produced in year $t$ depends on future production levels. Therefore, farmers form rational expectations regarding future storage cost (Muth 1961). To incorporate these rational expectations, equation 7 needs to be rewritten as:

(8) $E[B_t] = \bar{B} + \sum_{i=t}^{t+E[n]} SC_i = \bar{B} + E[\sum_{i=t}^{t+n} SC_i]$

Where these expectations are based on the probability distribution of future production.

For this analysis, we assume export spread levels return to normal after a maximum of two years.[8] Therefore, we use the reduced from of equation 8:

(9) $E[B_t] = \bar{B} + E[\sum_{i=1}^{2} SC_i]$

Note that the expectations still play a critical role even in the case of only two years. As highlighted previously, a good crop year is very likely to be followed by another relatively good crop year. Therefore, the probability of having to store grain for more than one year is higher in good crop years, so we can expect export spread levels to increase as the probability of having to store grain increases.

Given the theory background provided above, we next describe how the expected export spread is calculated when it is assumed that storage occurs for a maximum of two years. Assuming $EC$ is export capacity, $DU$ is domestic consumption, and the subscript $t$ represents time, expected export spread can be calculated as described in Table 2.

**Table 2: Expected Export Spread Calculations**

| **Production Level in year $t$ ($Y_t$)** | **Expected Export Spread Level in year $t$ ($E[B_t]$)** |
|---|---|
| Zero to ($EC_t$+$DU_t$) | Normal Export Spread ($\bar{B}$) |
| Over ($EC_t$+$DU_t$) | Normal Export Spread ($\bar{B}$)<br>+ Expected Storage Cost ($E[\sum_{i=1}^{2} SC_i]$) |

Export spread is effectively determined by the most "desperate to sell grain" farmers. Therefore, if there is positive storage, regardless of the amount, export spread increases by the expected storage cost. As the amount of storage increases, the probability of having to store for more than one year increases. This increases the expected storage cost. Expected storage cost can be formulated as:

(10) $E[\sum_{i=1}^{2} SC_i] = SC_1 + P.SC_2$

where $P$ is the probability of having to store grain for more than one year (i.e., probability of having to store grain in year 2 or more generally year $t$+1) and is calculated as:

(11) $$\mathrm{P}(Y_{t+1} > EC_{t+1} + DU_{t+1} - S_t) = 1 - F_{Y_{t+1}}(EC_{t+1} + DU_{t+1} - S_t)$$
$$= 1 - \int_{-\infty}^{EC_{t+1}+DU_{t+1}-S_t} f_{Y_{t+1}} dY_{t+1}$$

where is $Y_{t+1}$, $EC_{t+1}$, and $DU_{t+1}$ are production level, export constraint, and domestic use in year $t + 1$, and $S_t$ is storage level in year $t$. $F$ and $f$ represent PDF and cumulative distribution function (CDF), respectively. The PDF has a normal distribution:

(12) $f_{Y_{t+1}} \sim N(\mu_{t+1}, \sigma^2)$

where $\mu_{t+1}$ and $\sigma^2$ are expected production level and variance in year $t$+1. To calculate the probability in equation 11, we need the expected value and the variance of the PDF for production levels in year $t$+1. This expected value is the "expected production" level for year $t$+1. Typically export spread becomes an issue when there are significant carry-over stocks from one good year to another relatively good year. We assume farmers are aware of this fact and take it into account when forming their expectations of future production. This assumption is reflected in the AR model through the first lag.

If the production level in year $t$ is above its mean, then $\beta_1$ (%) of the difference from the mean is added to the expected production in year $t$+1. To incorporate this in the calculation of farmers' expectations, expected production in year $t$+1 is calculated as:

(13) $\mu_{t+1} = \bar{Y}_{t+1} + \beta_1(Y_t - \bar{Y}_t)$

where $\bar{Y}_t$ and $\bar{Y}_{t+1}$ are estimates of average production in years $t$ and $t$+1, respectively. Here we note that $Y_t$ is the production level in year $t$, and $\beta_1$ is the autocorrelation coefficient obtained from the AR model.

Farmers' expected losses from limited export capacity are calculated as the weighted average of above normal export spread levels, with probabilities of the occurrence of various expected export spread levels used as weights.

## DATA AND MODEL ASSUMPTIONS

We assume that grain is transported by rail (mostly) and truck from the regions of Alberta (AB), Western Saskatchewan (West SK), Eastern Saskatchewan (East SK), and Manitoba (MB) to export markets through West, East, and South ports. Descriptions of origins and destinations are presented in Table 3.

**Table 3: Origins and Destinations for Grain in the LP Model**

| Origins | Destinations |
|---|---|
| Alberta | West-Vancouver and Prince Rupert |
| West Saskatchewan | East- Thunder Bay |
| East Saskatchewan | South-Minneapolis |
| Manitoba | South- Pacific Northwest (through Minneapolis) |

Tables 4 and 5 present the data used in the model. Exportable grain supplies for each of the four regions are calculated as total production minus total domestic use, based on their historical share in total production and domestic use.

**Table 4: Export, Rail and Domestic Use Capacity for the 3 Provinces**

| | Capacity (MMT) |
|---|---|
| Export-West Coast- Vancouver and Prince Rupert | 27 |
| Export-East Coast | 11.25 |
| Export-South-Minneapolis | 1 |
| Export- South-PNW (through Minneapolis) | 3.75 |
| Rail Capacity | 40 |
| Domestic Use (MMT) | 20 |

*Source*: CGC (2015), AAFC (2015), Quorum Corporation (2015), Statistics Canada (2015b), Authors' Calculations.

Port and rail capacities are assumed to be represented by the record high 2013-14 movement levels. As reported in Table 4, total west, east, and south port export capacities add up to 43 million (metric) tonnes (MMT), whereas total rail capacity is computed as 40 MMT. Therefore, we assume that current export capacity is constrained by rail movements at a level of 40 MMT. Also, average domestic consumption of grain is estimated to be approximately 20 MMT per year. Further, we assume trucking can be used to export a maximum of 4.75 MMT of grain to the south (Quorum 2015).

If export capacity is limited, grain must be stored for at least one year. The cost of storing grain is assumed to be C$60/tonne per year (Table 5). This value reflects behavior observed in the 2013-14 and 2014-15 crop years when producers could either sell their grain at the current elevated export spread (as reported in Table 1 and Figure 2) or contract for delivery in the next crop year at a normal export spread.[9] While this storage cost is somewhat higher than intra-year storage rates, inter-year storage involves a decision to store grain from one year to the next. This can involve building additional grain storage, which might only be occasionally used by the producer.

Current rail freight rates are reported in Table 5. A C$30 fixed seaway shipping cost is added to east-moving freight rates. Freight rates for south movements to Minneapolis are obtained from Gray (1995) and inflated by 1% per year. Freight rates to the Pacific Northwest (PNW) include a $16/tonne per 160 kilometers trucking cost from Canadian origins to Minneapolis, and a $55/tonne rail freight for Minneapolis to PNW.[10]

**Table 5: Freight Rates and Storage Cost Data**

| Region | Freight Rates ($) | | | | | | One-Year Storage Cost ($) |
|---|---|---|---|---|---|---|---|
| | West Coast (Vancouver) | East Coast (Thunder Bay) | Seaway Shipping Cost | Total East Coast | South (Minneapolis) | South (PNW) | |
| **AB** | 34 | 46 | 30 | 76 | 84 | 71 | 60 |
| **West SK** | 40 | 41 | 30 | 71 | 54 | 71 | 60 |
| **East SK** | 48 | 31 | 30 | 61 | 55 | 71 | 60 |
| **MB** | 51 | 25 | 30 | 55 | 41 | 71 | 60 |

*Source*: Authors' Calculations, Quorum Corporation (2015), Gray (1995).

## RESULTS

### Future Production

Table 6 presents the results of the AR estimation on grain production. All independent variables are statistically significant and have plausible signs. We use the Schwarz Criterion to select optimal lag length. An augmented Dickey-Fuller test is used to ensure that production time series are stationary. As mentioned, the dummy variables take into account exceptionally low production levels in 1988 and 2002, and exceptionally high production level in 2013.

The estimated coefficients for the lagged dependent variables show that production levels are positively and negatively correlated with their first and second lag, respectively. The estimated coefficients for the time trend variable show that, on average, production level across the three Canadian provinces has increased by 449,267 metric tonnes a year.

**Table 6: Regression Results**

| | | |
|---|---|---|
| Provinces: | Alberta, Saskatchewan, Manitoba | |
| Dependent Variable: | Aggregate Production | |
| Estimation Method: | VAR | |
| Independent Variables | Coefficient | Standard Error |
| **Constant ($\beta_0$)** | -8.50E+08 | 2.0E+08*** |
| **Aggregate Production (Lag 1) ($\beta_1$)** | 0.302 | 0.12** |
| **Aggregate Production (Lag 2) ($\beta_2$)** | -0.299 | 0.14** |
| **Time Trend ($\beta_3$)** | 449,267 | 171,809*** |
| **Dummy for 1988 ($\beta_4$)** | -10,434,793 | 4,435,866*** |
| **Dummy for 2002 ($\beta_5$)** | -15,525,738 | 4,491,011*** |
| **Dummy for 2013 ($\beta_6$)** | 19,024,762 | 4,392,162*** |
| R-squared | 0.82 | |
| Adjusted R-squared | 0.78 | |
| F-Statistic | 21.46*** | |
| Observations after adjustment: | 36 | |

*Source*: Authors' estimation.

*Note:* Asterisks denote significance at the 5%(**), and 1%(***) levels.

**Probability Density Functions**

Using the results of the AR estimation and the PDF generation approach described in the methodology, future production is forecasted (see Table 7). Average grain production increases from approximately 55 MMT in 2016 to approximately 60 MMT in 2025 (see Table 7). The relevant probability distributions are similarly calculated from 2016 to 2025.

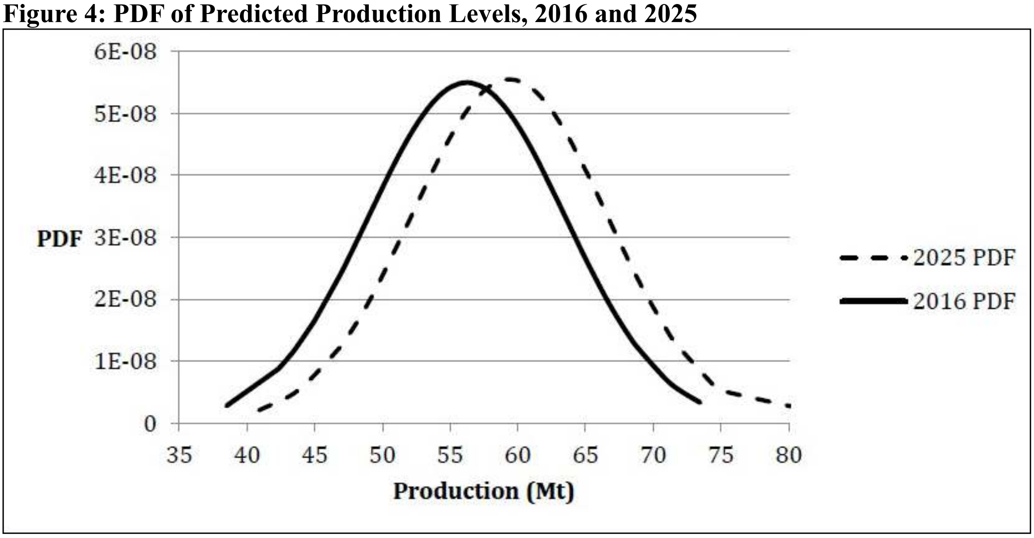
**Table 7: Production Forecast**

| Year (t) | Mean ($\bar{Y}_t$) (tonne) | Standard Deviation ($\sigma$) (tonne) |
|---|---|---|
| 2016 | 55,469,840 | 7,229,728 |
| 2017 | 55,919,107 | 7,229,728 |
| 2018 | 56,368,374 | 7,229,728 |
| 2019 | 56,817,641 | 7,229,728 |
| 2020 | 57,266,908 | 7,229,728 |
| 2021 | 57,716,175 | 7,229,728 |
| 2022 | 58,165,442 | 7,229,728 |
| 2023 | 58,614,709 | 7,229,728 |
| 2024 | 59,063,976 | 7,229,728 |
| 2025 | 59,513,243 | 7,229,728 |

*Source*: Authors' estimation.

As shown in Figure 4, the production probability distributions move to the right over time due to a systematic yield improvement of 449,267 tonnes a year.

**Figure 4: PDF of Predicted Production Levels, 2016 and 2025**




*Source*: Authors' estimation.

**Expected Export Spread**

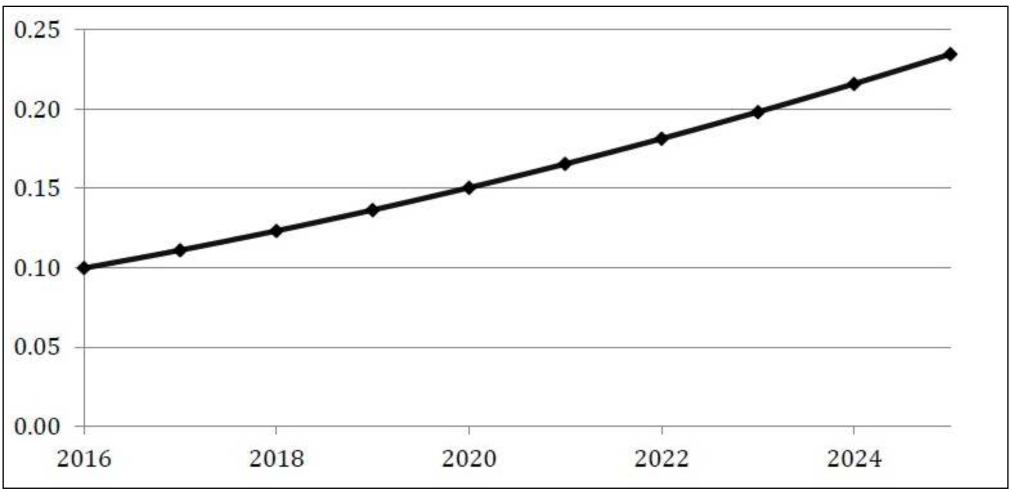
Table 8 shows the calculation of expected export spread levels for various production levels. Current rail capacity and domestic grain use add up to approximately 60 MMT, while an additional 4.75 MMT can be exported to the U.S. via trucking at a higher transportation cost. Therefore, we set expected export spread for production levels under 60 MMT equal to the normal export spread,[11] and production levels over 64.75 MMT must be stored for at least one year. Expected export spread for production levels over 64.75 MMT include expected storage cost.

**Table 8: Expected Export Spread Calculations**

| Production Level | Expected Export Spread Level |
|---|---|
| 0 to 60 MMT | Normal Export Spread |
| 60 to 64.75 MMT | Freight to South |
| Over 64.75 MMT | Normal Export Spread + Expected Storage Cost |

Since production levels increase over time, the probability of producing over the limit increases as well. This generates an increase in expected storage cost and, thereby, average expected export basis. Figure 5 illustrates the change in the probability that the region produces over 64.75 MMT of grain. This likelihood rises from 10% in 2016 to 23% in 2025.

**Figure 5: Increase in Probability of Producing over Limit over Time**




*Source*: Authors' estimation.

Expected export spread levels and rents are then calculated for a range of production levels in 2016 to 2025. Table 9 presents results for the last year forecasted, 2025. Expected export spread levels are calculated for each segment of the distribution. Recall that the average expected export spread is the weighted average of export spread levels reported for each segment, with weights the probabilities of production levels within each segment, as reported in column 2.

Critically, total expected export rents represent farmers' total potential future loss. This amount is effectively a transfer from farmers to grain companies. But some producers may be able to avoid the excess export spread by using forward-price and forward-contract deliveries. Also, if the limited export capacity causes insecure delivery schedules and consequently has a positive effect on FOB port prices, then a part of the total export rent is borne by international customers of Canadian grain.[12] So in 2025, the average expected export spread ranges from C$64 to C$81 per tonne for the three Canadian provinces (Table 9). We note that this amount is C$30 per tonne above normal and historical export basis, and implies expected export rents of over C$1.4 billion.

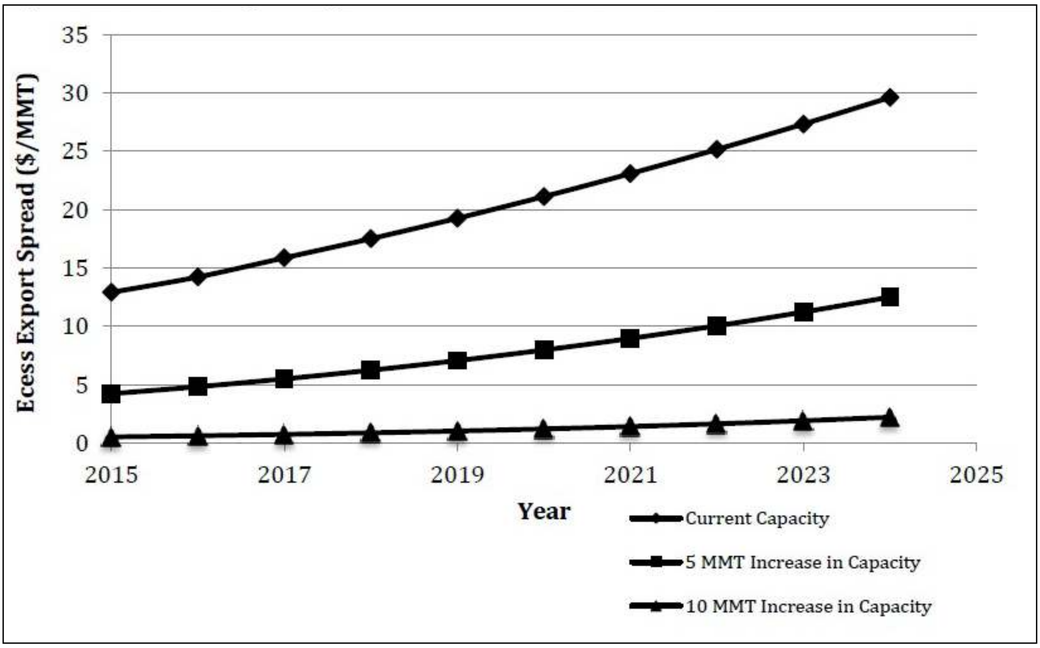
**Table 9: Expected Export Spread in 2025**

| 1 | 2 | 3 | 4 | Expected Export Spread ($/tonne) | | | |
|---|---|---|---|---|---|---|---|
| Production Range ($Y_t$) (MMT) | Prob. of 1 | Deliveries (MMT) | Prob. of over limit production next year | AB | West SK | East SK | MB |
| 33-35 | 0.000 | 14 | 0.50 | 34 | 39 | 48 | 51 |
| 35-37 | 0.001 | 16 | 0.50 | 34 | 39 | 48 | 51 |
| 37-39 | 0.001 | 18 | 0.50 | 34 | 39 | 48 | 51 |
| 39-41 | 0.003 | 20 | 0.50 | 34 | 39 | 48 | 51 |
| 41-43 | 0.006 | 22 | 0.50 | 34 | 39 | 48 | 51 |
| 43-45 | 0.011 | 24 | 0.50 | 34 | 39 | 48 | 51 |
| 45-47 | 0.019 | 26 | 0.50 | 34 | 39 | 48 | 51 |
| 47-49 | 0.031 | 28 | 0.50 | 34 | 39 | 48 | 51 |
| 49-51 | 0.047 | 30 | 0.50 | 34 | 39 | 48 | 51 |
| 51-53 | 0.064 | 32 | 0.50 | 34 | 39 | 48 | 51 |
| 53-55 | 0.082 | 34 | 0.50 | 34 | 39 | 48 | 51 |
| 55-57 | 0.098 | 36 | 0.50 | 34 | 39 | 48 | 51 |
| 57-59 | 0.108 | 38 | 0.50 | 34 | 39 | 48 | 51 |
| 59-61 | 0.110 | 40 | 0.50 | 34 | 39 | 48 | 51 |
| 61-63 | 0.104 | 42 | 0.58 | 54 | 59 | 68 | 71 |
| 63-65 | 0.091 | 44 | 0.71 | 54 | 59 | 68 | 71 |
| 65-67 | 0.074 | 46 | 0.82 | 146 | 151 | 160 | 163 |
| 67-69 | 0.055 | 48 | 0.90 | 149 | 155 | 164 | 167 |
| 69-71 | 0.039 | 50 | 0.95 | 152 | 157 | 166 | 169 |
| 71-73 | 0.025 | 52 | 0.98 | 153 | 158 | 167 | 170 |
| 73-75 | 0.015 | 54 | 0.99 | 154 | 159 | 168 | 171 |
| 75-77 | 0.008 | 56 | 1.00 | 154 | 159 | 168 | 171 |
| 77-79 | 0.004 | 58 | 1.00 | 154 | 159 | 168 | 171 |
| 79-81 | 0.002 | 60 | 1.00 | 154 | 159 | 168 | 171 |
| Average Expected Export Spread ($/tonne) | | | | 64 | 69 | 78 | 81 |
| Average Excess Export Spread ($/tonne) | | | | 30 | 30 | 30 | 30 |
| **Expected Export Rents ($)** | $1,432,574,902 | | | | | | |

*Source*: Authors' estimation.

Figure 6 is a graphical representation of excess export spread levels under three hypothetical scenarios. Scenario 1 corresponds to the current rail situation and, subsequently, comprises a total capacity limit of 40 MMT. Scenarios 2 and 3 assume a 5 and a 10 MMT expansion in both rail and total GH&T system capacity, respectively. In fact, excess export spread levels fall significantly when export capacity is expanded. At current capacity levels, excess export spread reaches C$30/MMT by 2025. Contrast this with a 10 MMT capacity improvement by 2025. In this case, excess export spread remains under C$3/MMT.

**Figure 6: Excess Export Spread Under Three Scenarios**




*Source*: Authors' estimation.

Finally, Table 10 summarizes total expected export rents for the 2016-25 period under the three capacity scenarios. The net present value (NPV) of expected export rents under current export capacity is estimated to be over C$5.6 billion for the 10-year estimation period. Assuming 20% of the exportable supplies can avoid an above normal export spread through forward-pricing, forward-contracting, or movement south of the border, farmer losses from limited export capacity are still about C$4.5 billion. Note as well that expected export rents decrease by approximately C$3.4 billion when the export capacity is improved by 5 MMT, while a 10 MMT increase in export capacity generates a C$5.3 billion decrease in expected export rents.

**Table 10: Expected Loss 2016-2025**

| Year | Expected Loss ($) Scenario 1 (Current Capacity) | Scenario 2 (5 MMT Increase in Total Capacity) | Scenario 3 (10 MMT Increase in Total Capacity) |
|---|---|---|---|
| 2016 | 612,253,621 | 213,360,937 | 29,251,864 |
| 2017 | 674,883,834 | 244,199,402 | 34,773,396 |
| 2018 | 755,710,573 | 278,618,174 | 41,204,065 |
| 2019 | 835,682,544 | 316,886,078 | 48,667,978 |
| 2020 | 921,265,020 | 359,269,105 | 57,298,871 |
| 2021 | 1,012,441,476 | 406,025,641 | 67,236,966 |
| 2022 | 1,109,284,116 | 457,397,255 | 78,643,497 |
| 2023 | 1,211,624,708 | 513,636,651 | 91,684,940 |
| 2024 | 1,319,436,821 | 574,936,653 | 106,525,055 |
| 2025 | 1,432,574,902 | 641,473,029 | 123,364,512 |
| NPV*($) | 5,642,797,981 | 2,239,295,615 | 368,928,292 |

* Net Present Value (NPV) is calculated assuming a 10% discount rate.
*Source*: Authors' estimation.

It is worth noting that this study does not explicitly take into account farmers' potential loss from the limited Canadian West Coast (i.e., Vancouver) port capacity. The Canadian west coast is a relatively less expensive export point for prairie grain, but the port is currently constrained to approximately 27 MMT (Quorum 2015). Exportable supply levels above 27 MMT must therefore be moved through other ports, but at a higher transportation cost. Future studies will need to quantify as well the cost to Canadian farmers stemming from increasingly insufficient West Coast export (port storage and handling) capacity.

## CONCLUSIONS AND POLICY OPTIONS

We have highlighted that limited grain export capacity in Canada reduces western Canadian crop prices but at a substantial cost to grain growers and the regional economy, while creating opportunities for grain handlers and processors. The ex post analysis done to begin this analysis estimates Canadian prairie farmers' losses attributable to payments of excess export spreads in the 2013-14 and 2014-15 crop years to be at least C$5 billion. We offer that this is a significant transfer from farmers to grain handlers.

The ex ante analysis indicated that current production trends, without any improvements in grain export capacity, increase the future likelihood of capacity constrained grain markets in Canada. To this end, the NPV of expected congestion related export rents, losses primarily borne by farmers, is estimated to be C$5.6 billion over the next 10-year (2016-2025) period. Using these estimates, we also find that a 10 MMT increase in annual export capacity essentially eliminates these rents.

Export capacity improvement can be achieved through a variety of solutions. Increased rail capacity seems essential, but any expansion must be accompanied by an improvement in handling coordination, especially at the port grain terminals. We expect that congestion at grain export positions (i.e., Vancouver) and over supporting rail lines is another potentially important issue that the grain handling system will continue to face unless increases in rail capacity, port capacity, and handling coordination go hand in hand.[13]

Regarding transportation costs, the Canadian MRE policy on grain movement caps the average revenue per ton-mile of grain moved by the railways. This policy eliminates the ability to sell less rail service at higher freight rates, yet also gives the railways strong incentives to lower their costs per ton-mile and to move the volume offered to them (Nolan and Peterson 2015). But the MRE policy is imperfect to the extent that it provides very little incentive for railways to invest in additional capacity, to move grain during higher cost periods (winter), or to provide properly scheduled service. Additional research is needed to examine whether and how the MRE formula might be modernized to create incentives for the railways to increase their capacity.

Finally, more research is needed to examine practical solutions to increase competition in the western Canadian grain handling and transportation system. More competition in the grain supply chain is one way to help optimize existing and future capacity utilization in the Canadian grain handling system.

**Endnotes**

1. In 2014, a large U.S. grain crop was associated with similar problems in the PNW.

2. Other studies based in Canada, such as that of Gray (2015), have often used the term "export basis." This created some confusion among reviewers so we adopted this terminology.

3. As the largest volume port, we assume that Vancouver FOB minus the elevator bid prices are a representative measure of the export spread for grains in western Canada.

4. This differs from the grain transportation situation in the United States, where the railways capture most of the rents (i.e., from capacity constraints) by raising grain rates or auctioning off rail car shipments to the highest bidder.
5. See Richardson (1978).

6. These periods are used because Statistics Canada does surveys of farm stocks to provide more accurate estimates of farm sales during these intervals.

7. This paper performs an inter-year analysis of storage and shipment capacity rather than an inter-seasonal analysis. Canadian shipments from western Canada to the West Coast are distributed over all four seasons quite equally. In fact, July appears to be the only month of the year in which the system would generally have a short break before harvest. More information regarding the distribution of shipments can be found in Table 2B-1 of Quorum 2013-14 Annual Report (Quorum 2015).
8. Because expected capacity is significantly above expected production, the joint probability of storing three consecutive years became less than 1% of expected storage costs and therefore was incorporated into the simulation model.

9. Notably, when the basis spiked in February 2014, the dismal export performance to that date created expectations that the 2013 crop would create at least two years of larger carryover stocks (Gray 2015).

10. It is worth noting that there may have been other unlicensed shipments to the U.S. via trucking that could not be accurately measured and included in this study.

11. In this study, we define normal basis as the freight rate not including the handling cost.

12. Insecure delivery schedules may also result in demurrage payments made by grain companies to the international buyers. For more on demurrage costs in Canadian grain marketing, see Wilson and Dahl (2000).

13. Fan et al. (2012) investigated several aspects of such congestion in the U.S.

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**References**

Agriculture and Agri-Food Canada (AAFC). *Canada: Outlook for Principal Field Crops, 2015-06-18,* 2015. Retrieved July 03, 2015, from AAFC: http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/crops/crops-market-information-canadian-industry/canada-outlook-for-principal-field-crops/?id=1378743094676

Agriculture and Agri-Food Canada (AAFC). *Weekly Price Summary,* 2014. Retrieved January 27, 2015, from AAFC: http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and- market-information/by-product-sector/crops/crops-market-information-canadian-industry/weekly-price-summary/?id=1378745200250

Allen, G. "Economic Forecasting in Agriculture." *International Journal of Forecasting* 10 (1), (1994): 81-135.

Ardeni, P. G. "Does the Law of One Price Really Hold for Commodity Prices?" *American Journal of Agricultural Economics* 71(3), (1989): 661-69.

Baulch, R. "Spatial Price Equilibrium and Food Market Integration." Dissertation (PhD). Food Research Institute, Stanford, 1994.

Billingsley, P. *Probability and Measure.* John Wiley and Sons, New York, 1979.

Brennan, M. J. "The Supply of Storage." *American Economic Review* 48(1), (1958):50-72.

Campbell, C., R. Zentner, S. Gameda, B. Blomert, and D. Wall. "Production of Annual Crops on the Canadian Prairies: Trends during 1976-1998." *Canadian Journal of Soil Sciences* 82(1), (2002): 45-57.

Canadian Grain Commission (CGC). *Canadian Grian Exports,* 1997-2015, 2015 Retrieved January 27, 2015, from CGC: https://www.grainscanada.gc.ca/statistics-statistiques/cge-ecg/cgem-mecg-eng.htm

Caves, D., K. Eakin, and A. Faruqui. "Mitigating Price Spikes in Wholesale Markets through Market-Based Pricing in Retail Markets." *The Electricity Journal* 13(3), (2000): 13-23.

Efron, B., and R. Tibshirani. *An Introduction to the Bootstrap*. Chapman & Hall/CRC, Washington, D.C., 1993.

Ehrich, R.L. "Cash-Futures Price Relationships for Live Beef Cattle." *American Journal of Agricultural Economics* 51(1), (1969):26-40.

Fackler, P. "Spatial Price Analysis: A Methodological Review." Mimeo., North Carolina State University, 1996.

Faminow, M., and B. Benson. "Integration of Spatial Markets." *American Journal of Agricultural Economics* 72(4), (1990):49-62.

Fan, L., W.W. Wilson, and B.L. Dahl. "Congestion, Port Expansion and Spatial Competition for US Container Imports." *Transportation Research Part E* 48(6), (2012):1121–1136.

Goodwin, B.K., T. J. Grennes, and M. K. Wohlgenant. "A Revised Test of the Law of One Price." *American Journal* of *Agricultural Economics* 72(3), (1990): 682-93.

Goodwin, B.K., and T.C. Schroeder. "Price Dynamics in International Wheat Markets." *Canadian Journal of Agricultural Economics* 39(2), (1991): 237-254.

Greene, W. *Econometric Analysis, 5th ed.* Pearson Education, Upper Saddle River, 2002.

Gray, R. *Basis Deductions for CWB Deliveries in Western Canada: A Proposal for Basis Calculations.* Winnipeg: Canadian Wheat Board, 1995.

Gray, R. *The Economic Impact of Elevated Export Basis Levels on Western Canadian Grain Producers.* Saskatoon: Saskatchewan Wheat Development Commission, 2015.

McKenzie, A.M. "The Effects of Barge Shocks on Soybean Basis Levels in Arkansas: A Study of Market Integration." *Agribusiness* 21 (1), (2005):37–52.

Muth, J. "Rational Expectations and the Theory of Price Movements." *Econometrica, 29* (3), (1961):315-335.

Nolan, J., and S. Peterson. "Grain Handling and Transportation Policy in Canada: Implications for the United States," *Choices: The magazine of food, farm and resource issues 30(3)*, (2015):1-7.

Quroum Corporation. *2013-14 Annual Report,* 2015. Retrieved August 20, 2015, from Quroum Corporation: http://www.quorumcorp.net/reports.html

Richardson, D. "Some Empirical Evidence on Commodity Arbitrage and the Law of One Price." *Journal of International Economics* 8(2), (1978):341-51.

Sarwar, G., and D.G. Anderson. "Railroad Rate Deregulation and Uncertainty of Farm-level Prices for Corn." *American Journal of Agricultural Economics* 71(4), (1989):883-890.

Samuelson, P.A. "Spatial Price Equilibrium and Linear Programming." *The American Economic Review* 42(3), (1952): 283-303.

Saskatchewan Ministry of Agriculture. *Market Trends,* 2014. Retrieved September 2015, from http://www.agriculture.gov.sk.ca/MarketTrends

Schmitz, A., and H. Furtan. *Canadian Wheat Board: Marketing in the New Millennium*. Canadian Plains Research Centre, Regina, Saskatchewan, 2000.

Sexton, R., C. Kling, and H. Carman. "Market Integration, Efficiency of Arbitrage and Imperfect Competition: Methodology and an Application to U.S. Celery." *American Journal of Agricultural Economics* 7(2), (1991):568-80.

Spiller, P., and R. Wood. "The Estimation of Transaction Costs in Arbitrage Models." *Journal of Econometrics* 39(3), (1988):309-26.

Statistics Canada. *Estimated Areas, Yield and Production of Principal Field Crops by Small Area Data Regions, in Metric and Imperial Units, Annual (CANSIM Table 001-0071)*, 2015a. Retrieved June 3, 2015, from Statistics Canada: http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=10071

Statistics Canada. *Farm Supply and Disposition of Grains as of March 31, July 31, August 31 (soybeans only) and December 31 (CANSIM Table 001-0043),* 2015b. Retrieved January 27, 2015, from Statistics Canada: http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=10043

Statistics Canada. *Estimated Areas, Yield, Production and Average Farm Price of Principal Field Crops, in Metric Units (CANSIM Table 001-0010),* 2014. Retrieved January 27, 2015, from Statistics Canada: http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=10010

Tadasse, G., B. Algieri, M. Kalkuhl, and J. von Braun. "Drivers and Triggers of International Food Price Spikes and Volatility." M. Kalkuhl, J. von Braun, and M. Toreto eds. *Food Price Volatility and Its Implications for Food Security and Policy*. Springer International Publishing (2016): 59-82.

Takayama, T., and G. Judge. "Spatial Equilibrium and Quadratic Programming." *Journal of Farm Economics* 46(1), (1964):67-93.

Tilley, D.S., and S.K. Campbell. "Performance of the Weekly Gulf-Kansas City Hard-Red Winter Wheat Basis." *American Journal of Agricultural Economics* 70(4), (1988):929-935.

United States Wheat Associates (USWA). *Weekly Price Report,* 2014. Retrieved January 27, 2015, from USWA: http://www.uswheat.org/

Von Braun, J., J. Lin, and M. Torero. "Eliminating Drastic Food Price Spikes–A Three Pronged Approach for Reserves." *Washington DC: IFPRI,* (2009).

Weymar, F.H. "The Supply of Storage Revisited." *American Economic Review* 56(5), (1966):1226-1234.

Williams, J.C., and B.D. Wright. *Storage and Commodity Markets*. Cambridge University Press, New York, NY, 1991.

Wilson, W.W., and B.L. Dahl. "Logistical Strategies and Risks in Canadian Grain Marketing." *Canadian Journal of Agricultural Economics* 48 (2), (2000):141–160.

Working, H. "The Theory of the Price of Storage." *American Economic Review* 39(6), (1949):1254-1262.

**_Book Review_**

*Hirsh, Max. Airport Urbanism:* Infrastructure and Mobility in Asia*. Minneapolis: University of Minnesota Press, 2016. ISBN 978-0-8166-9610-9.*

# Airport Urbanism

**by Shannon Sanders McDonald**

Transportation is one of the most important aspects in design; often referred to as mobility, the ability to move where one needs to go for work and pleasure is an assumed part of modern life and is a generator of urban and architectural form. Currently, we are seeing many new forms of mobility emerge, such as car share and driverless cars, as transportation and urban relationships have become strained in many locations. Within these urban discussions of challenged mobility, travel by plane is not commonly discussed. However, airplanes and airports can be the most important link of a journey for some, one that creates new urban challenges. The book, *AIRPORT Urbanism: Infrastructure and Mobility in Asia,* by Max Hirsh explores the airport and urban relationships currently in use in Asia.

Airports have typically been designed for an upwardly mobile traveler to connect to any place in the world in a timely fashion. Airports, soaring architectural visions that represent the modern connection to the world and aspirations of a place, now define the future that has arrived for many. Planes provide the ability to travel far distances, beyond state and country boundaries, for work and pleasure, thus creating our global society, which has become everyday for many. As Max Hirsh explains, this mobility was first seen among international business people and tourists, so airports were designed to meet their travel needs, providing places to exchange money, rest, eat and shop while emotionally preparing the traveler to enter new worlds. Amazing architectural accomplishments, airports are a grand vision of modern life. However, travelers must still find their way to the airport from within their existing urban environments, as airports are not typically designed within urban centers, and older ones now surrounded by growth are no longer able to serve international travel. Airports are large sprawling complexes meeting every need of the planes and people who use them: space for landing and takeoff, gates, fueling and baggage handling, shops and restaurants, restrooms, airline check-in, customs and border crossings, and now safety/security checks for everyone. They also serve cargo and mail needs, and are often the major economic engine of the community. A large international airport, such as Atlanta Hartsfield-Jackson airport, has 4,700 acres to accommodate all of these programs, naturally separating the airport complex from its urban center. Most people do not want to live near airports or within the flight patterns of planes because of noise and visual intrusion, and often codes limit many building types and building heights near airports. These complexes are not walkable internally nor do they provide the ability for passengers to walk to the airport. Connections to highways, rail, and transit systems are crucial, while internal movement systems such as movable walkways and people movers are used to navigate within the ever expanding airport.

New urban ideas have emerged from these challenges, such as, recently, the aerotropolis (an aviation metro area or sometimes known as an airport commerce city, an urban area near an airport). This concept is based on large scale visions of sports, commercial, and recreation centers that bring crowds of people to one location for a specific activity. This is in contrast to a thriving urban area where people enjoy living, working, walking, and being within a complex group of building types, uses, and urban spaces. An urban center is a more spontaneous interactive, interconnected place—as contrasted with traveling by plane to an activity area such as an aerotropolis. One is a local vision and the other is international. The overlap of urban areas and airport mobility is what Max Hirsh is describing in his book as now occurring in Asia. This type of interconnection has come about from a bottom-up approach to meeting the needs of the everyday person now using planes, not those of the international business traveler or upscale tourist.

Hirsh's book, at the broader level, addresses the "urban implications of paradigmatic social and technological shifts-in particular as they relate to the accelerated cross-border movement of goods, people, capital and ideas." He describes the new flying public: budget tourists, retirees, and migrant workers using visual, archival, and ethnographic approaches from multiple urban disciplines. He has conducted research about transportation in a rapidly developing area of the world – China and Southeast Asia. Autobiographical vignettes begin and end the text, reflecting Hirsh's own personal experiences with this type of mobility. He noticed over time more security checks and fewer passport controls, along with construction, construction, and more construction. The focus of the book is on five cities in East and Southeast Asia – Bangkok, Hong Kong, Kuala Lumpur, Shenzhen, and Singapore. For example, Hong Kong, within three short decades experienced a tenfold increase in passenger air traffic and overhauled its airport infrastructure, creating what is now mainly an international airport. Meanwhile, the well-publicized Airport Express (the high-speed airport train), one of the innovative and amazing infrastructure systems connecting Hong Kong and the airport, is used by only 15% of airport passengers. The new flying public relies on other options that move passengers more cheaply from a wider range of locations around the city, for example, SKY PIER, a cross boundary ferry terminal creating a "transborder" system.

Max Hirsh uses the term *nouveaux globalizes* to define this group of people who are accounting for the double-digit year-on-year increases in air traffic in this area. They have had profound implications for airport design in ways not recognized by glamorous star architecture airport design strategies. The additions and changes to the urban infrastructure servicing this large and growing population have previously not been studied, and this book provides an excellent description and analysis of these systems, which have "radically reordered the cross-border flow of goods and people in the 'Pearl River Delta.'" What was not understood by airport elite consultants was that the everyday traveler represented a wider socioeconomic spectrum and a wider dispersion throughout the city. They also had different travel needs and patterns of travel, such as a Filipino cleaning women working in Hong Kong. The leap in individual mobility experienced now by almost everyone, often frequently for job opportunities, has been enabled by continuing advances in transportation and telecommunication. Often these travelers are considered "transborder" air passengers, as during parts of their journey they are literally in non-places, neither in China or Hong Kong but rather in an "extraterritorial maritime corridor that functions as an extension of international airspace." The architecture has truly become "placeless, with no social or aesthetic function" and "a strange set of political and economic contradictions that led to its genesis." Hirsh believes that his study shows the "vanguard role that such transborder infrastructure systems play in both anticipating and advancing systemic changes in the global flow of goods, people and information."

Hirsh provides very detailed descriptions of the existing systems, spaces, and flow of people as they navigate hallways, busses, ferries, and trains as part of their Asian airport travel experience. In the new airport, the city is linked in unassuming and often maze-like ways, as checking into your flight can now occur in a booth at a local shopping mall. The book describes the quickly expanding everyday user demographic and the current travelers' ad-hoc transportation conditions, with the traveler often not even seeing the exterior of the airport. All the while, better solutions are not being explored. In the early 2000s, Atlanta's Hartfield-Jackson International airport had explored creating a check-in system that began at metro stations along the link to the airport. Theoretically, one could have checked one's luggage, and checked into one's flight miles away from the airport – but the events of 9/11 and security screening ended this approach. Other technological ideas are being explored to create secure check-in of luggage and people even from remote locations, including a vehicle that could pick you up at your home and travel directly into the airport, depositing you at your gate with all systems complete.

Referencing texts such as *Splintering Urbanism* and *The Rise of the Network Society* that have described new airports as designed for a global managerial elite, scholars and architects discuss airports as non-places, areas separated from the flow of everyday life. However, Max Hirsh has brought to our attention an entirely new urban system of travel based upon "mobility, infrastructure and the everyday." Grounding his observations and experiences within these emerging urban corridors of home to airport, he briefly discusses historical transportation transitions, such as the automobile, and their effect on urban design. He takes up the fundamental question of how changes in human mobility lead to shifts in urban form – also connecting geographic mobility and social mobility with spatial and conceptual understandings of our modern world.

While the relationship of mobility to urban form is studied intensively by architects and urban planners, this newly emerging protected flow of people across borders while just going to and from an airport is presenting new potentials of power and purpose. Hirsh, linking mobility and the study of the everyday, has opened up the deeper analysis of spatial changes that can have broader urban social and political implications. The book takes up connections of home to airport, drawing on design theorists, such as Melvin Webber and Henri Lefebvre, who have tried to decode such connections for the everyday traveler. This focus advances the discussion of modern mobility and communication and of their impact on spatial change.

Hirsh concludes his detailed analysis of these systems by referring to writers and theorists such as Kevin Lynch and Margaret Crawford. Kevin Lynch favors incremental design, rather than the grand gesture of the airport, as the approach best suited to urban environments; Margaret Crawford brings out how daily life has been interrupted on a grand scale and how the pick-up of movement has fundamentally changed the organization of space. Hirsh also acknowledges anthropologist Pal Nyir, stating that "travel and displacement heighten people's susceptibility to new ideas and interpretations of the world, and relax the boundaries of what is socially acceptable." Air travel has come to dominate mobility in this region of cross-border transportation and "has not developed an aesthetic vocabulary that appropriately reflects the new regime of hypermobility," nor have the changes in public policy been coordinated with innovations in urban design. As Hirsh says, "architects and urban planners will be much better equipped to engage with these societal transformations if *scholars* begin to participate more actively in public conversations about urban development," thereby drawing attention to broader changes in global mobility patterns and to implications to urban form, these having been often overlooked by policymakers and designers. I could not agree more.

***Shannon Sanders McDonald*** *is an assistant architecture professor at Southern Illinois University. Her research and areas of interest are with emerging movement technologies and their impact on the built environment. She has written and spoken extensively on these areas and written a book* – The Parking Garage: Design and Evolution of a Modern Urban Form. *An exhibit based on the book was on display at the National Building Museum. She has also practiced architecture with a focus on public buildings. She is licensed in four states, LEED and NCARB certified. She holds a master of architecture from Yale University, 1992; a master of fine arts from Maryland Institute of Art, 1980, and bachelor of science degrees in art teacher education and in psychology from Towson State University, 1976.*

# Transportation Research Forum

## Statement of Purpose

The Transportation Research Forum is an independent organization of transportation professionals. Its purpose is to provide an impartial meeting ground for carriers, shippers, government officials, consultants, university researchers, suppliers, and others seeking an exchange of information and ideas related to both passenger and freight transportation. The Forum provides pertinent and timely information to those who conduct research and those who use and benefit from research.

The exchange of information and ideas is accomplished through international, national, and local TRF meetings and by publication of professional papers related to numerous transportation topics.

The TRF encompasses all modes of transport and the entire range of disciplines relevant to transportation, including:

| | |
|---|---|
| Economics | Urban Transportation and Planning |
| Marketing and Pricing | Government Policy |
| Financial Controls and Analysis | Equipment Supply |
| Labor and Employee Relations | Regulation |
| Carrier Management | Safety |
| Organization and Planning | Environment and Energy |
| Technology and Engineering | Intermodal Transportation |
| Transportation and Supply Chain Management | |

## History and Organization

A small group of transportation researchers in New York started the Transportation Research Forum in March 1958. Monthly luncheon meetings were established at that time and still continue. The first organizing meeting of the American Transportation Research Forum was held in St. Louis, Missouri, in December 1960. The New York Transportation Research Forum sponsored the meeting and became the founding chapter of the ATRF. The Lake Erie, Washington D.C., and Chicago chapters were organized soon after and were later joined by chapters in other cities around the United States. TRF currently has about 300 members.

With the expansion of the organization in Canada, the name was shortened to Transportation Research Forum. The Canadian Transportation Forum now has approximately 300 members.

TRF organizations have also been established in Australia and Israel. In addition, an International Chapter was organized for TRF members interested particularly in international transportation and transportation in countries other than the United States and Canada.

Interest in specific transportation-related areas has recently encouraged some members of TRF to form other special interest chapters, which do not have geographical boundaries – Agricultural and Rural Transportation, High-Speed Ground Transportation, and Aviation. TRF members may belong to as many geographical and special interest chapters as they wish.

A student membership category is provided for undergraduate and graduate students who are interested in the field of transportation. Student members receive the same publications and services as other TRF members.

## Annual Meetings

In addition to monthly meetings of the local chapters, national meetings have been held every year since TRF's first meeting in 1960. Annual meetings generally last three days with 25 to 35 sessions. They are held in various locations in the United States and Canada, usually in the spring. The Canadian TRF also holds an annual meeting, usually in the spring.

Each year at its annual meeting the TRF presents an award for the best graduate student paper. Recognition is also given by TRF annually to an individual for Distinguished Transportation Research and to the best paper in agriculture and rural transportation.

Annual TRF meetings generally include the following features:

- Members are addressed by prominent speakers from government, industry, and academia.
- Speakers typically summarize (not read) their papers, then discuss the principal points with the members.
- Members are encouraged to participate actively in any session; sufficient time is allotted for discussion of each paper.
- Some sessions are organized as debates or panel discussions.

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6. The abstract should briefly describe the contents, procedures and results of the manuscript, not its motivation, and should not exceed 100 words.

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