TECHNICAL SKILLS REQUIRED FOR TRANSPORTATION ENGINEERING PROFESSIONALS

Prepared by

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ABSTRACT

Having a safe, efficient, accessible, and environmentally-conscious transportation system is vital for the economic development of any nation. Newest technologies in the transportation realm require different set of skills for these specialized engineering professionals. Universities have to continually evaluate if their undergraduate academic offerings in Civil Engineering satisfy the industry requirements in the transportation field. The main objective of this study is to identify the knowledge depth and technical skills currently required for young professionals in the transportation engineering discipline. Results from the students' surveys show that students prefer topics such as Transportation Planning and Urban Engineering, while they feel the courses prepare them best in Highway Geometric Design topics. The interviews made to employers indicate that the industry's current priorities are Infrastructure Management and Transportation Planning and Mass Transportation (in the future). The identification of these skills can be useful to recognize the needs of the industry and suggest improvements to the academic offerings in transportation engineering of local universities. The long-term goal is to help universities to continue providing competent specialists capable of obtaining employment and compete with experienced professionals, as well as being able to provide innovative solutions to the current and future transportation problems. It was concluded that the current most important skill in the transportation discipline is the use of technology.

RESUMEN EJECUTIVO

Tener un sistema de transporte seguro, eficiente, accesible y eco-amigable es vital para el desarrollo económico de cualquier nación. Las últimas innovaciones tecnológicas en el campo del transporte requieren nuevas habilidades de los profesionales especializados de la ingeniería. Las universidades tienen que evaluar si la oferta académica sub-graduada en Ingeniería Civil cumple los requisitos de la industria en el campo del transporte. El objetivo principal de este estudio es identificar la profundidad de conocimientos y habilidades técnicas en la actualidad requeridas a los jóvenes profesionales en la disciplina de la ingeniería del transporte. Los resultados de las encuestas a los estudiantes muestran que estos prefieren temas como la Planificación de Transportación e Ingeniería Urbana, sin embargo, sienten que los cursos los prepararan mejor en temas como Diseño Geométrico de Carreteras. Las entrevistas realizadas a los empresarios indican que las prioridades actuales de la industria son Gestión de Infraestructura, Planificación del Transporte y Medios de Transporte (en el futuro). La identificación de estas habilidades será útil para reconocer las necesidades de la industria y sugerir mejoras a la oferta académica en ingeniería de transporte de las universidades locales. El objetivo a largo plazo es ayudar a las universidades a que sigan proporcionando especialistas competentes capaces de obtener un empleo y competir con profesionales con experiencia, además de ser capaz de proveer soluciones innovadoras a los problemas de transporte actuales y futuras. Se concluyó que una de las destrezas mas importantes en la disciplina de la transportación es el uso de la tecnología.

I dedicate this project…

To God Almighty, Who has provided me knowledge, strength, and life.

To my parents, Pedro J. Vélez-Ramos and Zulma J. Rodríguez-Muñoz, my sister Sheyla G. Vélez-Rodríguez, and the rest of my family, who have believed in me from the beginning of my career and have provided unconditional support.

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

ACRONYMS

AAR	Association of American Railroads
AASHTO	American Association of State Highway and Transportation Officials
ABET	Accreditation Board for Engineering and Technology
ACT	Autoridad de Carreteras y Transportación (Puerto Rico Highway and Transportation Authority)
AGC	American General Contractors
AMA	Autoridad Metropolitana de Autobuses (Metropolitan Bus Authority)
APTA	American Public Transit Association
APWA	American Public Works Association
ARTBA	American Road & Transportation Builders Association
ASCE	American Society of Civil Engineers
ATI	Alternativa de Transporte Integrado (Integrated Transportation Alternative)
BEE	Board of Examiners of Engineers
CIAPR	Colegio de Ingenieros y Agrimensores de Puerto Rico (College of Engineers and Surveyors of Puerto Rico)
COOP	Cooperative Education Program
CPM	Construction Project Management
DTOP	Departamento de Transportación y Obras Públicas (Department of Transportation and Public Works)
EIT	Engineer in Training
ETC	Electronic Toll Collection
FE	Fundamental Engineering (Exam)

FHWA	Federal Highway Administration
GIS	Geographic Information Systems
GIT	Georgia Institute of Technology
HCM	Highway Capacity Manual
HCS	Highway Capacity Software
HSM	Highway Safety Manual
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
LLP	Limited Liability Partnership
MAP-21	Moving Ahead for Progress in the 21st Century
MST	Missouri University of Science & Technology
MUTCD	Manual on Uniform Traffic Control Devices
NCEESS	National Council of Examiners for Engineering and Surveying
NYU-Poly	Polytechnic Institute of New York University
ORT	Open Road Toll
PE	Professional Engineering Exam
POT	Port Mapping Protocol
PPP	Public–Private Partnership
PR	Puerto Rico
PSC	Professional Services Corporation
PUPR	Polytechnic University of Puerto Rico
TMC	Transportation Management Center
TMS	Transportation Management Systems

TRB	Transportation Research Board
TU	Tren Urbano
TUO	Tren Urbano Office
UARK	University of Arkansas
UC Denver	University of Colorado at Denver
UCB	University of California at Berkeley
UH	University of Houston
UIUC	University of Illinois at Urbana-Champaign
UPRM	University of Puerto Rico at Mayagüez
URI	University of Rhode Island
US	United States
USDOT	U.S. Department of Transportation
USU	Utah State University
WSDOT	Washington State Department of Transportation
WSU	Washington State University

DEFINITIONS

1. ***Ability*** is the capability of cunning to achieve an activity.[1]
2. ***Capabilities*** are potential possibilities a person has to perform an action.[1]
3. ***Professional Skill*** is the ability to employ the knowledge and discipline in a workplace.[2]
4. ***Skill*** is an ability to perform an activity.[1]
5. ***Technical Skill*** is a proficiency in a specific field of study.[2]
6. ***Transportation Infrastructure*** is the physical component of transportation facilities or systems in a location.[3]
7. ***Transportation Systems*** is a system that involves vehicle, guide way, and operation which allows the movements of people and goods.[3]

[1] Rivas, R. (2012). What are the skills, abilities, capabilities, attitude and aptitude?

[2] Crebert, G., Patrick, C.-J., Cragnolini, V., Smith, C., Worsfold, K., & Webb, F. (2011). Professional Skills Toolkit. (Retrieved from the World Wide Web 4th April, 2011)

[3] Definition composed of various references.

1. INTRODUCTION

Latest technology innovations in the transportation field require new minimum set of skills for the specialized engineering professionals. Universities have to continually evaluate if the current undergraduate academic offerings in Civil Engineering satisfy the industry requirements in the transportation field.

Having a safe, efficient, accessible, and environmentally-conscious transportation system is vital for the economic development of any nation. In addition, transportation becomes essential for the population preparedness and recovery in the case of a natural or man-made disaster. Advances in technology, demand for transportation, population growth, globalization, and other factors are pushing to the limit the mobility of individuals (*ASCE, 2012*). The preservation of the transportation systems is fundamental because, as time passes, facilities deteriorate and therefore it increases the necessary investment costs for maintenance and restoration of these facilities. Aging infrastructure, need for new revenue sources, traffic congestion, fuel and energy demands, environment deterioration, climate change, infrastructure aging, lack of financing and equity options, emergencies, safety, outdated institutions, and lack of human and intellectual capital are the most critical problems faced today by the transportation industry (*Kanafani and Morris, 2009*).

The Federal Highway Administration [FHWA] established the Every Day Counts initiative in the year 2009 to promote the implementation of proven technologies in transportation in order to urgently identify and promote innovate measures such as shortening project delivery, improve safety, and protect the environment (*Méndez, 2012*). This initiative has taken place as the financial crisis continues and the public demands for greater accountability

and efficient use of the government resources. However, innovative transportation research and development of the field will be limited due to the reduction of government funding (*Lewis, 2013*). The Transportation Reauthorization Act "Moving Ahead for Progress in the 21st Century" [MAP-21] has decreased federal grants for research and educational funding by an annual average of 7% which corresponds to a decrease of $29.8 Million per year (*Brah, 2005; and FHWA, 2012a*). As a consequence, this funding is not sufficient for the United States [US] and its territories (*FHWA, 2012a*). The American Society of Civil Engineers [ASCE] estimates that the US will require a five-year investment plan of approximately $2,188 Billion in order to upgrade the transportation infrastructure, including roads, bridges, transit, and rail networks (*ASCE, 2010*). New ways to attract private investments in transportation have been established by the use of Public Private Partnerships [PPP]. Examples of these partnerships in Puerto Rico [PR] include the Teodoro Moscoso Bridge (PR-17) and the José De Diego Expressway (PR-22). Parts of these funds could be assigned to universities, which provide undergraduate and graduate scholars, laboratories, and research experiences (*ASCE, 2010*). If the investment on education is limited, the professional development and knowledge of the future engineers is abridged, resulting in unskilled and less competitive professionals. The FHWA, the Institute of Transportation Engineers [ITE], and the Transportation Research Board [TRB] Committee in Transportation Education have all developed separate efforts in transportation professional development.

The Commonwealth of Puerto Rico has similar issues in transportation funding and professional development. In addition, the migration of approximately 230,000 young professionals in a 10-year period to the Mainland US in search for better job opportunities has reduced the supply of qualified transportation engineers. This migration represents about 40% of

the young professionals with higher education (*Velázquez, 2013*). Statistics reveal that 24% of the Puerto Rican engineers migrated to the continental US on 2006 (*Enchautegui, 2008*). It is essential that universities remain at the forefront of engineering education in providing high quality engineers.

2. OBJECTIVES

The main objective of this study was to identify the knowledge depth and technical skills currently required for young professionals in the transportation engineering discipline. The identification of these skills as well as the needs of the industry could be useful for suggesting improvements to the academic offerings in transportation engineering in universities in Puerto Rico. The long-term goal is to help universities to continue providing competent specialists capable of obtaining employment, compete with experienced professionals, and be able to provide innovative solutions to the current and future problems in transportation infrastructures, systems, and modes. The general objectives of the study were to:

- Identify the current and future technical and professional skills required for transportation engineers, including communication and teamwork skills, and
- Analyze the academic offerings and opportunities for undergraduate students in the two main engineering schools in Puerto Rico, the University of Puerto Rico at Mayagüez [UPRM] and the Polytechnic University of Puerto Rico [PUPR].

The specific objectives of the study were to:

- Review the theoretical and conceptual knowledge related to transportation required by the Fundamental Engineering [FE] and Professional Engineering [PE] exams, and the Accreditation Board for Engineering and Technology [ABET],

- Compare undergraduate curriculums in transportation engineering from both local universities (UPRM and PUPR) and top, mid, and lower ranked US universities,
- Develop a survey for employers of transportation professionals to identify the knowledge depth and technical skills required by their companies,
- Develop a survey for Civil Engineering undergraduate students to identify their career preferences and their interests in transportation,
- Compare the students' developed skills with the ones required by the practice,
- Identify the Civil Engineering courses that address the skills required according to the companies surveyed, and
- Make recommendations of improvements to the transportation courses based on the results of the study.

Some of the beneficiaries of this research are students, entities, society, and science. Students can benefit from this study indirectly by participating in the questionnaire, as they can identify which area is of most interest; also from understanding which areas should they seek to specialize based on the current demand. Governmental agencies and companies do not have an immediate benefit; however these entities can use the results of this research for future employment evaluations. Society will benefit from future professionals that are well trained and capable of solving problems in transportation. Science will benefit of the results for future studies and improve the transportation education.

3. METHODOLOGY

The study methodology consisted of 14 activities, as shown in Figure 1. It was established that the first step to develop a successful research study is to identify the objectives, define the scope, and develop the project proposal. Referral to some web conference and workshops focused on education were recommended to broaden the perspective of educational issues.

The next step was to identify relevant literature that could help on the development of the research project (*WSDOT, 2012; MiCSC, 2013*). The literature review was focused in the areas of the general problematic of transportation engineering, the lack of human capital, local issues, required skills, curriculum evaluation and comparison, requirements of the NCEES and ABET, and the specific technical skills required by public and private transportation-related institutions (*Yehia, 2012*). The objective was to seek information and compare the actual core skills offered to students and understand how it benefits them when seeking job opportunities. Some of the specific goals were to identify the relevance and pertinence of undergraduate courses in transportation and their practical usefulness in today's industry. Current topics, such as infrastructure sustainability and technological involvements were researched in the undergraduate curriculum of the universities.

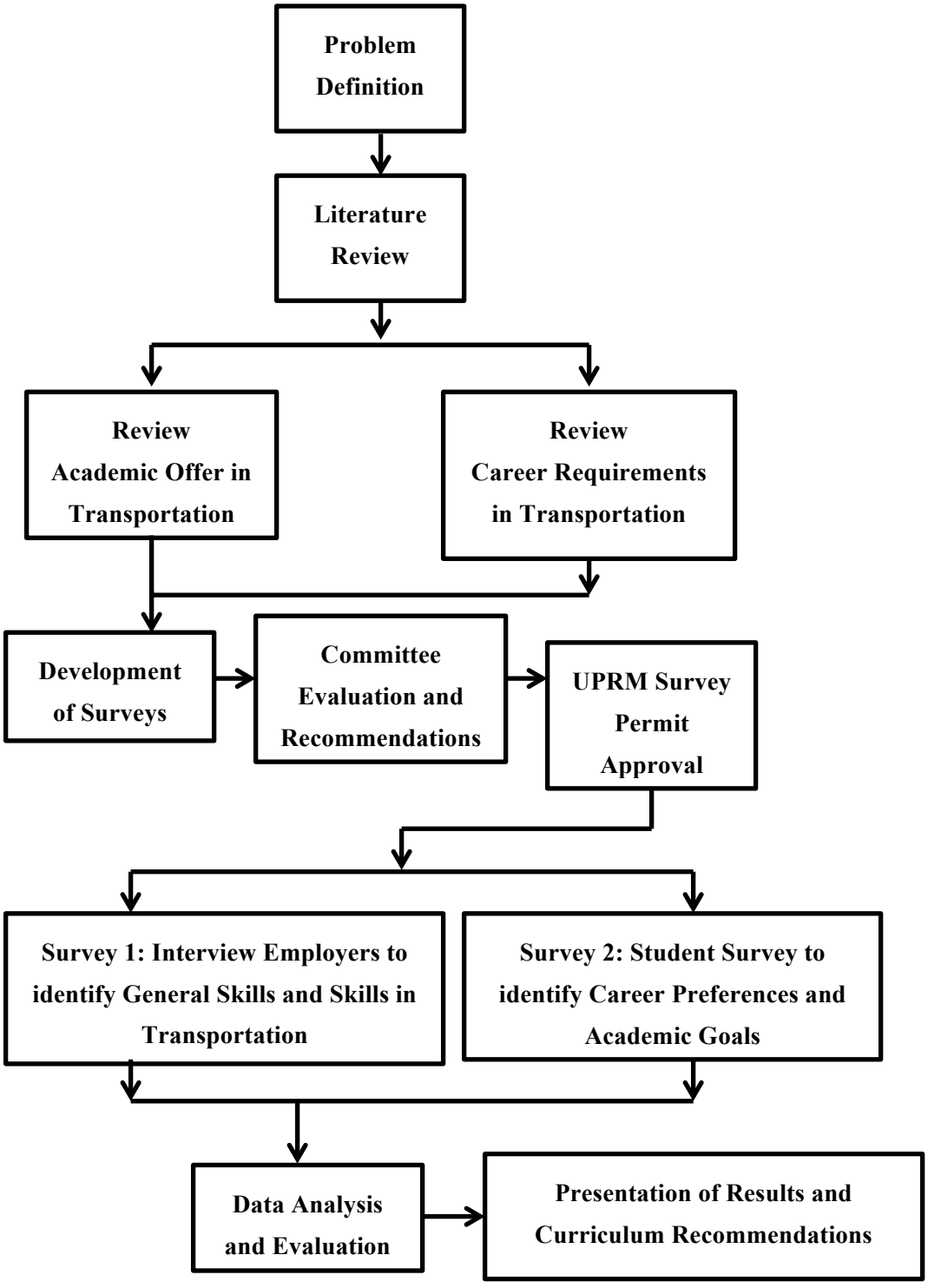

Figure 1 Flow Chart of the Study Methodology

The data collection for this research project included information from public institutions as well as private companies involved in the transportation industry to identify the required employee's technical skills and theoretical and knowledge depth requirements. The study evaluated how research programs, scholarships, research centers, institutes, and Cooperative Educational Programs [COOP] help undergraduate students in the development of their skills and therefore improve their professional profiles. The additional purpose was to identify how these programs help students achieve their academic and career goals and promote specialization in transportation. It was determined that it was also important to identify the reasons for some students to be attracted to transportation engineering and why others are not interested in this field. As part of the study, reviews were performed on the number of faculty members and students enrolled in Civil Engineering programs in Puerto Rico and compare these with US Universities.

To collect the desired data, a survey for Civil Engineering undergraduate students was developed; this included questions to obtain the students' profile and their interests for a professional career in transportation engineering. The student survey was offered to students in the Civil Engineering programs of the UPRM and PUPR schools, including participants of research programs, scholarships, and COOP Plan. The purpose was to gather their profile information and interest in a career in Transportation Engineering and to identify how participation in these programs helped them in their professional development. A permit from the UPRM Committee for the Protection of Human Subjects in Research was obtained for carrying out these surveys. Appendix A presents the letter of approval. The student survey was administered to fourth and fifth year UPRM Civil Engineering students and fourth year PUPR students using a stratified random sample selection technique. The surveys took place at the

classroom and during a course period. The sample size was based on the population of enrolled students within their fourth or later year in college.

In addition, an interview process with employers of Civil Engineers was also developed to gather information. A series of interviews were performed to officials in managerial positions at several companies and governmental agencies focused in the transportation field. The purpose of the interviews was to identify significant professional and particular skills desired by these employers. The sample for the interviews included Civil Engineering and Transportation related agencies and companies. The potential individuals for interview were identified from the use of directories from the College of Engineers and Surveyors of Puerto Rico [CIAPR, by its acronym in Spanish], the American General Contractors [AGC], the ITE - Puerto Rico Section, and other agencies such as the Highway and Transportation Authority [ACT, by its acronym in Spanish], Tren Urbano Office [TUO], the Metropolitan Bus Authority [AMA, by its acronym in Spanish], the Integrated Transportation Alternative [ATI, by its acronym in Spanish], and Novotren. Additional companies from the private sector that were included in this process were CMA Architects & Engineers LLP, CSA Group, Klein Engineering PSC, Del Valle Group, Atkins Caribe LLP, and Steer Davies Gleave.

After collecting the data from the surveyed students and interviewing employers, an analysis was performed to understand the trends in the academia and industry. The statistical method used for the analysis in the study was Descriptive Statistics, which allows the presentation of quantitative measurements. Results are shown using pie charts, columns, and tables to demonstrate trends or preferences.

Finally, conclusions and recommendations were presented based on the results of the study.

4. LITERATURE REVIEW

The literature review for this study included information about transportation organizations that have provided resources in order to improve the transportation profession, ABET's requirements for the Civil Engineering program endorsement, National Council of Examiners for Engineering and Surveying [NCEES] essentials for examining the transportation area, and main undergraduate Civil Engineering program's characteristics in two Puerto Rico universities.

4.1. Transportation Organizations

The ITE, an international organization that has a membership roster of nearly 17,000 transportation professionals worldwide, has a commitment to improve the development of the transportation professionals by providing online training opportunities, such as seminars, workshops, and learning modules (*ITE, 2011*). Some of the topics in these training opportunities include Geometric Design, Complete Streets, Intelligent Transportation System [ITS], Pavements, Highway Engineering, Planning and Policy, Safety, and Traffic Engineering, among others. Another initiative that contributes to expand the professional's knowledge are the ITE Journal and ITE Journal of Transportation, a monthly magazine and a scholarly journal, respectively, that include articles related to transportation engineering and planning, safety, and efficient movement of surface transportation. ITE has twelve councils that contribute with knowledge and technical products by addressing important issues related to transportation. One of the councils is the Transportation Education Council, which serves as discussion forum to support programs and projects related to rising and evolving educational needs (*ITE, 2011*).

The United States Department of Transportation [USDOT] and the FHWA provide a program for educational employment called the Professional Development Program. In this

program candidates are employed to work with leaders and innovators around the US with various local and federal agencies in order to acquire technical and leadership skills. The FHWA web page offers numerous educational and technical resources that are freely available, such as reports, magazines, guides, and trainings, among others resources (*FHWA, 2012b*).

Another organization with efforts to improve the transportation profession is the Transportation Research Board. With this purpose in mind, TRB established the Transportation Education and Training Committee in order to provide interaction and communication between the private and public sectors, governmental agencies, and the academia involved in transportation education and training. Some of the initiatives at the TRB Annual Meeting include lectern sessions, discussion panels, workshops, and committee meetings. These events allow the discussion of the current state of the transportation education, recent developments, innovations, professional needs, trainings, and other developments (*TRB, 2012*).

4.2. ABET Requirements

The Accreditation Board for Engineering and Technology [ABET] is a nonprofit organization that has accredited 3,100 programs at 670 colleges and universities in 24 countries around the world (*ABET, 2011a*). ABET also certifies programs focused in science and computing. Currently, Puerto Rico has two Civil Engineering programs that are ABET accredited; these are the UPRM at Mayagüez and the PUPR at San Juan (*ABET, 2011b*). Various general criteria need to be meet in order to obtain accreditation, which are related to students, program educational, objectives, student outcomes, continuous improvement, curriculum, faculty, facilities, and institutional support.

According to the ABET Board of Directors, under the Curriculum criterion, universities must "prepare graduates to apply knowledge of mathematics through differential equations,

calculus-based physics, chemistry, and at least one additional area of basic science" (*ABET, 2013*)." The curriculum must be consistent with the program educational objectives, which are:

- Apply knowledge of four technical areas appropriate to Civil Engineering,
- Conduct Civil Engineering experiments, and analyze and interpret the resulting data,
- Design a system, component, or process in more than one Civil Engineering context,
- Explain basic concepts in management, business, public policy, and leadership, and
- Explain the importance of professional licensure.

Students expected level of knowledge is essential under the general criteria for ABET accreditation and the program should present compliance with student's outcomes A to K. For the faculty members it is required to "demonstrate that faculty are teaching courses that are primarily design in content and are qualified to teach the subject matter by virtue of professional licensure, or by education, and design experience." The program must demonstrate that it is not critically dependent on one individual (*ABET, 2011b*).

4.3. NCEES Transportation Engineering Exam Specifications

The Fundamental Examination [FE] prepared by the National Council of Examiners for Engineering and Surveying [NCEES] for the general Civil Engineering discipline features the areas of Construction, Geotechnical, Structural, Transportation, Environmental and Water Resources. The NCEES, in coordination with the Puerto Rico Board of Examiners of Engineers [BEE], provide examination, license, and certifications to authorize the practice of Engineering in Puerto Rico. This is made in accordance to Law 173 of August 12, 1988, and its amendments (*Senate of Puerto Rico, 1988*). The second evaluation, the Professional Examination [PE], is for a specific topic; the realm of transportation focuses on traffic analysis, geometric design, transportation planning, traffic safety, and other topics (*NCEES, 2013a*).

4.4. Main Undergraduate Programs in Civil Engineering in Puerto Rico

Many of the curriculums in Civil Engineering schools in the US fluctuate between 126 and 132 credit-hours and typically are 4-year programs. However, both universities in Puerto Rico, UPRM and PUPR, require over 140 credit-hours for a Bachelor's Degree in Civil Engineering.

The UPRM was founded in the year 1911 as a Land-Grant public university. Currently, there are 666 faculty members and 11,054 enrolled students (*UPRM, 2013*). The university offers Bachelor, Master, and Doctoral degrees for two of the four mayor disciplines; these four disciplines are Engineering, Agricultural Sciences, Business Administration, and Art and Sciences. All the Engineering undergraduate programs are established as 5-year programs and semester based. The Engineering school offers degrees in Civil, Industrial, Electrical and Computer, Mechanical, and Chemical Engineering fields. The Civil Engineering curriculum requires 179 credit-hours, including nine credit-hours (three courses) in Transportation-related courses. At present, the Civil Engineering and Surveying Department has 32 faculty members and four of these are full-time professors in the transportation field. The Civil Engineering program had 671 students enrolled at the undergraduate level during the second semester of the 2012-2013 academic calendar (*UPRM, 2013*).

The PUPR (Hato Rey Campus), founded in the year 1966, is a private and non-for-profit university. The university offers Bachelor and Master degrees for the three disciplines offered: Architecture, Management and Entrepreneurship, and Engineering and Geomatic Sciences. The Engineering school offers degrees in the fields of Civil, Industrial, Electrical, Mechanical, Chemical, Environmental, Computer, and Mechanical in Aerospace Science Engineering. In the third quarter of the 2012-2013 academic calendar, the PUPR had a total enrollment of 4,743

students, of which 85% are undergraduates, and 665 are enrolled in Civil Engineering (15.8% of total enrollment). The PUPR has a total of 206 faculty members (tenure track and full-time professors) of which 31 are from the Civil and Environmental Engineering Department, two of these are full-time professors and two work part-time in the transportation discipline (*PUPR, 2013*). In June 2012, the School of Engineering reduced their academic requirements to a 4-year program in a quarter term format (*Vázquez E., 2012*). The Civil Engineering program currently requires a total of 149 credit-hours for the bachelor's degree (*PUPR, 2014b*), including ten credit-hours (three courses and one laboratory) in Transportation-related courses. Table 1 presents a summary of the UPRM and PUPR university details and Civil Engineering programs.

Table 1 Comparison of UPRM and PUPR offers and Civil Engineering programs

		UPRM	PUPR
University	Mayor Disciplines	Engineering, Agricultural Sciences, Business Administration, and Art and Sciences	Engineering, Architecture, and Business Administration
	Faculty Members	666 total	206 total
	Enrolled Students	11,054 total	4,743 total
Civil Engineering	CE Degrees	Bachelor, Master, and Doctoral	Bachelor, Master, and Doctoral
	Bachelor Program Duration	5 years (semester-based)	4 years (quarter-based)
	CE Program Requirements	179 credit-hours	149 credit-hours
	CE Faculty Members (includes full-time & part-time)	32	33
	Enrolled Students	671	665
	Minimum Requirements in Transportation-related Courses	9 credits-hours in 3 core courses	10 credits-hours in 3 core courses and 1 laboratory
	Transportation Faculty	3 tenured professors (1 is currently on leave), 2 full-time professors	1 tenured professor, 1 full-time, and 2 part time professors
	Elective Credits in Transportation (at BS level)	9 credit-hours in 3 courses	9 credit-hours in 3 courses
	Transportation Graduate Specialty	ME, MS, and PhD	None

Comparing both universities is notable that UPRM is a larger university for its number of disciplines offered, and number of faculty members. The number of students enrolled in Civil Engineering are similar for both universities. Assessing the Civil Engineering program, both universities offer Bachelor, Master, and Doctoral degrees. However, only UPRM offers Masters and Doctoral degrees in the Transportation Engineering sub-discipline. A significant difference is that the UPRM provides a 5-year program in Civil Engineering, while PUPR offers a 4-year program. This goes in hand with the number of credits required to obtain a bachelor's degree, where UPRM has a 179 credit-hours requirement and PUPR has 149 credit-hours. Nonetheless it is important to highlight that the UPRM program is structured in semesters and the PUPR in quarter terms. The differences in the Civil Engineering program are not significant, as the UPRM has about 1% more enrolled students than PUPR.

5. ACADEMIC OFFERINGS

To understand the current academic offerings and to be in a position to identify the future skills essential for specialized engineers in transportation is vital to understand the history, deepness in knowledge, industries' needs, current and future professional and technical skills required for the career, and the academic offers in Puerto Rico and US. With this in perspective, one is capable of comparing industry needs versus the students' outcomes and suggest recommendations to the curriculum.

5.1. Related Studies of the Deepness in Knowledge

Deepness in knowledge is gained by diverse methods. It could be by reviewing other people's research studies, studying in the academia or with other resources, and opportunities. This section presents studies that are related to the deepness in knowledge of the transportation

area. Then an evaluation of the curriculum is made in order to understand the technical skills students that are being offered. Finally, opportunities and resources available in the academia are presented.

From the literature review, the fourth research study provides supporting details that identify skills required to employees. Incorporating these findings to the academic offering could provide greater deepness in knowledge and better-prepared professionals for the transportation industry. The first study identifies the general skills for Civil Engineers. The second and third studies provide specific qualities and skills for Civil Engineers specialized in transportation. The final study identifies attributes companies look when employing Civil Engineers.

5.1.1. Knowledge Required for a Civil Engineer

Employers look for Civil Engineers who are capable of planning, designing, and supervising construction projects, including the maintenance of structures and facilities (*MyMajors, n.d.*). The knowledge required for Civil Engineers is:

- Application of science, mathematics, engineering, and technology,
- Design of technical plans, blueprints, drawings, and models,
- English reading, writing, defining, rules, and spelling,
- Application of physics principles to fluid, material, dynamics, mechanical, electrical, and structures,
- Principles for the transportation of people and goods by air, ground (highways and rails), and maritime,
- Administration and management of projects,
- Safety and security equipment, policies, procedures, and strategies, and

- Law and Government Policy, codes, procedures, regulations, executive orders, agency rules, and political processes and others.

5.1.2. Careers in Transportation Engineering

There are four main branches within engineering: civil, mechanical, electrical and chemical. Transportation is a realm under Civil Engineering that addresses the design, construction, and operation of highways, transit, railroads, air and maritime facilities, and others. These are typically grouped in two main realms areas, transportation infrastructure and transportation systems. Some of the skills required for Civil Engineers are (*Monica M. Suter, n.d.*):

- Ability to interpret engineering plans,
- Knowledge in science and mathematics,
- Logical thinking,
- Experience in field, construction and surveying,
- Engineering computer software domain such as computer-aided design programs, spreadsheets, simulations, and others, and
- Visual and practical capabilities.

5.1.3. Transportation Engineers: Skills and Qualities

A good transportation engineer should have strong qualities such as problem solving, creativity, logical thinking, teamwork, and effective written and verbal skills. The transportation engineer should also, have a thorough personality (reformer, helper, achiever, individualist, investigator, loyalist, enthusiast, challenger, and peacemaker), strong knowledge in mathematics, passionate for design and engineering, have intellectual curiosity for other transportation systems,

and be an effective communicator (*Science Buddies, 2014*). Transportation engineers are specialists in:

- Reviewing planned developments for urban and rural areas to determine their impacts in traffic systems,
- Design and redesign airport runways to accommodate larger aircrafts,
- Simulate basic intersections and roundabouts to streamline traffic, and
- Develop facilities for pedestrians and cyclists.

The projected job growth of the profession is between 14% and 20% until 2020 (*MyPursuit, n.d.*). Important educational complements are the reading of technical publications, and attend seminars and conferences.

5.1.4. Griffith Graduate Attributes Professional Skills Toolkit

Working experiences help to improve and acquire new sets of professional skills. Academic programs that expose students to work-integrated learning experiences help them to transition smoothly from the academic environment to the professional world. Today's work places seek for particular attributes in graduate students that make them more competitive and endurance. Some of the attributes companies seek are (*Griffith University, n.d.*):

- Competent in culturally diverse and international environment,
- Effective communicators and team members,
- Innovative and creative along with critical judgment,
- Knowledgeable and skilled in their disciplines, and
- Socially responsible and engaged in their communities.

It is highly relevant to develop in students the professional skills as they will find practical value to the theoretical concepts and put them in practice, understand the cultural environment as well as the constant evolution of the world, develop communicative and interactive abilities, and recognize future carrier plans and areas interest (*Griffith University, n.d.*).

5.1.5. Academic Schemes

Universities that offer Civil Engineering degrees have different academic curriculums to forge diverse kinds of engineers. Civil Engineers could have a general formation or an area of specialty. To understand how the academic preparation is focused to address specific purposes, four schemes are presented.

The first scheme is the *General Engineer*. The nature of this curriculum is to provide students a well-rounded education with basic knowledge on the mayor divisions of the Civil Engineering (*Marquette, 2014*). The general concept is to offer fundamental courses, electives, and various areas of specialty. Some universities might emphasize more in one particular area of specialty than others.

The second scheme is the *Fundamental Engineer.* The curriculum for this type of engineering degree is characterized for providing basic courses in sciences, mathematics, and engineering (*UNICAN, n.d.*). However, it allows students to decide what will be their area of specialty. Figure 2 shows a general set of course topics that a fundamental engineer would take in a 4-year program.

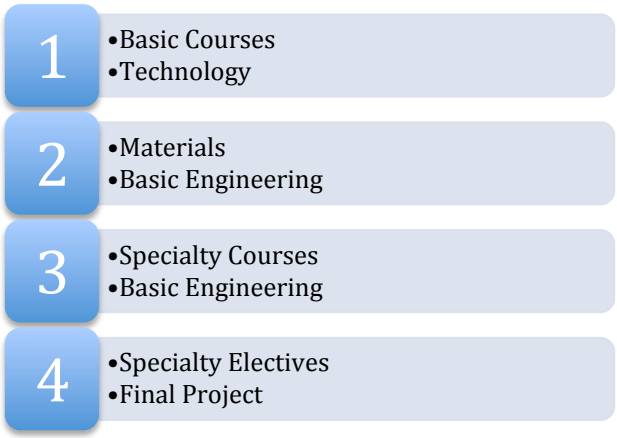

Figure 2 Fundamental Engineer Curriculum Structure (*UNICAN, n.d.*)

The third scheme is *Required Level of Knowledge at Entrance to the Engineering Program.* This is a strategy used by some universities to reduce the curriculum time frame to a 4-year program, nevertheless require strong knowledge in mathematics, sciences, and languages. An example of this is that starting courses in a particular curriculum are Calculus, Physics, and Advance Language. If students do not meet the expected level additional courses will be added to meet the standard. In the US the top universities have this requirement at the entry level (*Berkeley University, 2013; Georgia Tech, 2014; UIUC, 2012*).

The fourth scheme is *Course Coverage.* Engineering schools must consider if the focus of the academic offer will be on quality or quantity. Comparing engineering degrees granted in the US with China and India, results indicate that US provides 1.5 times more degrees when compared to China and 3.8 times degrees than India. The US graduates 758 engineers per million of habitants, China follows with 497 and India with 199. Vivek Wadhwa, Executive in Residence at Duke's Pratt School of Engineering states that "an important key factor often left out of battle is, quality, not quantity, and that means not scaring away bright students, foreign and domestic" (*Inside Higher ED, n.d.*).

5.2. Curriculum Assessment of UPRM and PUPR

The UPRM undergraduate program in Civil Engineering offers students a 5-year program, which requires a minimum of 179 credit-hours. The areas of specialty are Environmental and Water Resources, Structural, Geotechnical, Construction Management, and Transportation Engineering. The Civil Engineering program is housed in one Department with the Surveying and Topography program; although separate degrees, provide courses in combination for both.

The PUPR undergraduate program in Civil Engineering offers a 4-year program that consists of 149 credit-hours, and provides students knowledge in the related areas of Structural Engineering, Geotechnical Engineering, Highway and Transportation Engineering, Water Resources and Environmental Engineering, and Construction Engineering. The Civil Engineering program is separated of the Environmental Engineering; although some courses are provided in combination for both degrees. Table 2 lists a detailed distribution of the course sequence for both universities that a student has to follow, including language, mathematics, sciences, socio-humanistic topics, General Engineering, and Civil Engineering.

Table 2 Bachelor in Civil Engineering course plan for UPRM and PUPR (*UPRM, 2014a; PUPR, 2014b*)

University	UPRM											PUPR											
Year	1st year		2nd year		3rd year		4th year		5th year		TOTAL	1st year			2nd year			3rd year			4th year			TOTAL
Semesters/Trimester	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd		1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	
General Courses										Total	**72**												Total	**50**
Language	6	6	3	3							18		3	3	3	3								12
Physical Education	1	1									2													0
Socio Humanistic							3	6	3	3	15							3			3		3	9
Math	5	4	4	3	3						19	4	4	4	3									15
Science	4	4	5	5							18	4	5	5										14
General Engineering	2	2	6	6	9	7	3				**35**	4	1		3	10	9	1						**28**
Civil Engineering Credits										Total	**72**												Total	**71**
Technical Electives										3	3												3	3
Transportation							3	3	3		9							3	3	4				10
Geotechnical								4			4							4	4					8
Methods/Statistics					2	2					4				3									3
Materials						3					3						4							4
Structures						3	6	3	3		15							3	4	3	3	3		16
Water								3	3		6								3	3	3			9
Management										3	3									3	3			6
Topography					3	3					6						1							1
Environmental							3				3											3	1	4
Seminar										1	1													0
Capstone										3	3											1	3	4
Free Electives									6	6	12											3		3
Subtotal	18	17	18	17	17	18	18	19	18	19		12	13	12	12	13	14	14	14	13	12	10	10	
TOTAL	179											149												

NOTES: The numbers for each cell represent the number of credit-hours. Free elective courses can be taken under any discipline.

The significant difference between UPRM and PUPR is that PUPR required less General courses and General Engineering courses. UPRM requires two physical education credits, four more credits in both math and science courses, and six more credits in both language and socio-humanistic courses as part of the curriculum, when compared to PUPR.

PUPR requires 71 credit-hours in Civil Engineering whereas UPRM requires 72 credit-hours. A difference is that UPRM covers seven more credits in General Engineering than PUPR. When adding all Engineering courses that an undergraduate student needs to take, both universities are comparable, with PUPR requiring 99 and UPRM requiring 107.

Both universities follow the scheme of General Engineering, with the major emphasis on Structural Engineering. PUPR also follows the scheme of Required Level of Knowledge at Entrance to the Engineering Program. UPRM offers a one-credit hour Seminar course, which is a course not available at PUPR. A final project course (Capstone Design) is a requisite by both

universities; however students in the UPRM take this course in one semester, and students at the PUPR take two-quarter periods for the equivalent course. During their first quarter PUPR students develop a proposal and on their second quarter students develop the final project. UPRM Capstone course provides one semester to develop both the proposal and the design of a project.

Transportation courses offered at the undergraduate level from both universities are listed in Table 3. The three core courses for both universities focus on the same subjects, though there is a difference in the offering and scheme of laboratories. The INCI 4007 course at UPRM offers a highway geometric design laboratory as part of the three credit-hours course *Highway Location and Curve Design*. PUPR offers the *Highway and Transportation Engineering Laboratory* (CE 3331) as a separate course to address transportation studies, where students apply their transportation knowledge on computer software used in the practice.

Table 3 Comparison of UPRM and PUPR transportation related courses per credit-hours

Courses	UPRM (credit-hours)	Courses	PUPR (credit-hours)
CORE COURSES			
INCI 4007 Highway Location and Curve Design	3	CE 3310 Route Location and Geometric Design	3
INCI 4137 Introduction to Transportation Engineering	3	CE 3330 Transportation Engineering and Urban Planning	3
INCI 4026 Highway Engineering	3	CE 3320 Highway Engineering	3
Not available	-	CE 3331 Highway and Transportation Engineering Laboratory	1
ADVANCED UNDERGRADUATE COURSES			
INCI 5029 Principles of City Planning INCI 5146 Introduction to Traffic Engineering INCI 5065 Production of Bituminous Materials	9	CE 5220 Pavement Design CE 5308 Urban Transportation Planning CE 5312 Public Transportation	9
GRADUATE COURSES (could be taken by undergraduate students with special permit)			
INCI 6045 Pavement Design INCI 6046 Urban Transportation Planning INCI 6047 Traffic Engineering INCI 6048 Transportation Systems Analysis INCI 6049 Transportation Systems Evaluation INCI 6050 Advance Transportation System Analysis INCI 6051 Mass Transportation INCI 6068 Pavement Management INCI 6090 Geometric Design of Highways INCI 6108 Road Safety Analysis INCI 6119 Data Analysis and Modeling of Transportation Systems INCI 6995 Special Topics: Pedestrian and Bicycle Transportation	36	None	0
TOTAL	*54*		*19*

The first transportation engineering courses are typically taken by UPRM students during the first semester of the fourth year. Usually the first course of transportation in the Civil Engineering curriculum sequence is the *Highway Location and Curve Design* (INCI 4007). It is a three credit-hour course and consists of two hours of conference and three hours of computational laboratory per week. The main topics covered according to the 2013-2014 UPRM

Catalog are: highway location surveys, study and design of simple and compound circular, parabolic, and transition curves, earthwork, and a special project. It was identified from official syllabus provided by the Civil Engineering Department the specific topics cover in the course, which are:

- Highway development process,
- Highway functional classification,
- System characteristics,
- Typical sections,
- Cross section elements,
- Highway design control factors,
- Determination of roadside clear zone,
- Traffic control devices: signs and markings,
- Horizontal alignment components,
- Route location surveys,
- Preliminary route design,
- Circular curve elements,
- Degree of curvature concepts,
- Superelevation and side friction factor,
- Sight distance on circular curves,
- Widening on horizontal curves,
- Compound and reverse circular curves,
- Circular curve field location methods: deflection angles and chords, offsets, and location from PI,

- Design of curve transition segments,
- Spiral curve elements,
- Deflection angles,
- Vertical alignment development,
- Terrain and grade considerations,
- Elements of symmetrical vertical curves, profile elevations, and turning point,
- Elements of unsymmetrical vertical curves and turning point,
- Sight distance on vertical curves,
- Length of vertical curves,
- Coordination between horizontal and vertical alignments,
- Earthwork: area and volume computations,
- Mass diagram and haul analysis, and
- Other elements affecting highway design.

The INCI 4007 course provides students the opportunity to put the knowledge into practice with the Highway Location and Curve Design Laboratory, which is part of the course. The topics covered in the laboratory are:

- Introduction to course and computations period,
- AutoCAD and Eagle Point (EP) basic commands,
- Creating a surface model in EP Surface Modeling,
- Route location study,
- Roadway cross-section layout in EP Road Calc.,
- Horizontal alignment design with EP Road Calc.,
- Profile and vertical alignment with EP Road Calc.,

- Coordination between horizontal and vertical alignments,
- Earthwork analysis and final design checks, and
- Route evaluation and formatting for plotting in EP.

The second course in the curriculum sequence at UPRM is the *Introduction to Transportation Engineering* (INCI 4137). This three credit-hour course is lectured three hours per week and has as pre-requisite *Applied Statistics for Civil Engineering* (INCI 4136). The topics covered in this course include general concepts of transportation such as: demand, service and equilibrium; transportation planning process and economics; transportation systems components, operation, and design. The specific topics covered in the course are:

- Decision Making, Demand vs. Cost
- Trip Generation
- Traffic Assignment
- Sample Size
- Speed Studies
- Parking Studies
- Volume Studies
- Flow Density and Speed Relationships
- Multilane Level of Service
- Freeway Level of Service
- Intersections Level of Service
- Two-lane Highways Level of Service
- Intersections and Sight Triangle Concepts
- No Control and STOP Controlled Intersections

- Critical Lane Concepts
- Traffic Signal – Green Times
- Yellow, All Read, and Pedestrian Considerations
- Design Signal Timing
- Warrants for Traffic Signals
- Delays

The third and final course of transportation in the sequence for undergraduate level in UPRM is *Highway Engineering* (INCI 4026). The INCI 4007 and INCI 4137 courses are prerequisites of INCI 4026, which consist of three credit-hours, lectured three hours per week. The topics cover in this course are: highways systems classification, planning and administration; geometric design; traffic engineering; subgrade structure; design of flexible, and rigid pavement. From the syllabus of the course it was identified that there are multiple references. The specific topics covered in the course are:

- Highway design process,
- Highway administration, transportation planning, and highway location,
- Urban vs. rural functional classification,
- Environmental considerations in road design,
- Schematic or conceptual design vs. detailed design,
- Cross sectional elements,
- Context sensitive design,
- Ethics issues in highway transportation projects,
- Driver, pedestrian and vehicle characteristics,
- Highway safety,

- Tort liability,
- Roadside design, roadside topography recoverable, non-recoverable, critical slopes, and barn roof section,
- Clear zone,
- Design of flexible, semi-rigid and rigid systems,
- Modified Thrie Beam Guardrails,
- Conservation of momentum, crash cushion devices,
- Design of crash cushion devices by conservation of momentum,
- MUTCD overview,
- Elements of traffic control,
- Plan advance warning transition, buffer, work areas, termination areas, and typical applications,
- Design of a traffic control plan for work zone,
- Framework for pavement evaluation and design, pavement types, wheel loads, elements of thickness design, and AASHTO road test,
- Present Serviceability Index (PSI) concept,
- Reliability concept,
- Traffic Analysis: Equivalency Single Axle Load (ESAL),
- Material characteristics, soil considerations, California Bearing Ratio (CBR) test, Resilient Modulus, and Base and sub-base drainage considerations,
- Structural design of flexible pavements,
- WinPAS computer program – design example,
- Condition surveys, Pavement Condition Index (PCI),

- Structural vs. functional failures, description of pavement, distresses, density, and severity,
- Framework for transportation system evaluation,
- Time value of money, cash flow equivalence, analysis of present worth, equivalent uniform annual cost, benefit/cost, rate of return, graphical method,
- Methods of engineering economic analysis,
- Incremental benefit/cost and rate of return,
- Introduction to elements of detailed geometric design: design standard, design controls and criteria, and
- Elements of detailed geometric design: sight distance, horizontal alignment, and vertical alignment.

Other elective courses related to the transportation field which are available for undergraduate students at the UPRM are *Principles of City Planning* (INCI 5029), *Production of Bituminous Materials* (INCI 5065), and *Introduction to Traffic Engineering* (INCI 5146).

At PUPR, transportation courses are taken since the first quarter of the third year. The first course in transportation is *Route Location and Geometric Design* (CE 3310). This course consists of three credit-hours and is lectured two hours per week. The pre-requisites are: *Principles of Surveying for Engineers Laboratory* (SURV 2095), *Algorithms, Programming, and Numerical Analysis* (CEE 2310), and *Algorithms, Programming, and Numerical Analysis Laboratory* (CEE 2311). The topics covered in the CE 3310 course according to the 2013 PUPR curriculum are: route study, horizontal alignment and simple and compound circular curves, profile alignment and vertical parabolic curves, spiral curve and superelevation, introduction to traffic engineering safety, and earthwork. The specific topics covered in the course are:

- Introduction to road design and highway standards,
- Horizontal alignment-tangent layout,
- Horizontal alignment-simple circular curves basic parameters,
- Horizontal alignment-simple circular curves special cases,
- Horizontal alignment-compound and reverse circular curves,
- Horizontal alignment-curve layout,
- Horizontal alignment-superelevation rate and runoff,
- Horizontal alignment-attainment of superelevation using the tangent to circular curve method,
- Horizontal alignment- attainment of superelevation using transition spiral curves,
- Horizontal alignment- attainment of superelevation using transition spiral curves,
- Vertical alignment-layout,
- Vertical alignment- parabolic curves,
- Highway safety-stopping and passing sight distance on horizontal curves,
- Highway safety-minimum length of sag and crest vertical curves,
- Highway safety-widening on highway curves,
- Earthwork-transverse cross sections,
- Earthwork-mass diagram and quantities calculations, and
- Earthwork-mass diagram and quantities calculations.

The second course related to Transportation Engineering at PUPR is *Highway Engineering* (CE 3320). This is a three credit-hours course, lectured two hours per week. The pre-requisites for this course are: *Construction Materials* (CE 2510), *Geotechnical Engineering I* (CE 3210), *Route Location and Geometric Design* (CE 3310). The topics covered in the course

are: roadside design principles, traffic control devices, pavement design, traffic flow theory principles, capacity and level of service of two-lane highways, capacity and level of service of multilane highways, capacity and level of service of basic freeway segments, freeway weaving analysis, interchange design principles, and at-grade intersection design principles. The specific topics covered in the course are:

- Roadside Design Principles,
- Traffic Control Devices,
- Design of flexible pavements – ESAL,
- Design of flexible pavements – AASHTO Method,
- Design of rigid pavements - AASHTO Method,
- Design of rigid pavements – Slabs,
- Traffic flow theory,
- Highway capacity and level of service: two-lane highways,
- Highway capacity and level of service: multilane highways,
- Highway capacity and level of service: freeway segments,
- Highway capacity and level of service: freeway weaving,
- Interchanges,
- Intersection design: design principles-alignment and channelization,
- Intersection design: design principles-turning roadways, and
- Intersection design: design principles-sight distance.

The third and final course in the sequence of transportation courses at the PUPR is *Transportation Engineering and Urban Planning* (CE 3330), and the laboratory *Highway and Transportation Engineering Laboratory* (CE 3331). The CE 3330 is a three credit-hours course,

lectured two hours per week. The pre-requisites for this course are CE 3320 and co-requisite CE 3331. The topics covered in the course are: intersection capacity and level of service, planning and design aspects of transportation systems, urban transportation planning models, development principles of transportation facilities, design and operational analysis of pedestrian and bicycle facilities, and public transportation. The specific topics covered in the course are:

- Intersection Control: warrants,
- Intersection Control: signal timing,
- Intersection Capacity and Level of Service,
- Transportation Economics,
- Land Use/Transportation System,
- Urban Transportation Planning,
- Design principles and operational analysis of Pedestrian Facilities,
- Design principles and operational analysis of Bicycle Facilities, and
- Public Passenger Transportation.

At PUPR, the *Highway Laboratory* (CE 3331) is a one credit-hour, lectured four-hours per week, and has CE 3320 as pre-requisite. The topics covered are: data collection techniques and use of equipment associated with different types of transportation studies, application of statistics and probability in transportation data presentation and analysis, and application of computer software. The specific topics covered in the course are:

- Presentation Techniques of Data and Technical Written Reports,

Volume Studies:

- Purpose and applications,
- Methods of counting and equipment use,

- Field Procedures,
- Data analysis,

Intersection Counts:

- Count periods,
- Manual data collection techniques,
- Automatic data collection and use of equipment,
- Data conversion and presentation,
- Data analysis,

Intersection Delay and Saturation Flow Measurement:

- Manual procedure,
- Mechanical procedures and use of equipment,

Arrivals and Departures:

- Data collection techniques,
- Application of distribution probability models,

Traffic Control Devices:

- Equipment and applications,
- Use of equipment,
- Field inspection,

Transportation Planning Data:

- Area definition and zoning,
- Data collection and forecasting techniques,
- Data analysis,
- Parking Studies, and

- Public Transportation Studies.

The transportation elective courses available for undergraduate students at the PUPR are: *Pavement Design* (CE 5220), *Urban Transportation Planning* (CE 5308), and *Public Transportation* (5312).

Table 4 presents a summary of the general topics covered at the three core courses offered at UPRM and PUPR.

Table 4 Comparison of general topics of UPRM and PUPR transportation core courses (*UPRM, 2014a; PUPR, 2014b)*

Topics	UPRM	Topics	PUPR
Highway Location and Curve Design (INCI 4007)[1]	Highway location surveys, study and design of simple and compound circular, parabolic, and transition curves; earthwork; laboratory special project.	**Route Location and Geometric Design (CE 3310)**[1]	Route study; horizontal alignment and simple and compound circular curves; profile alignment and vertical parabolic curves; spiral curve and superelevation; introduction to traffic engineering safety; and earthwork.
Introduction to Transportation Engineering (INCI 4137)[2]	Demand, service and equilibrium; transportation planning process and economics; components, operation and design of the transportation systems, intersection capacity and level of service.	**Transportation Engineering and Urban Planning (CE 3330)**[2]	Intersection capacity and level of service; planning and design aspects of transportation systems; urban transportation planning models; development principles of transportation facilities; design and operational analysis of pedestrian and bicycle facilities; and public transportation.
Highway Engineering (INCI 4026)[3]	Highways systems classification, planning and administration; geometric design; traffic engineering; subgrade structure; design of flexible and rigid pavement.	**Highway Engineering (CE 3320)**[3]	Roadside design principles; traffic control devices; pavement design; traffic flow theory principles; capacity and level of service of two-lane highways; capacity and level of service of multilane highways; capacity and level of service of basic freeway segments; freeway weaving analysis; interchange design principles; and at-grade intersection design principles.
Laboratory[4]	Not available.	**Highway and Transportation Engineering Laboratory (CE 3331)**[4]	Data collection techniques and use of equipment associated with different types of transportation studies; application of statistics and probability in transportation data presentation and analysis; and application of computer software.

NOTE: Superscript numbers correspond to the equivalent course offered at UPRM and PUPR.

Examining the offerings of both universities in PR, most general topics covered at the three core courses are very similar. A difference between the course offerings is that the UPRM program includes a computational laboratory period within the INCI 4007 course that is focused in highway location and geometric design application. On the other hand, the PUPR includes a separated single credit-hour course for the laboratory experience with a more diverse coverage of transportation software applications. It is important to indicate that the material of any of these courses (both UPRM and PUPR) can vary across different instructors.

5.3. Complementary Resources and Opportunities

As part of the deepness in knowledge, UPRM and PUPR provide students with other complementary resources and opportunities to develop general and technical skills in transportation related areas, such as COOP, Summer Internships and Exchanges, Transportation Technology Transfer Center, and Students Organizations.

The UPRM and PUPR provide students with opportunities to integrate academic knowledge with professional experiences through the COOP. This program allows students assess their career interests and broadens the perspective of the specialty field by applying academic concepts to a real world workplace (*UPRM, 2014b; PUPR, 2014*)

The UPRM–University of Rhode Island [URI] and UPRM–Purdue Transportation Summer Transportation Research Exchange Programs allow students from UPRM and from both US universities to exchange research experiences in transportation since 2005. In these programs students perform research in various areas of interest such as: pavement, pedestrians, traffic signals, rail, models, freights, and others. For a period of ten weeks, students travel to URI or Purdue to execute their research. As part of the program a faculty mentor is assigned to students to guide them during the process. At the end of the internships, students have to present

their final report to faculty members and students in both universities. This effort has allowed students to familiarize with transportation problems. Having the opportunity to relocate to other campuses and states has allowed students to identify differences with their hometown and develop solutions from a global perspective. Internships also help to broaden their minds and expose them to professional experience through the collaboration of the corresponding State Department of Transportation or Transportation Centers (*PRTTT, 2014a*).

Another supporting program offered at UPRM is the Abertis Scholarship, a signed collaborative agreement between UPRM and the Abertis Foundation with the objective to promote the study of transportation infrastructure, technology transfer, and road safety (*PRTTT, 2014b*). Another transportation scholarship program available at UPRM is the Dwight David Eisenhower Transportation Fellowship Program, a FHWA-sponsored scholarship, which promotes students to consider transportation as a career choice and provides economic support while promoting students to carry out a research project in a transportation-related topic.

The Puerto Rico Transportation Technology Transfer Center located at the UPRM Department of Civil Engineering, is one of 57 centers of the United States, promotes research and the development of transportation activities at Puerto Rico and the US Virgin Islands since April 1, 1986. The center offers activities, services, and programs that allow student, municipalities, Puerto Rico's Department of Transportation and Public Works [DTOP by its acronym in Spanish], and other agencies, to perform transfer of newest technology and perform research. This center is part of the UPRM system and is the only one of this type for transportation related topics in Puerto Rico (*PRTTT, 2014c*).

Currently the PUPR offers opportunities for students with the Dwight Davis Eisenhower and the PUPR-ATI Inspection Program. The PUPR Eisenhower Fellowship serves the same

purposes as the one available at UPRM. The inspection program is a collaborative agreement between Alternate Concepts Inc. and PUPR since 2007. In this program students are motivated to develop professionally and encourage the study of transportation infrastructure, inspection, and maintenance. Throughout the internship, students perform continuous inspections and maintenance evaluations to the physical structure and drainage elements of the Tren Urbano heavy rail system.

The Civil Engineering and Surveying Department at UPRM and the Civil and Environmental Engineering at PUPR promote that students participate in Student Organizations. The UPRM and the PUPR have 10 and 7 Civil Engineering related Students Organizations, respectively. Both universities feature the Institute of Transportation Engineers [ITE] student chapters, ITE-UPRM and ITE-PUPR, which interacts with ITE Professional Chapter in Puerto Rico. This allows students to share with professionals actively involved in the transportation field, learn about new technologies and transportation innovation, and provides the discovery of professional opportunities. Members have the opportunities to enrich with academic and professional experiences. These organizations strive to promote the professional development of students in their field of study or area of interest. Participating in these organizations benefit students to acquire Civil Engineering skills required for the profession, such as leadership, networking, creativity, competition, and many others (*UPRM-CE, 2014*). Other transportation organizations at the professional level that complement the careers are: ITE, TRB, AASHTO, American Public Transit Association [APTA], American Public Works Association [APWA], American Road & Transportation Builders Association [ARTBA], Association of American Railroads [AAR], Transport Canada, and USDOT.

5.4. Academic Offerings in the US

It is important to analyze the academic offerings in other US jurisdictions, such that one is capable of comparing and identifying variations and justify changes in a curriculum due to its pertinence for Puerto Rico's transportation academic offerings. In order to maintain within the scope of this research, only US institutions were considered.

The U.S. News & World Report is an annual report that ranks the best Colleges, Graduate Schools, and High Schools (*Hobsons, n.d.*). According to the U.S. News (*2014*) there are 267 universities within the US that are considered in the rankings that offer Civil Engineering undergraduate programs and are accredited by ABET. The US News offers various rankings such as: National Universities, Regional Universities, National Liberal Arts Colleges, Unranked, and Ranked Not Published [RNP] for National and Regional Universities. Tables 5, 6, and 7 present the 2014 rates for top undergraduate engineering schools offering bachelors or masters degree as its highest degree, doctorate as the highest degree, and Civil Engineering program, respectively.

Table 5 Top Engineering Schools offering bachelors or masters degrees

Rank School (State) (*Public)	Peer assessment score(5.0=highest)	Rank School (State) (*Public)	Peer assessment score(5.0=highest)	Rank School (State) (*Public)	Peer assessment score(5.0=highest)
1. Rose-Hulman Inst. of Tech. (IN)	4.4	22. Calif. State Poly. Univ.-Pomona*	3.3	41. Lawrence Technological Univ. (MI)	3.0
2. Harvey Mudd College (CA)	4.3	22. The Citadel (SC)*	3.3	41. Mercer university (GA)	3.0
3. United States Military Academy (NY)*	4.1	22. Gonzaga University (WA)	3.3	45. California Maritime Academy*	2.9
4. Franklin W. Colin Col. Of Engineering (MA)	4.0	22. Loyola Marymount University (CA)	3.3	45. California State U. – Long Beach*	2.9
4. United States Air Force Acad. (CO)*	4.0	22. U.S. Merchant Marine Acad. (NY)*	3.3	45. California State U. – Los Angeles*	2.9
4. United States Naval Academy (MD)*	4.0	22. Univ. of Colo. – Colorado Springs*	3.3	45. California State U. – Sacramento*	2.9
7. Cooper Union (NY)	3.9	22. University of San Diego	3.3	45. LeTourneau University (TX)	2.9
8. Cali. Polytechnic State U. – San Luis Obispo*	3.8	22. Valparaiso University (IN)	3.3	45. Loyola University Maryland	2.9
9. Bucknell University (PA)	3.7	30. Bradley University (IL)	3.2	45. Manhattan College (NY)	2.9
10. Embry-Riddle Aeronautical U. (FL)	3.6	30. Lafayette College (PA)	3.2	45. New York Inst. of Technology	2.9
10. Milwaukee School of Engineering	3.6	30. Miami University-Oxford (OH)	3.2	45. Northern Arizona University*	2.9
10. Santa Clara University (CA)	3.6	33. Ohio Northern University	3.1	45. Northern Illinois University*	2.9
13. Baylor University (TX)	3.5	33. Rowan University (NJ)*	3.1	45. Oregon Inst. of Technology*	2.9
13. San Jose State university (CA)*	3.5	33. Seattle University	3.1	45. Penn State Univ.-Erie, Behrend Col.*	2.9
13. United States Coast guard Acad. (CT)*	3.5	33. Trinity University (TX)	3.1	45. SUNY Maritime College	2.9
13. Villanova University (PA)	3.5	33. University of Michigan-Dearborn*	3.1	45. Trinity College (CT)	2.9
17. Embry-Riddle Aeronautical U. – Prescott (AZ)	3.4	33. University of Portland (OR)	3.1	45. Univ. of Arkansas-Little Rock*	2.9
17. Keltering University (MI)	3.4	33. Virginia Military Institute*	3.1	45. Univ. of Massachusetts-Dartmouth*	2.9
17. Smith College (MA)	3.4	33. Webb Institute (NY)	3.1	45. University of the Pacific (CA)	2.9
17. Swarthmore College (PA)	3.4	41. Boise State University (ID)*	3.0	45. Western New England University (MA)	2.9
17. Union College (NY)	3.4	41. Grand Valley State University (MI)*	3.0	45. Youngstown State University (OH)*	2.9

Source: US News (2013). Civil Engineering undergraduate programs. Best Colleges 2013.

Table 6 Top Engineering School offering doctorate as highest degree

Rank School (State) (*Public)	Peer assessment score(5.0=highest)	Rank School (State) (*Public)	Peer assessment score(5.0=highest)	Rank School (State) (*Public)	Peer assessment score(5.0=highest)
1. Massachusetts Inst. of Technology	4.9	26. University of Pennsylvania	3.5	53. University of Arizona*	3.0
2. Stanford University (CA)	4.8	26. Univ. of Southern California	3.5	53. University of Delaware*	3.0
3. University of California-Berkeley*	4.7	26. University of Washington*	3.5	59. Clemson University (SC)*	2.9
4. California Institute of Technology	4.6	32. North Carolina State U. – Raleigh*	3.4	59. Illinois Institute of Technology	2.9
5. Georgia Institute of Technology*	4.5	32. University of California – Davis*	3.4	59. Tuffs University (MA)	2.9
5. U. of Illinois-Urbana-Champaign*	4.5	32. University of Colorado – Boulder*	3.4	59. University of Iowa*	2.9
7. Carnegie Mellon University (PA)	4.3	35. Brown University (RI)	3.3	59. Univ. of Massachusetts-Amherst*	2.9
7. Cornel University (NY)	4.3	35. Case Western Reserve Univ. (OH)	3.3	59. University of Utah*	2.9
7. University of Michigan-Ann Arbor*	4.3	35. Iowa State University*	3.3	65. Colorado State University*	2.8
10. Purdue Univ.-West Lafayette (IN)*	4.2	35. Lehigh University (PA)	3.3	65. Michigan Technological University*	2.8
10. University of Texas-Austin*	4.2	35. Univ. of California – Santa Barbara*	3.3	65. Missouri Technological University*	2.8
12. Princeton University (NJ)	4.1	35. University of Florida*	3.3	65. Missouri Univ. of Science & Technology*	2.8
13. Northwestern University (IL)	4.0	35. University of Virginia*	3.3	65. Polytechnic Institute of New York University	2.8
13. Univ. of Wisconsin-Madison*	4.0	35. Vanderbilt University (TN)	3.3	65. Rochester Inst. of Technology (NY)	2.8
15. Texas A&M Univ. College Station*	3.9	43. Arizona State University*	3.2	65. Stony Brook – SUNY*	2.8
15. Virginia Tech*	3.9	43. Michigan State University*	3.2	65. Syracuse University (NY)	2.8
17. John Hopkins University (MD)	3.8	43. Rugers, the St. U. of N.J. – New Brunswick*	3.2	65. University at Buffalo – SUNY*	2.8
17. Rice University (TX)	3.8	43. University of Notre Dam (IN)	3.2	65. University of Connecticut*	2.8
19. Columbia University (NY)	3.7	43. Washington University in St. Louis	3.2	65. University of Rochester (NY)	2.8
19. Duke University (NC)	3.7	43. Yale University (CT)	3.2	65. University of Tennessee*	2.8
19. Pennsylvania State U. – University Park*	3.6	49. Colorado School of Mines*	3.1	65. Washington State University*	2.8
19. Univ. of California – Los Angeles*	3.7	49. Dartmouth College (NH)	3.1	65. Worcester Polytechnic Inst. (MA)	2.8
23. Harvard University (MA)	3.6	49. University of California – Irvine*	3.1	78. Brigham Youth Univ. – Provo (UT)	2.7
23. Univ. of Maryland-College Park*	3.6	49. University of Pittsburgh*	3.1	78. Kansas State University*	2.7
23. Univ. of Minnesota – Twin Cities*	3.6	53. Auburn University (AL)*	3.0	78. Oregon State University*	2.7
26. Ohio State University-Columbus*	3.5	53. Boston University	3.0	78. University of Illinois – Chicago*	2.7
26. Rensselaer Polytechnic Inst. (NY)	3.5	53. Drexel university (PA)	3.0	78. University of Kansas*	2.7
26. Univ. of California – San Diego*	3.5	53. Northeastern University (MA)	3.0		

Source: US News (2013). Civil Engineering undergraduate programs. Best Colleges 2013.

Table 7 Top universities engineering specialties

Aerospace / Aeronautical / Astronautical	Civil	Environmental / Environmental Health
1. Massachusetts Inst. of Technology	1. University of California-Berkeley*	1. Stanford University (CA)
2. Georgia Institute of Technology*	2. U. of Illinois – Urbana-Champaign*	2. University of California-Berkeley*
3. University of Michigan – Ann Arbor*	3. Georgia Institute of Technology*	3. Georgia Institute of Technology*
4. Stanford University (CA)	4. Massachusetts Inst. of Technology	4. University of Michigan – Ann Arbor*
5. U. of Illinois – Urbana-Champaign*	5. Stanford University (CA)	5. U. of Illinois – Urbana-Champaign*
	5. University of Texas-Austin*	
Biological / Agricultural	**Computer Engineering**	**Industrial / Manufacturing**
1. Purdue Univ. – West Lafayette (IN)*	1. Massachusetts Inst. of Technology	1. Georgia Institute of Technology*
2. U. of Illinois – Urbana-Champaign*	2. Carnegie Mellon University (PA)	1. University of Michigan – Ann Arbor*
3. Texas A&M Univ. College Station*	3. Stanford University (CA)	3. University of California-Berkeley*
4. Iowa State University*	4. University of California-Berkeley*	4. Stanford University (CA)
5. North Carolina State U. – Raleigh*	5. U. of Illinois – Urbana-Champaign*	5. Purdue Univ. – West Lafayette (IN)*
Biomedical / Biomedical Engineering	**Electrical / Electronic / Communications**	**Materials**
1. Johns Hopkins University (MD)	1. Massachusetts Inst. of Technology	1. Massachusetts Inst. of Technology
2. Duke university (NC)	2. Stanford University (CA)	2. U. of Illinois – Urbana-Champaign*
3. Massachusetts Inst. of Technology	3. University of California-Berkeley*	3. University of California-Berkeley*
4. Georgia Institute of Technology*	4. U. of Illinois – Urbana-Champaign*	4. Georgia Institute of Technology*
5. Univ. of California – San Diego*	5. Georgia Institute of Technology*	4. Northwestern University (IL)
		4. Stanford University (CA)
Chemical	**Engineering Science / Engineering Physics**	**Mechanical**
1. Massachusetts Inst. of Technology	1. U. of Illinois – Urbana-Champaign*	1. Massachusetts Inst. of Technology
2. University of California-Berkeley*	2. Cornell University (NY)	2. University of Michigan – Ann Arbor*
3. Stanford University (CA)	3. Massachusetts Inst. of Technology	3. Georgia Institute of Technology*
4. Univ. of Minnesota-Twin Cities*	3. Stanford University (CA)	4. Stanford University (CA)
5. California Institute of Technology	3. University of California-Berkeley*	4. University of California-Berkeley*

Source: US News (2013). Civil Engineering undergraduate programs. Best Colleges 2013.

According to Lynn O'Shaughnessy, speaker on issues related to parents with teenagers entering college of CBS News, there are four limitations on the U.S. News college rankings; however these variables are not a limitation to the research, because the focus of the study is the curriculum. The four limitations are (*CBS, 2012*):

- Cost of fuel estimate is higher than the one estimated by the colleges,
- Academic quality is not quantified,
- Survey cheating by universities, and
- Base for ranking is on beauty contest.

The US News ranking was used for identifying groups of universities. For this study the universities were grouped in three main portions and sorted by national rank: top, mid, and minor. The final selections of universities studied within each group category were elected by convenience. A total of three universities were selected. The convenience method was used because the purpose was to identify universities from the highest, center, and lowest rank groups.

5.4.1. Top Universities

The first three national ranked universities are listed as follows

- University of California—Berkeley [UCB], Berkeley, CA.
- University of Illinois—Urbana-Champaign [UIUC], Champaign, IL.
- Georgia Institute of Technology [GIT], Atlanta, GA.

The scheme followed by the top ranked UCB, UIUC, and GIT is the Fundamental Engineer and Required Level of Knowledge at Entrance.

5.4.1.1. University of California—Berkeley

UCB is a particular university for its location in California. California is a state that has a high seismic activity; for such reason engineering codes and regulations are different from other

states. For such reason Berkeley prepares students differently. UCB offers undergraduates the opportunity of a four-year Bachelor of Science in Civil Engineering, with the alternatives of five different minors, of which Transportation Engineering is one. The minimum requirement for the program is 120 credit-hours, of which two transportation courses are requisites and one is a design elective which is discretional to take (*Berkeley, 2013*).

The first course related to transpiration engineering is taken during the second year (third semester) and is a three credit-hours, lectured two hours per week, titled *Transportation Systems Engineering – Civil And Environmental Engineering* (CE 155). According to the Berkeley's General Catalog, the topics covered are "Operation, management, control, design, and evaluation of passenger and freight transportation systems and their economic role. Demand analysis, overall logistical structure, performance models and modeling techniques: time-space diagrams, queuing theory, network analysis, and simulation; Design of control strategies for simple systems, Feedback effects, Paradoxes; Transportation impact modeling, noise, and air pollution; Multi-criteria evaluation and decision making; and Financing and politics" (*Berkeley, 2014*).

The second course is a design elective that students with a particular interest have the flexibility to emphasize in such area: *Transportation Facility Design – Civil and Environmental Engineering* (CE 153). This course is a three credit-hour course, lectured two hours and three hours of laboratory work per week. Prerequisite for this course is the CE 155. According to the undergraduate catalog the course is a capstone class that has as objectives: design transportation facilities based on operational capacity, site constraints, and environmental design considerations; emphasis on airports, including landside and airside elements, and environmental assessment and mitigation techniques.

The final course that applies to transportation concepts is the *Civil & Environmental Systems Analysis* (CE 191). The objective is to solve a large-scale problem of the real world. The curriculum indicates that the areas to address in this course include: planning or management of the transportation systems; design of public transportation system for an urban area; water supply maintenance; repair and replacement policies of reinforced concrete bridge decks; traffic signal control for an arterial street; and scheduling in a large-scale construction project.

5.4.1.2. University of Illinois—Urbana-Champaign

Considering that Berkeley University is in California and might address particular areas, a second university was evaluated to address any possible significant differences. For this reason the university that was evaluated was **UIUC** which is the second best ranking in the US national list. The curriculum establishes a total of 128 credit-hours for the Bachelors in Civil Engineering, distributed in mathematics, sciences, electives, civil engineering technical courses, and other courses. Students select which electives they will attend and elect a major and secondary area of concentration within the Civil Engineering department (*UIUC, 2014*).

The main areas of specialty are: Construction Engineering and Management, Construction Materials Engineering, Environmental Engineering, Geotechnical Engineering, Environmental Hydrology and Hydraulics, Structural Engineering, and Transportation Engineering. If students decide to specialize in transportation they have to take courses of three main areas: Science Electives, Civil Engineering Core Courses, and Advanced Technical Courses. Science electives are not mandatory, however they provide some general courses recommended in Geology, Statistics, Mechanical Engineering, and others. For the Civil Engineering Core Courses is required to take *Behavior of Materials* (CEE 300) and *Transportation Engineering* (CE 310). The Advanced Technical Courses required are one from the areas of facilities, systems, and railroads, and one from the recommended list; these are:

Facilities: *Asphalt Materials, I* (CEE 405)

Pavement Design, I (CEE 406)

Airport Design (CEE 407)

Systems: *Airport Design* (CEE 407)

Geometric Design of Roads (CEE 415)

Traffic Capacity Analysis (CEE 416)

Railroads: *Railroad Transportation Engineering* (CEE 408)

Railroad Track Engineering (CEE 409)

Railway Signaling and Control (CEE 410)

Railroad Project Design & Construction (CEE 411)

Recommended: *Concrete Materials* CEE 401, CEE 405, CEE 406, CEE 407, CEE 408, CEE 409, CEE 410, CEE 411, *Geometric Design of Roads* CEE 415, Traffic Capacity Analysis CEE 416, *Foundation*

Engineering (CEE 480), *High Speed Rail Engineering* (CEE 498 HSR), *High Speed Rail Planning* (CEE 498 HRP), *High Speed Rail Construction Management* (CEE 498 HRM), *Public Transportation* (CEE 498 PT)

5.4.1.3. Georgia Institute of Technology

Considering a third university to compare the top three ranked in the US is **GIT**. The Civil Engineering curriculum requires a total of 129 credit-hours of language, humanities, social sciences, major courses, major requirements, technical electives, technical electives of focus area. The program takes four years with a flexible design that allows students meet their personal educational objectives of focus area (*Georgia Tech, 2014*). The main areas of specialty are: Structural Engineering, Construction Engineering & Management, Hydraulic Engineering, Environmental Engineering, Geotechnical Engineering, and Transportation Planning and Design.

The first course related to transpiration engineering is taken during the senior year and is a three credit-hours titled *Transportation Planning & Design* (CE 4600). It is an introduction to transportation engineering with focus in the planning, design, and operation of transportation facilities. The institution provides no further details of the course description on their webpage, nor provides syllabus.

5.4.1.4. Comparison of Top Rank Universities

The three universities offer bachelor degrees in Civil Engineering in a four-year program. Scheme followed by the top universities is the Required Level of Knowledge at Entrance and Fundamental Engineering curriculum.

A transportation engineering course is provided at Berkeley and Georgia, where topics like highway design, planning, and operation of facilities are covered. The difference between

UCB and UIUC is that UIUC provides a wider range of courses and requires students with specialty in transportation engineering to take courses in facilities, systems, and railroads. It was intended to study the particular topics covered by course, however after communicating with the universities their response was that syllabus are only provided to students attending classes and no exceptions are allowed.

5.4.2. Mid-ranked Universities

A special consideration to identify the middle ranking universities was performed; as some universities were listed, though no rank was available. For such reason the 128th rank was the mid point for consideration, with four universities presented. The Polytechnic Institute of New York University was selected to evaluate its curriculum offerings. The four universities are:

- Missouri University of Science & Technology [UST], Rolla, MO.
- Polytechnic Institute of New York University [NYU-Poly], Brooklyn, NY.
- University of Arkansas [UARK], Fayetteville, AR.
- Washington State University [WSU], Pullman, WA.

The scheme followed by the selected mid ranked universities is Required Level of Knowledge at Entrance, and they vary in the curriculum structure as UST is a Fundamental Engineering university, and NYU and UARK are General Engineering universities. WSU is a special university that offers opportunities both Fundamental and General Engineering curriculums.

5.4.2.1. Missouri University of Science & Technology

MST provides a 4-year program requiring 127 credit-hours for the bachelor degree in Civil Engineering. The program allows students to follow the general curriculum or specialize in one of the following areas: Construction Engineering, Environmental Engineering, Geotechnical Engineering, Materials Engineering, Structural Engineering, and Water Resources Engineering.

No emphasis in Transportation Engineering is offered. Students take one course related to transportation area at the second semester of their junior year (*Missouri S&T, 2012a*).

The only course related to the transportation area is *Transportation Engineering* (CE 211), a 3 credit-hour course focused in: study of operating characteristics of transportation modes (highways, railways, inland waterways, airways, and pipelines), traffic control devices, safety, system capacity, design of routes, planning of urban transportation systems, and economic evaluation of transportation alternatives (*Missouri S&T, 2012b*).

5.4.2.2. Polytechnic Institute of New York University

NYU-Poly offers a 4-year program with 128 hour-credits for the Bachelor of Science in Civil Engineering degree. The first two years students take courses in sciences, mathematics, general engineering, computer sciences, humanities and social sciences. In their last two years, courses belong to the Civil Engineering field as well as free electives. A total of three courses can be taken in the desired area of specialty (*NYU, 2014*).

The first course in transportation related area provided is *Traffic Engineering I* (CE 2323). This credit-hours course covers the following topics in accordance to the program catalog: introduction to traffic engineering; characteristics of road users, vehicles, highways, and control devices; quantification of traffic stream; design and uses of traffic control devices and signal timing; coordination of signals on arterials and networks; highway safety issues, policies, programs, and mitigation measures.

The second course offered is the *Design of Traffic Facilities* (CE 3343) as a three credit-hours course. The topics covered on this course are: introduction to the design of highway traffic facilities; basic design concepts of horizontal and vertical alignment, superelevation and cross-section design; fundamentals of intersection and interchange design; pavement design; design of

parking facilities; and bikeway and walkway design. The course is complemented with a design laboratory.

The final course available at the undergraduate level is a free elective called *Traffic Engineering II* (CE 4333), offered in a three credit-hours scheme. The topics covered are: highway capacity and level of service analysis on uninterrupted and interrupted flow facilities; signalized and unsignalized intersections; freeways, freeway weaving and ramp junctions; rural and suburban multilane highways; two-lane rural highways; suburban and urban arterials; and intersections.

5.4.2.3. University of Arkansas

UARK offers a 4-year program for the Bachelor Degree in Civil Engineering, with a total 128 credit-hours. For the first two years, students take courses in sciences, mathematics, general engineering, computer sciences, humanities and social sciences. The last two years, students take courses in the Civil Engineering field. One course of three credit-hour in the transportation related area is required as part of the general curriculum for undergraduates. This course is *Transportation Engineering* (CVEG 3413), were students are introduced to highway and transportation engineering, planning, finance, economics, traffic, and geometric design of transportation facilities; theory and application of driver, vehicle and roadway characteristics as they relate to roadway and intersection design; safety, capacity, traffic operations, and environmental effects for highway engineering. The specific topics covered in the course are:

- Infrastructure: Identify sources to solve basic transportation problems,
- Traffic flow theory: Compute queue length, capacity, and Level of Service (LOS); Solve problems in speed, volume, and density relationships,

- Traffic operations and planning: Describe basic concepts of trip generation and perform calculations; Recognize importance of the Manual of Uniform Traffic Control Devices (MUTCD); and Calculate signal change intervals,
- Roadway geometry: Solve problems in horizontal and vertical curve geometry; and Compute needed sight distance, and
- Transportation materials: Describe basic pavement materials and structures: soils, rigid, pavement, flexible pavement, rehabilitation, maintenance.

Specific design oriented courses are required for students and they must choose two from the following list: *Environmental Design Project* (CVEG 4812), *Geotechnical Design Project* (CVEG 4822), *Structural Design Project* (CVEG 4832), and/or *Transportation Design Project* (CVEG 4842). The CVEG 4842 *Transportation Design Project* course consists of two credit-hours, where students should design a comprehensive engineering project that solves transportation related issues (*UARK, 2013a and UARK, 2013b).*

5.4.2.4. Washington State University

WSU offers a Bachelor Degree in Civil Engineering with a curriculum of 128 credit-hour based on a 4 year program. In the first two-years, students take courses in sciences, mathematics, general engineering, computer sciences, humanities and social sciences. During their junior year, students take multiple courses of Civil Engineering sub-disciplines. On the sophomore year, students have two course alternatives; first alternative is to take courses in administration, ethics, Civil Engineering laboratories, electives, and capstone; the second alternative is to take a specialty in Environmental Engineering, Water Resources, Structural Engineering, Infrastructure Engineering or Construction Engineering (*WSU, 2013a*).

The transportation specialty is not available, however students who specialize in Construction or Infrastructure take the of *Pavement Design* course (CE 473). In this course the general topics covered are: pavement performance evaluation, material characterization, traffic analysis, pavement structural response analysis, transfer function application, and pavement design procedures for both flexible and rigid pavements (*WSU, 2013b*).

Students in the general and specialty program take one course in transportation related field. The *Transportation Engineering* (CE 322) course includes the following general topics: road-vehicle interaction, geometric design, traffic flow and queuing theory, highway capacity and level of service, and introduction to pavement design and materials. The specific topics covered in the course are the same as the ones provided in the catalog, and the course covers the following topics:

- Highways and the Economy
- Highways, Energy, and the Environment
- Highways as Part of the Transportation System
- Highway Transportation and the Human Element
- Highways and Evolving Technologies
- Scope of Study
- Tractive Effort and Resistance
- Aerodynamic Resistance
- Rolling Resistance
- Grade Resistance
- Available Tractive Effort
- Vehicle Acceleration

- Fuel Efficiency
- Principles of Braking
- Principles of Highway Alignment
- Vertical Alignment
- Horizontal Alignment
- Combined Vertical and Horizontal Alignment
- Traffic Stream Parameters
- Basic Traffic Stream Models
- Models of Traffic Flow
- Queuing Theory and Traffic Flow Analysis
- Traffic Analysis at Highway Bottlenecks
- Level-of-Service Concept
- Level-of-Service Determination
- Basic Freeway Segments
- Multilane Highways
- Two-Lane Highways
- Design Traffic Volumes
- Intersection and Signal Control Characteristics
- Traffic Flow Fundamentals for Signalized Intersections
- Development of a Traffic Signal Phasing and Timing Plan
- Analysis of Traffic at Signalized Intersections

5.4.2.5. Comparison of Mid Rank Universities

The four mid-ranked universities offer Bachelor Degrees in Civil Engineering in four-year programs. The scheme followed by these universities is the Required Level of Knowledge at Entrance. UST follows the Fundamental Engineering scheme, while NYU and UARK follow the General Engineering. WSU provides Fundamental and General Engineering opportunities.

The Transportation Engineering course is similar in all four universities, which covers mainly road design, safety, traffic, level of service, and planning. However, NYU provides undergraduates three courses in transportation engineering, when the other universities offer one or two.

5.4.3. Lower Ranked Universities

The lower ranked universities in the list for undergraduate studies in Civil Engineering are in the 190th position. The lowest ranking was given to the University of Houston and it was considered its curriculum as the minor university ranked.

- Utah State University [USU], Logan, UT.
- University of Houston [UH], Houston, TX.
- University of Colorado—Denver [UC Denver], Denver, CO.

The scheme followed by the selected minor ranked universities is Required Level of Knowledge at Entrance. The curriculum structure varies, as USU is a Fundamental Engineering university, while UH and UC Denver follow the General Engineering structure.

5.4.3.1. Utah State University

USU offers a Bachelor Degree in Civil Engineering on a 4-year program. The minimum requirement for graduation is 120 credit-hours. For the first two-years the courses taken are sciences, mathematics, general engineering, and social sciences. During the junior year students

take courses of Civil Engineering. On the sophomore year students take Civil Engineering design I, II, and III, technical elective, and specialty courses of Environmental Engineering, Structures, Fluid Mechanical and Hydraulics, Geotechnical, Transportation Engineering, and Water Resources Engineering (*USU, 2012a*).

For students specializing in transportation engineering the first course provided is *Introduction to Transportation Engineering* (CEE 3210). According to the catalog, the course is given as an introduction to the basic concepts of roadway geometric design, intersection and highway capacity analysis, traffic flow characteristics, traffic studies, signal design, and transportation project evaluation (*USU, 2012b*).

A second course *Geographic Information Systems for Civil Engineers* (CEE 5190) provides GIS concepts attending data structures, spatial entities, and queries. Also includes location referencing methods, data collection techniques, current applications, and institutional and organizational issues.

The third course *Traffic Engineering* (CEE 5220) includes general topics: characteristics, measurements, and analysis of volume, speed, density, and travel time; capacity and level of service analysis; signalization and traffic control devices.

A fourth course *Geometric Design of Highways* (CEE 5230) covers the principles of highway location and planning, with full consideration of economic, environmental, and other impacts; capacity analysis of intersections and highways, passing-lane design, and risk-cost based horizontal and vertical alignment design; and introduction to design software through coursework and term projects.

The fifth course *Urban and Regional Transportation Planning* (CEE 5240) helps students learn how to examine travel demand forecasting, data collection, and survey data

analysis techniques. The course focuses on ground transportation use, interactions and impact of market-based policies on travel demand. Theories and applications of traditional and advanced trip distribution, mode choice, and route assignment models.

5.4.3.2. University of Houston

UH provides a Bachelor Science in Civil Engineering of 130 credit-hours on a 4-year program. On the first year students take the fundamentals of Civil Engineering with sciences, mathematics, general engineering, and history courses. Later, the curriculum requires concentration courses, Civil Engineering, and history. One significant finding is that this program does not offer transportation engineering as part of the bachelor degree. Another significant result is that part of the requirements is a total 12 credit-hours on politics and history to complete the degree. It was found that there are three courses in transportation and one is provided by the Civil Engineering Department. These are: *Transportation Engineering* (CIVE 4337), *Transportation Economics and Policy* (SCLT 3385), and *Transportation Law* (SCLT 3389). The CIVE 4337 is a senior technical elective course, and is recommended for strong seniors. This could be since the graduate program does not offer a Master o Doctorate degree in transportation.

5.4.3.3. University of Colorado—Denver

UC Denver has a 130 credit-hours requirement for the Bachelor Science in Civil Engineering. The sequence of the curriculum establishes the first two years for the fundamental courses of Civil Engineering courses with science, mathematics, and some introductory engineering courses. On the last two years, Civil Engineering and specialty courses are provided (*UC Denver, 2013a*).

Transportation engineering courses are taken during the third year (5th semester), starting with *Transportation Engineering* (CVEN 3602). The catalog states that it is a three credit-hours course and students are introduced to concepts and methods of transportation engineering, planning, and management (*UC Denver, 2013a*). Particular topics covered are: vehicle dynamics, traffic flow fundamentals, accident analysis, signal timing, highway capacity analysis, level of service analysis, freeway operations, and evaluation procedures for alternative transportation projects. The specific topics covered in the course are:

- Driver & Vehicle Characteristics,
- Vehicle Dynamic Characteristics,
- Passing & Stopping Distances,
- Speed Studies,
- Volume Studies,
- Travel Time & Parking Studies,
- Highway Safety Studies,
- Accident Countermeasures,
- Traffic Flow Fundamentals,
- Speed/Density Relationship,
- Shock Waves & Queuing Models,
- Intersection Design and Dimensions,
- Sight Distances at Intersections,
- Two-Lane Rural Road Capacity,
- Basic Freeway Section Capacity,
- Basic Freeway Section Capacity II,

- Intersection Control,
- Webster's and Highway Capacity Manual [HCM] Timing Methods,
- Signalized Intersections,
- Simplified Operational Analysis I,
- Simplified Operational Analysis II,
- Evaluating Transportation Alternatives,
- Engineering Economic Analysis,
- Multi-Objective Project Comparisons, and
- Overview of Transportation Planning Process.

The second course in the curriculum is *Highway Engineering* (CVEN 4602), which is a design elective that consists of 3 credit-hours. In this course the following topics are covered according to the catalog: evaluation of alternate highway routes; discusses highway drainage, finance, maintenance, pavement design, traffic operations and principles of economic analysis; and analysis of the impact of the highway on the environment. The specific topics covered in the course are:

- Functional Classification,
- Design Speed/Design Vehicle,
- Intersection Design,
- Roundabout Design,
- Vertical Alignment,
- Vertical Alignment,
- Horizontal Alignment,
- Horizontal Alignment,

- Coordinating the Horizontal & Vertical Alignments,
- Cross-Section Elements,
- Climbing Lanes/Emergency Escape Ramps,
- Bike Facility Design,
- Parking Facility Design,
- Interchange Design,
- Diverging Diamond Interchanges,
- Highway Earthwork and Final Plans,
- Transportation Planning,
- Forecasting Travel Demand,
- Highway Drainage,
- Soils,
- Bituminous Materials,
- Flexible Pavements, and
- Rigid Pavements.

5.4.3.4. Comparison of Lowest Ranked Universities

All three universities offer Bachelor Degrees in Civil Engineering in a four-year program. The scheme followed by these is Required Level of Knowledge at Entrance. USU follows the Fundamental Engineering scheme, while UH and UC Denver follow the General Engineering.

There is one course that is similar in USU and UC Denver and is the *Introduction to Transportation Engineering* (CEE 3210) and *Transportation Engineering* (CVEN 3602) respectively. In general, basic concepts of transportation engineering, road design, planning,

traffic flow, level of service, and others are presented in the courses. USU offers a wider variety of courses at undergraduate level as the curriculum provides a specialty area of focus.

5.5. Comparison of Academic Offerings in Puerto Rico vs. US

One of the significant differences in the curriculum between UPRM, PUPR and US Institutions is that UPRM maintains a 5-year base program, while many universities around the US provide 4-year programs. Another important difference is that students in the US specialize in one or more realm in Civil Engineering, such as transportation. The total number of credits-hours required on Structural Engineering topics at local universities are the highest with 15 and 16 credit-hours for UPRM and PUPR, respectively, compared to the other areas of focus offered in Civil Engineering.

Table 8 presents a summary of the topics covered from the chosen top, mid and minor ranked universities with Civil Engineering programs.

Table 8 Comparison of transportation related courses from top, mid and minor ranked universities

University	Course	Topics
UCB	Transportation Systems Engineering – Civil And Environmental Engineering (CE 155) [2]	Operation, management, control, design, and evaluation of passenger and freight transportation systems. Their economic role. Demand analysis. Overall logistical structure. Performance models and modeling techniques: time-space diagrams, queuing theory, network analysis, and simulation. Design of control strategies for simple systems. Feedback effects. Paradoxes. Transportation impact modeling; noise; air pollution. Multi-criteria evaluation and decision-making. Financing and politics.
	Transportation Facility Design – Civil And Environmental Engineering, coded (CE 153)	Capstone class that has as objectives: design transportation facilities based on operational capacity, site constraints, and environmental design considerations; emphasis on airports, including landside and airside elements, and environmental assessment and mitigation techniques.
	Civil & Environmental Systems Analysis (CE 191)	Solve a large-scale problem of the real world. The curriculum presents that the areas to address include: planning or management of the transportation systems; design of public transportation system for an urban area; water supply maintenance; repair and replacement policies of reinforced concrete bridge decks; traffic signal control for an arterial street; and scheduling in a large-scale construction project.
NYU-Poly	Traffic Engineering I (CE 2323) [1]	Introduction to traffic engineering; characteristics of road users, vehicles, highways, and control devices; quantification of traffic stream; design and uses of traffic control devices and signal timing; coordination of signals on arterials and networks; highway safety issues, policies, programs, and mitigation measures.
	Design of Traffic Facilities (CE 3343) [2]	Introduction to the design of highway traffic facilities; basic design concepts of horizontal and vertical alignment, superelevation and cross-section design; fundamentals of intersection and interchange design; pavement design; design of parking facilities; and bikeway and walkway design. The course is complemented with a design laboratory.
	Traffic Engineering II (CE 4333) [3]	Highway capacity and level of service analysis on uninterrupted and interrupted flow facilities; signalized and unsignalized intersections; freeways, freeway weaving and ramp junctions; rural and suburban multilane highways, two-lane rural highways, suburban and urban arterials and intersections.
CU Denver	Transportation Engineering (CVEN 3602) [2/3]	Introduction to concepts and methods of transportation engineering, planning and management. Particular topics are cover which are: vehicle dynamics, traffic flow fundamentals, accident analysis, signal timing, highway capacity analysis, level of service analysis, freeway operations, and evaluation procedures for alternative transportation projects.
	Highway Engineering (CVEN 4602) [3]	Evaluation of alternate highway routes; discusses highway drainage, finance, maintenance, pavement design, traffic operations and principles of economic analysis; and analysis of the impact of the highway on the environment.

NOTE: Superscript numbers correspond to the equivalent course offered at UPRM and PUPR.

The main difference between UCB, NYU-Poly, and CU Denver is that UCB focuses mainly on transportation systems and NYU-Poly and CU Denver focuses in infrastructure. CU Denver requires only one core course in transportation for all undergraduates, and two elective courses if specializing in the area. The topics covered in both courses are addressed at UPRM either on the transportation courses or in other required courses. UCB and NYC-Poly curriculums require that students take two courses in transportation and one is a free elective, which is recommended if specializing in the area. Both universities provide a number of topics that are not covered currently at UPRM, such as bikeway and walkway design, airports, freight, modeling, and others. UCB Transportation Facility Design and Civil Environmental System Analysis courses have no equivalence to UPRM curriculum, as most of the general topics covered are not address and could be integrated as presented in Table 8.

Comparing the specific topics covered at UPRM and PUPR, with the selected universities at US, the new academic offering at local universities should consider integrating the listed topics in Table 9 and 10. Integrating these topics is of particular importance, as current academic offerings at US universities address them at undergraduate level and the industry expects professionals with knowledge in the mentioned areas.

Table 9 New specific topics to the UPRM Academic Offerings

Course	New Specific Topics	
Highway Location and Curve Design (INCI 4007)	• Bikeway and Walkway Design • Climbing Lanes/Emergency Escape Ramps • Design Vehicle • Diverging Diamond Interchanges • Highway safety-widening on highway curves	• Interchange Design • Intersection Design • Mitigation techniques • Multilane highway design • Parking Facility Design • Roundabout Design
Introduction to Transportation Engineering (INCI 4137)	• Airports, landside and airside elements • Design principles and operational analysis of Bicycle Facilities • Design principles and operational analysis of Pedestrian Facilities • Driver & Vehicle Characteristics • Freight transportation systems • Highway Safety Studies	• Intersection Capacity and Level of Service • Intersection Control: signal timing • Intersection Control: warrants • ITS • Passing & Stopping Distances • Public Passenger Transportation • Public transportation system for urban areas • Traffic Volume Studies • Transportation management • Travel Time & Parking Studies • Vehicle Dynamic Characteristics
Highway Engineering (INCI 4026)	• Accident Countermeasures • Speed/Density Relationship • Shock Waves & Queuing Models	• Intersection Design and Dimensions • Rigid Pavements • Parking Facilities
Transportation Engineering and Highway Design Laboratory (INCI XXXX)	*Volume Studies*: • Data analysis • Field Procedures • Methods of counting and equipment use • Purpose and applications *Intersection Counts:* • Automatic data collection and use of equipment • Count periods • Data analysis • Data conversion and presentation • Manual data collection techniques	*Intersection Delay and Saturation Flow Measurement* • Application of distribution probability models *Arrivals and Departures:* • Data collection techniques • Manual procedure • Mechanical procedures and use of equipment *Traffic Control Devices:* • Equipment and applications • Field inspection • Use of equipment *Transportation Planning Data:* • Area definition and zoning • Data analysis • Data collection and forecasting techniques Parking Studies Public Transportation Studies

Table 10 New specific topics to the PUPR Academic Offerings

Course	New Specific Topics	
Route Location and Geometric Design (CE 3310)	• Bikeway and Walkway Design • Climbing Lanes/Emergency Escape Ramps • Design Vehicle • Diverging Diamond Interchanges • Highway safety-widening on highway curves	• Interchange Design • Intersection Design • Mitigation techniques • Multilane highway design • Parking Facility Design • Roundabout Design
Transportation Engineering and Urban Planning (CE 3330)	• Airports, landside and airside elements • Driver & Vehicle Characteristics • Freight transportation systems • Highway Safety Studies	• Intersection Control: signal timing • Intersection Control: warrants • ITS • Passing & Stopping Distances • Traffic Volume Studies • Transportation management • Travel Time & Parking Studies • Vehicle Dynamic Characteristics
Highway Engineering (CE 3320)	• Accident Countermeasures • Speed/Density Relationship • Shock Waves & Queuing Models	• Intersection Design and Dimensions • Rigid Pavements • Parking Facilities
Highway and Transportation Engineering Laboratory (CE 3331)	None	

There are numerous topics that will be new to the UPRM and PUPR curriculums; however, the courses are already filled with extensive material. Currently, UPRM offers many of them at graduate courses; nevertheless, it is fundamental to provide a transportation laboratory. Here students will be able to develop technological skill using transportation software as well as apply their knowledge on real world projects. PUPR should consider including some of the topics to the current courses, and offer new technical elective courses that could address most of them.

5.6. Current and Future Program Requirement

It is important to consider NCEES and ABET programs examinations requirements and evaluation criterions, as they are the entities that evaluate the theoretical and conceptual knowledge, and standardize the engineering profession. A fundamental component for the Civil Engineering profession practice in Puerto Rico is the Licenciature. This license is obtained after examining with the NCEES, which is an organization authorized by the BEE and entitle to establish the areas of knowledge to examine. One of the main requisites to qualify for licensing is that the academic program should be recognized by one of the following institutions: Council for Higher Education, ABET, or BEE. The following considerations present the pertinent considerations for the transportation related area.

5.6.1. NCEES

NCEES examination consists of two tests: Fundamentals of Engineering [FE] and Professional Engineering [PE]. The FE is a general exam for seven different engineering disciplines and is the first phase to achieve the PE License. It is computer base test with a total of 110 multiple questions to be answered in 5 hours and 20 minutes. Questions may be provided in the International System of units or US Customary System. The Civil Engineering FE exam attends the areas of mathematics, probability and statistics, computational tools, ethics and professional practice, engineering economics, statistics, dynamics, mechanics of materials, materials, fluid mechanics, hydraulics and hydrologic systems, structural analysis, structural design, geotechnical engineering, transportation engineering, environmental engineering, construction, and surveying (*NCEES, 2013b*). The questions related to transportation engineering range from 8 to 12 and are derived from the following areas:

- Geometric design of streets and highways,

- Geometric design of intersections,
- Pavement system design (e.g., thickness, subgrade, drainage, rehabilitation),
- Traffic safety,
- Traffic capacity,
- Traffic flow theory,
- Traffic control devices, and
- Transportation planning (e.g., travel forecast modeling).

The PE exam attempts to measure the capacity of the discipline of specialty. It consists of two parts, one offered during the morning and the other one during the afternoon, for a total duration of 8 hours. In the morning session the exam addresses 40 questions from the general areas of Civil Engineering, and other 40 questions in the afternoon from one of five specialty areas within Civil Engineering: construction, geotechnical, structural, transportation, and water resources and environmental. This is an open book test with methods of evaluation in design, analysis, and application.

The morning session integrates the areas of construction, geotechnical, structural, transportation, and water resources and environmental (*NCEES, 2014*). Figure 3 lists the specific topics cover in the afternoon session for the transportation specialty. Approximately 53% of this exam is focused in traffic analysis and geometric design and 15% in traffic safety. The lowest percentage is assigned to transportation planning with approximately 8% of the exam.

		Approximate Percentage of PM Exam
I.	**Traffic Analysis** A. Traffic capacity studies B. Traffic signals C. Speed studies D. Intersection analysis E. Traffic volume studies F. Sight distance evaluation G. Traffic control devices H. Pedestrian facilities I. Driver behavior and/or performance	**22.5%**
II.	**Geometric Design** A. Horizontal curves B. Vertical curves C. Sight distance D. Superelevation E. Vertical and/or horizontal clearances F. Acceleration and deceleration G. Intersections and/or interchanges	**30%**
III.	**Transportation Planning** A. Optimization and/or cost analysis (e.g., transportation route A or transportation route B) B. Traffic impact studies C. Capacity analysis (future conditions)	**7.5%**
IV.	**Traffic Safety** A. Roadside clearance analysis B. Conflict analysis C. Work zone safety D. Accident analysis	**15%**
V.	**Other Topics** A. Hydraulics 1. Culvert design 2. Open channel – subcritical and supercritical flow B. Hydrology 1. Hydrograph development and synthetic hydrographs C. Engineering properties of soils and materials (e.g., index properties, identification of types of soils, suitable or unsuitable soil, boring logs) D. Soil mechanics analysis (e.g., soil behavior, soil classification, soil compaction) E. Engineering economics 1. Value engineering and costing F. Construction operations and methods (e.g., erosion control measures, excavation/embankment) G. Pavement structures (e.g., flexible and rigid pavement design)	**25%**

Figure 3 PE Exam Specifications for Civil Engineering – Transportation (*NCEES, 2014*)

Comparing the listed topics that NCEES evaluates in the exam, the UPRM undergraduate courses should include more topics related to pedestrian facilities.

5.6.2. ABET

Assessing the requirements established by ABET which were listed in section 3.2, the UPRM program is in compliance with the curriculum objectives. An additional consideration is that ABET evaluates to provide accreditation is the student outcomes A to K which are listed below:

- Ability to apply mathematics, science and engineering principles,
- Ability to design and conduct experiments, analyze and interpret data,
- Ability to design a system, component, or process to meet desired needs,
- Ability to function on multidisciplinary teams,
- Ability to identify, formulate and solve engineering problems,
- Understanding of professional and ethical responsibility,
- Ability to communicate effectively,
- The broad education necessary to understand the impact of engineering solutions in a global and societal context,
- Recognition of the need for and an ability to engage in life-long learning,
- Knowledge of contemporary issues, and
- Ability to use the techniques, skills and modern engineering tools necessary for engineering practice

These outcomes are addressed in the transportation courses with examinations, quizzes, group participation, projects, lectures, and assigned readings.

5.7. Students Survey Results

A survey was completed with the participation of fourth and fifth year Civil Engineering UPRM students and fourth year PUPR students, including participants of research, scholarships, and COOP. Appendix B presents the form used to survey students. The objective was to identify the professional and technical skills of students who are close to start their professional career.

5.7.1. Demographic Profile

There were two samples in the survey, students of UPRM and PUPR. A total of 93 students were surveyed, 55 from UPRM and 38 from PUPR. The survey distribution was 59% from UPRM and 41% from PUPR. The survey was performed at the UPRM during the second semester and at PUPR through the third quarter of 2012-2013. UPRM had a total of 307 students enrolled in their 5^{th} academic year in the Civil Engineering program and PUPR has a total of 103 students enrolled in their 4^{th} academic year, for a total of 410 students enrolled in both universities. Based on the number of students that answered the survey and the total enrollment, the percentage of error of the sample size was calculated. It was then determined that the survey has a 9% error with a 95% confidence level when combining surveys from both universities.

Various questions were presented to identify the characteristics of the population. The first question presented was gender; 68% of the sample students were men and 32% were women. Distribution of men and women by institutions showed that the sample from UPRM consisted of 65% of men and 35% women, and in PUPR these percentages were 71% and 29%, respectively. This indicates that more surveyed men and women were from the UPRM than from the PUPR, and the women rate in the sample at the UPRM was higher than the PUPR. Detailed distributions are presented in Figure 4.

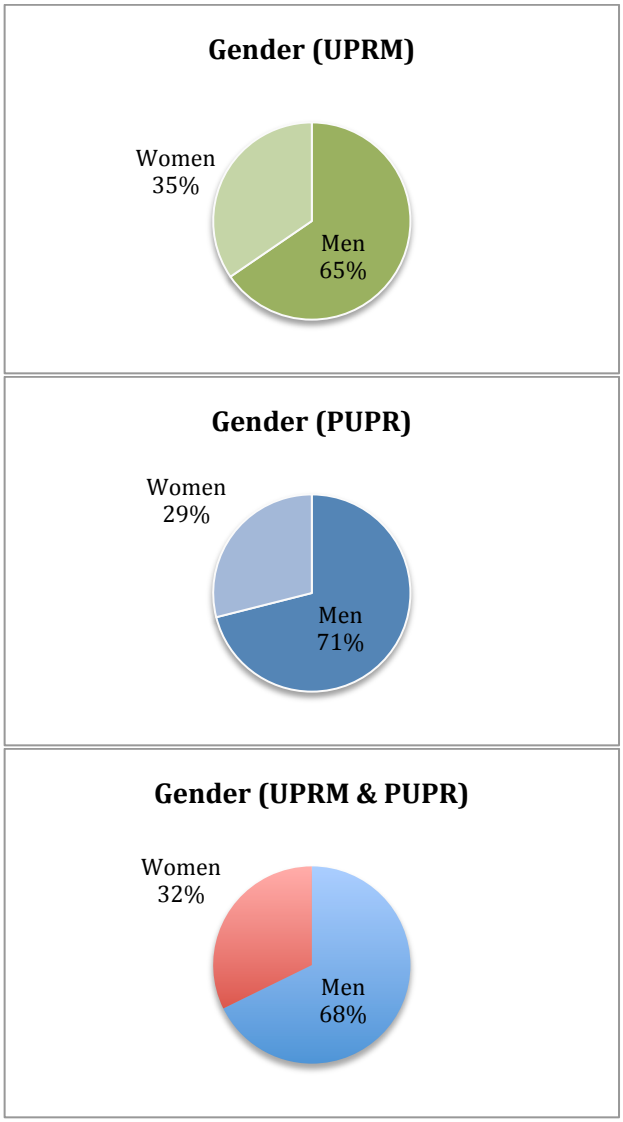

Figure 4 Gender for UPRM, PUPR, and total students

Comparing ages between universities, results revealed that from the total sample 70% of the respondents were students from the 20-24 age group from UPRM and 30% were from PUPR. When considering students with ages ranging from 25-29, 42% were from UPRM and 58% were from PUPR. Students with 30 years or older were all from PUPR. This represents a variation of

ages between populations that indicates that students at UPRM are mainly young adults. The PUPR students are young adults and adults. Age distributions are presented in Figure 5.

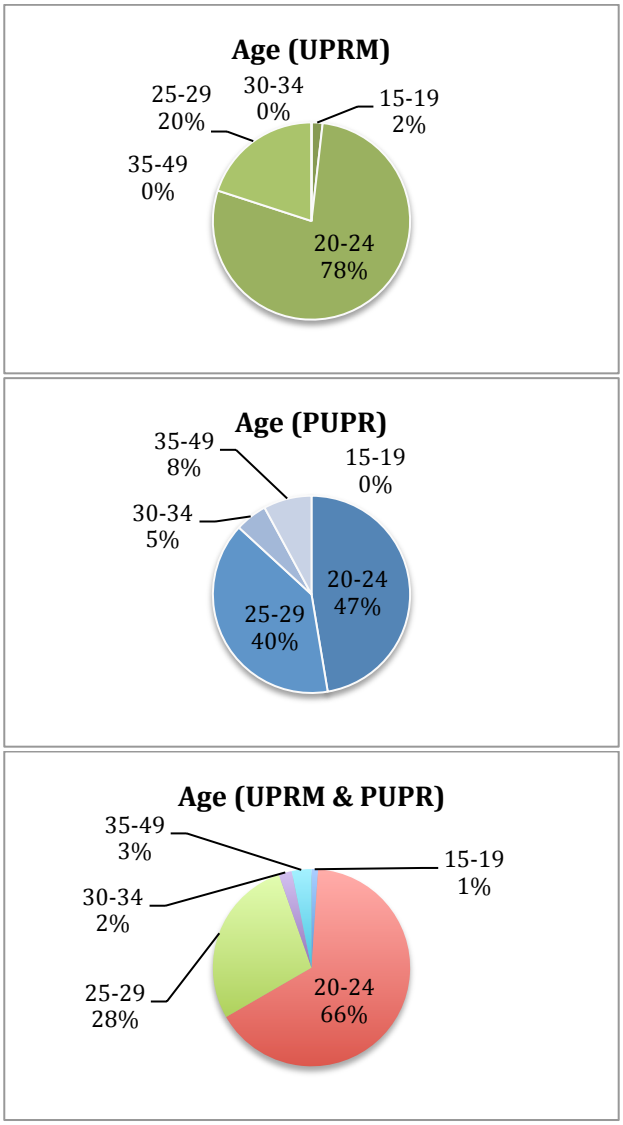

Figure 5 Age for UPRM, PUPR, and total students

The marital status question reveals that 78% of the sample was single, 15% was married, 5% lived with someone and 1% was divorced. About 63% of single persons are from UPRM and 37% are from PUPR. Results are presented in Figure 6.

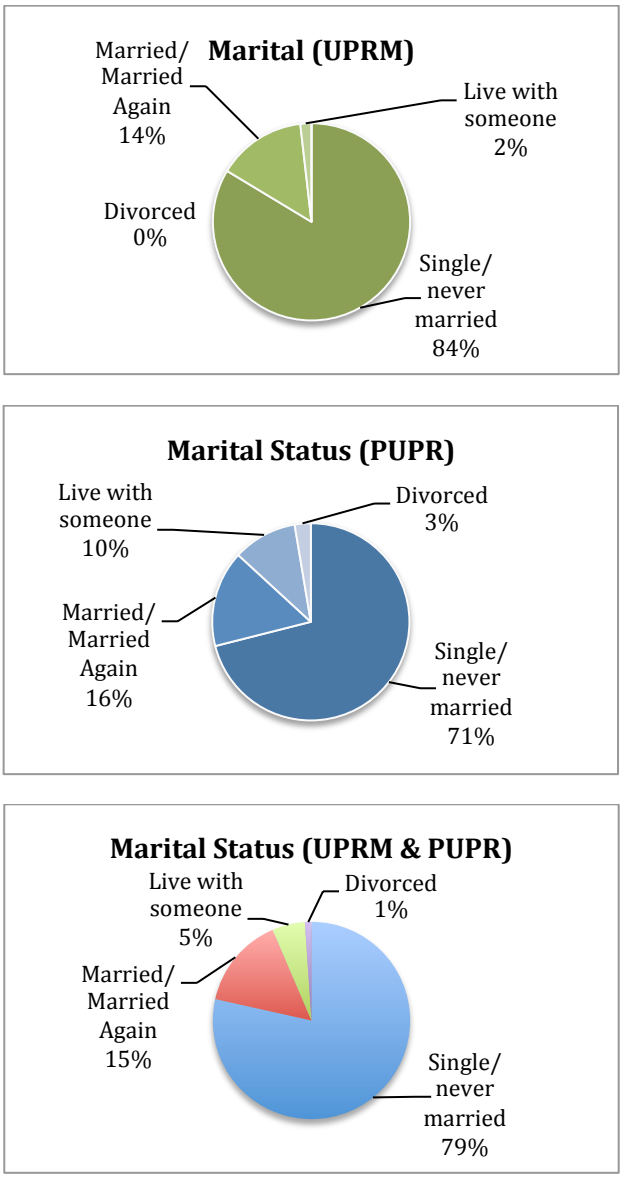

Figure 6 Marital statuses for UPRM, PUPR, and total students

Approximately 83% of students at both universities indicated that they did not have children, 15% had only 1 or 2 children, and 2% had 3 to 4 children. The proportion of 1 or 2 children at UPRM and PUPR is even; PUPR have the total of students with 2 or 3 children in the survey. Distributions are presented in Figure 7.

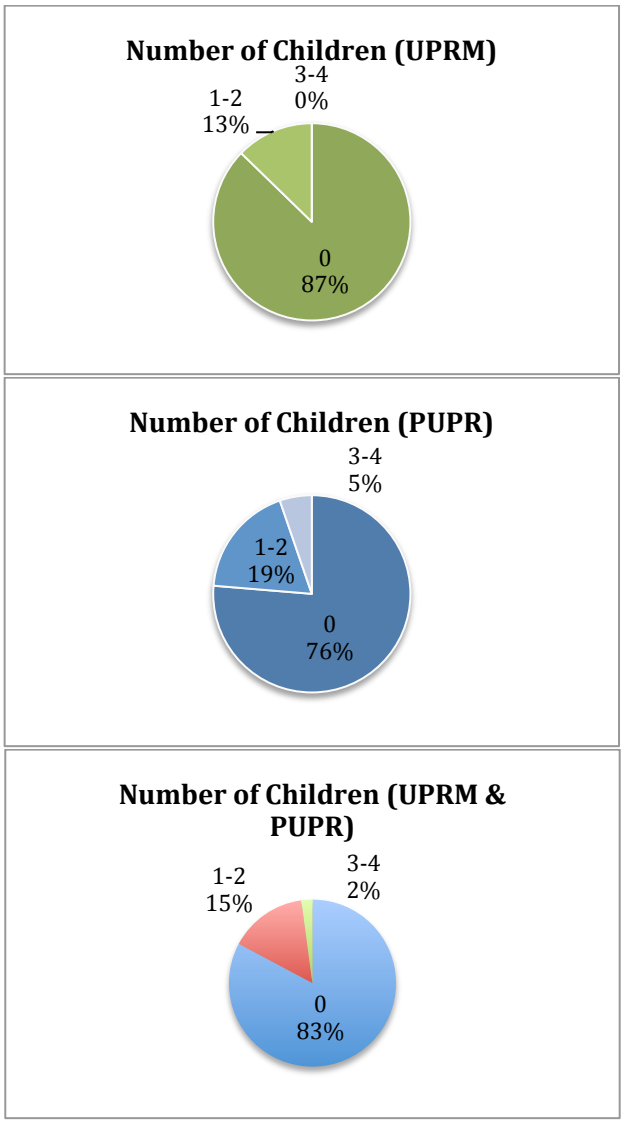

Figure 7 Number of Children for UPRM, PUPR, and total students

A question related to their academic degree was asked with the purpose to identify at what level of study the students were positioned. About 99% of the population answered that they have completed 141 or more credits; this was evidence that the students surveyed were either junior or seniors. Results are presented in Figure 8.

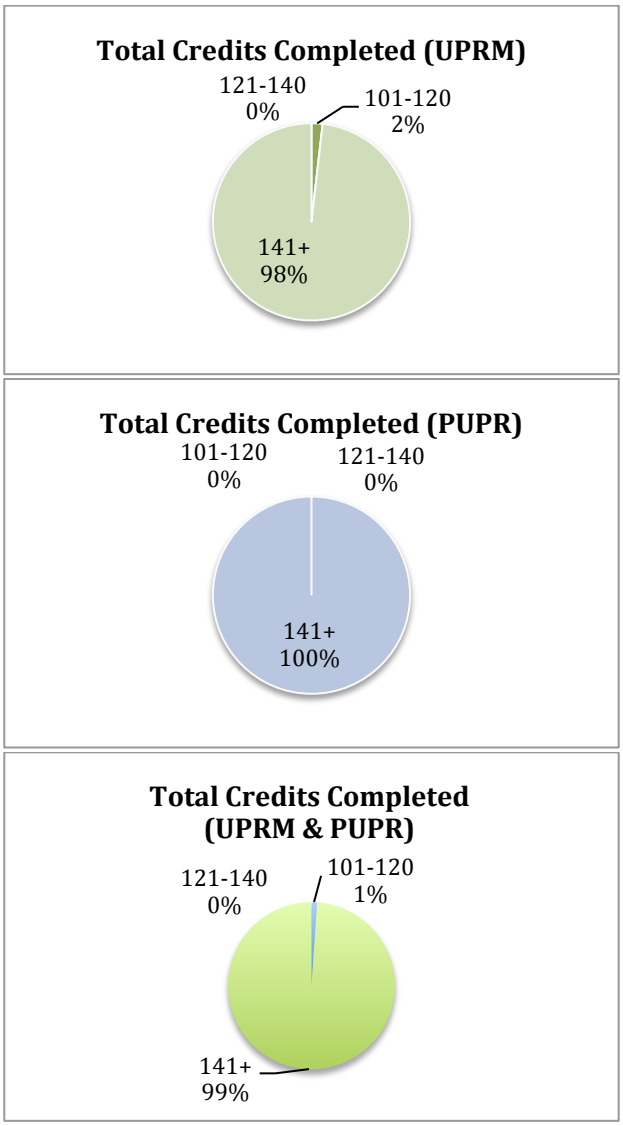

Figure 8 Total credits completed for UPRM, PUPR, and total students

The next question was to identify the concentrations of study: Civil Engineering Environmental Engineering, or Surveying. The results indicated that the majority was under the Civil Engineering program (89%). Results are presented in Figure 9.

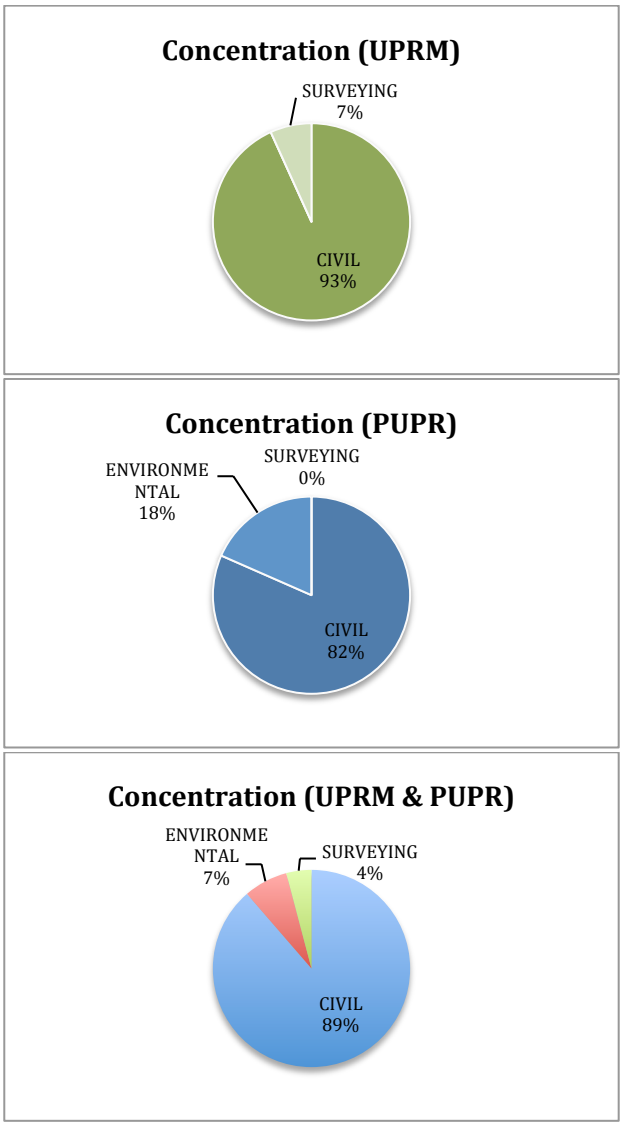

Figure 9 Concentration for UPRM, PUPR, and total students

Considering that students were juniors or seniors, the results concur with the curriculum sequence where they should finish or should be ending their transportation courses, as the results reveal in Figure 10.

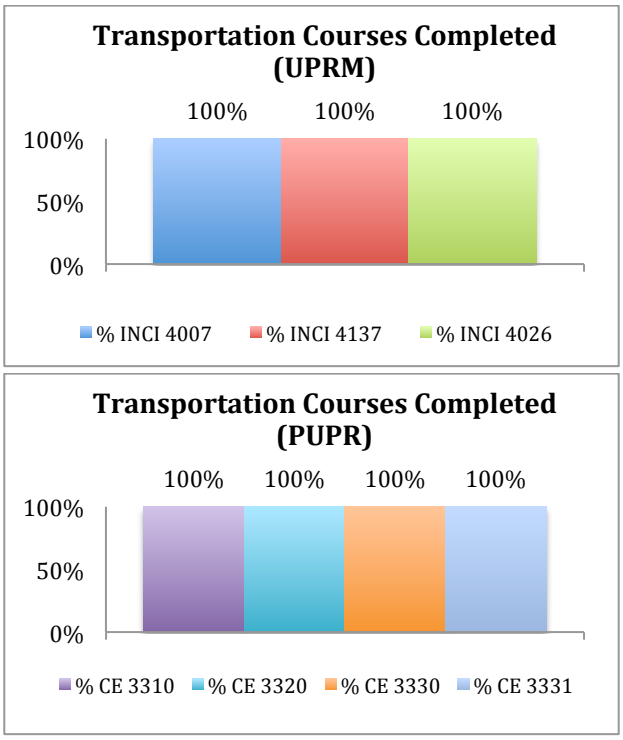

Figure 10 Transportation core courses completed for UPRM and PUPR students

For the question related to their academic Grade Point Average, there were variations between universities, though in general the percentages for each range were: 17% (4.00-3.50), 34% (3.49-3.00), 34% (2.99-2.00), and 47% (1.99-0.99). At UPRM the highest GPA index was 3.49-3.00 and at PUPR it was 2.99-2.00. Figure 11 shows details for this question.

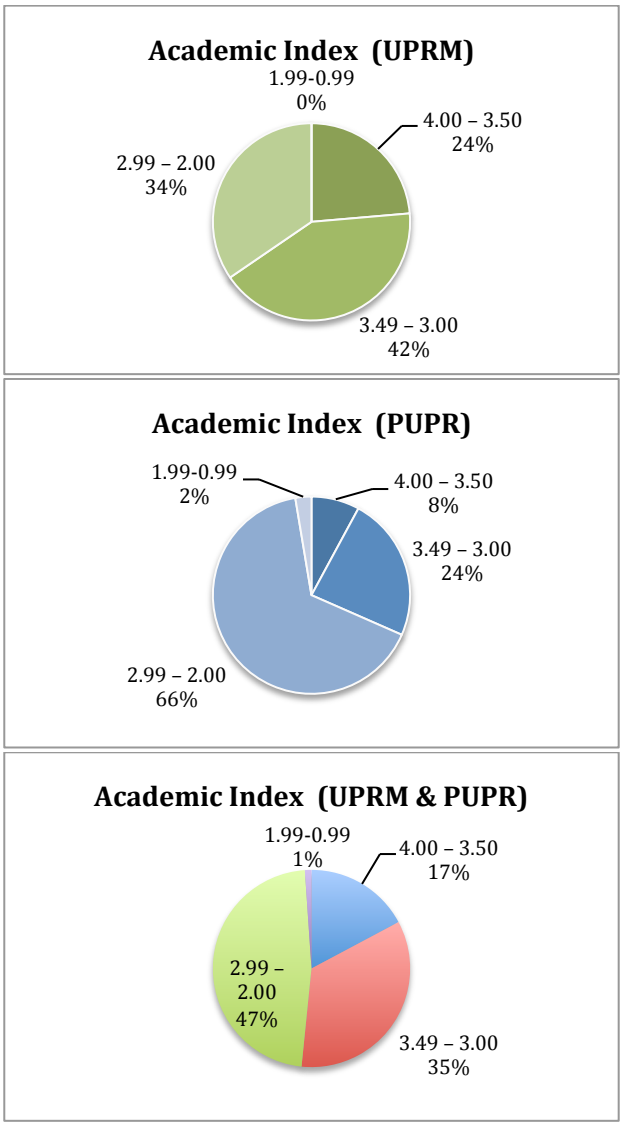

Figure 11 Academic index for UPRM, PUPR, and total students

5.7.2. Professional Career Interests

The second part of the survey focused on identifying the professional career interest of students. Questions related to academic degree, preferences in engineering and transportation preferences were performed.

First, to identify the level of interest of pursuing graduate school at both universities, students were requested to rate their interest ranging from 1 to 7, where 1 was "not interested" and 7 was "very interested." The results in general indicated that 26% were very interested, 18%

were interested, 26% were somewhat interested, 13% were neutral, 9% were somewhat not interested, 4% were not interested, and 3% were not interested at all. The tendencies for both universities are very similar as shown in Figure 12.

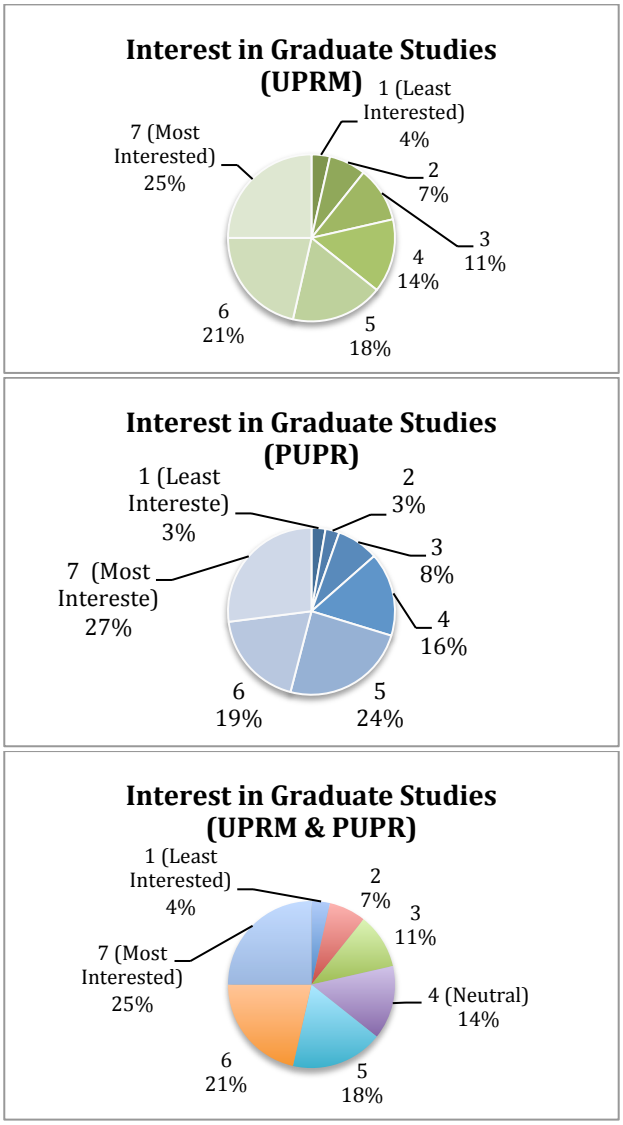

Figure 12 Interest in graduate studies for UPRM, PUPR, and total students

The second question was: In the next 10 years, what is your academic goal? The overall results indicate that the expected degrees were: bachelors 9%, masters 67%, Doctorate 15%, and Post-doctorate 0%. The results indicate that 82% of the students expect to achieve graduate studies in the near future. However, according to faculty members this does not represent the

reality, as 8 of 10 students that graduate do not pursue masters or doctoral degrees. Some of the reasons that could explain this are: students are not willing to spend more time on the academia, possibility to drop out, specializing could reduce employment opportunities, academic employments for PhD graduates are limited in Puerto Rico, and high costs and time spending. Details of the distribution of the degree goal are shown in Figure 13.

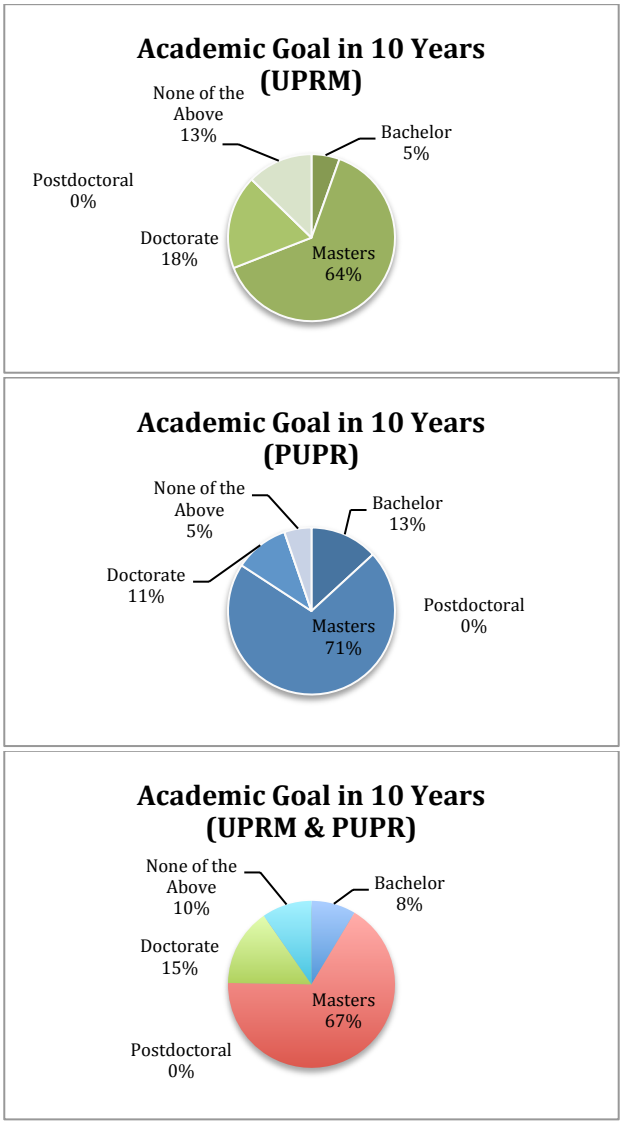

Figure 13 Academic goals in 10 years for UPRM, PUPR, and total students

Students who answered survey question number one (interest in graduate studies) with scores of 1 or 2 were asked not to answer question three. The reason is that if students are not interested in graduate studies, they should not answer what universities are of their interest to perform the graduate studies.

The third question applied for students who answered with an interest level 3 or higher the first question (Identify the level of relevance of attending graduate school at both universities, rate you interest ranging from 1 to 7, where 1 was "not interested" and 7 was "very interested"). These students were asked to identify in a scale of 1 to 5 their preferred university where they would attend graduate studies where the most preferred was indicated with a 5 and the least preferred with a 1. The results from the UPRM surveyed student's show that the most preferred graduate institution were UPRM and other in the US with each obtaining 40.7% of the answers. On the other hand, PUPR students prefer first the PUPR and other in the US with 33%. Combining both universities the highest preference is first place are US universities (37%), second place UPRM (22%), and third PUPR (17%). In general students prefer to go to the US to go to graduate school. Figures 14, 15, and 16 provide detailed graphs of the preferences by university for UPRM, PUPR, and total students surveyed.

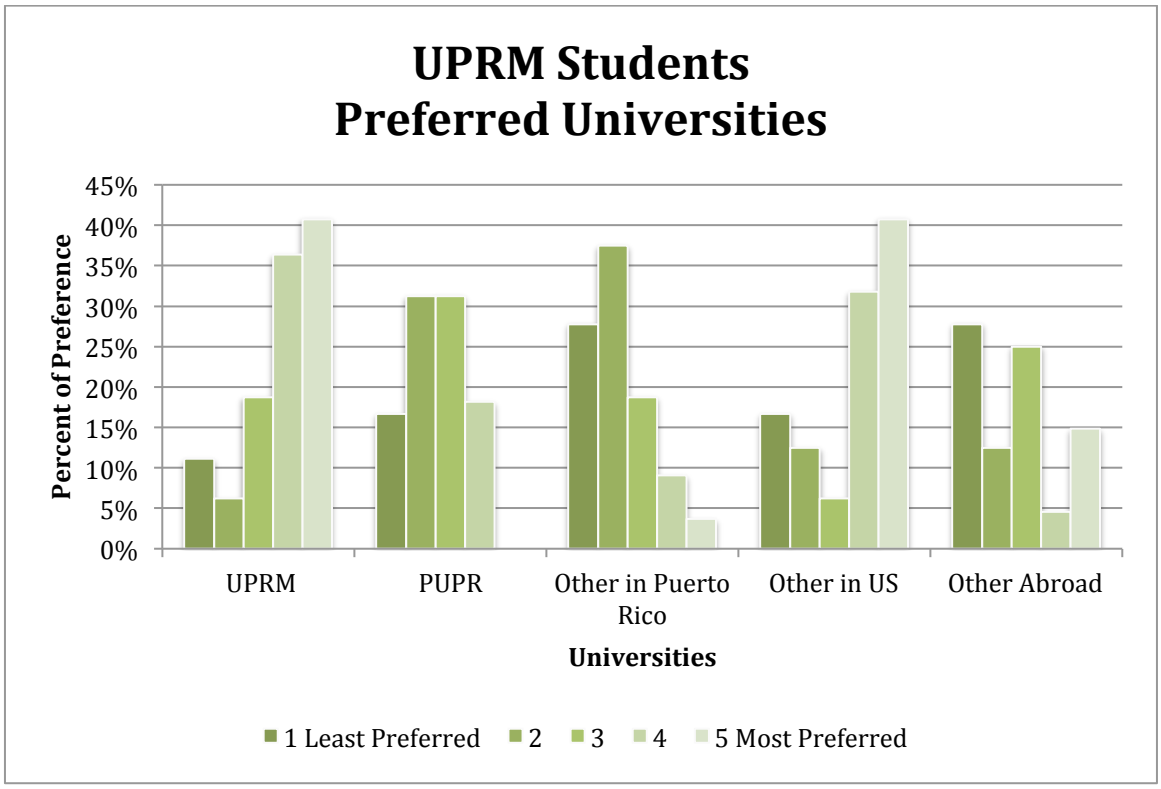

Figure 14 University preference for graduate studies for UPRM students

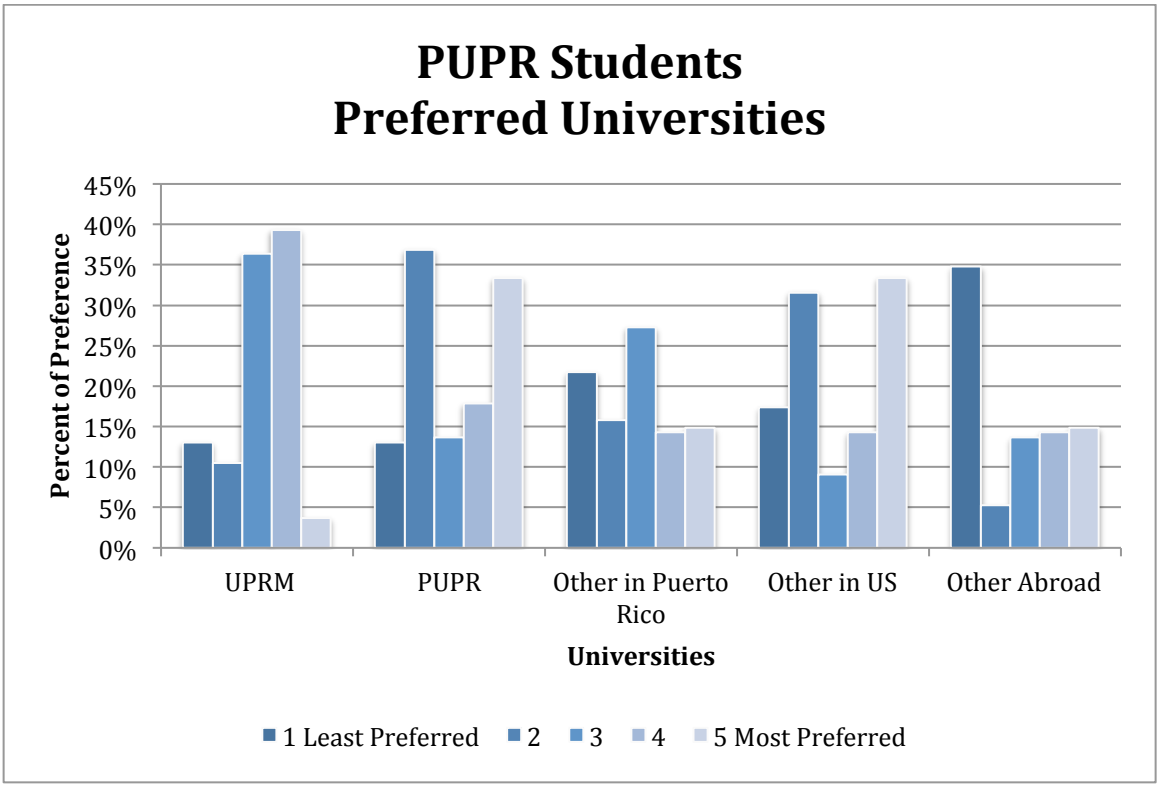

Figure 15 University preference for graduate studies for PUPR students

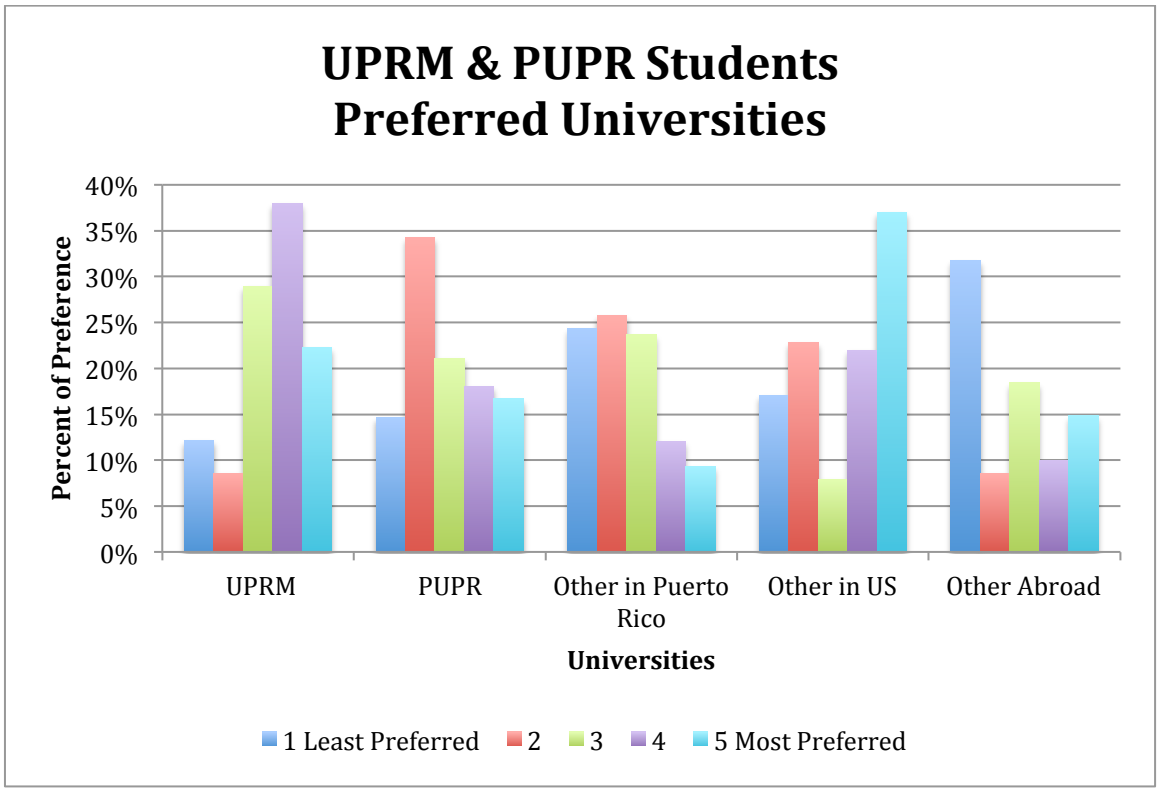

Figure 16 University preference for graduate studies for UPRM and PUPR students

There was an open question in which students specified which other university prefer to go to graduate school in Puerto Rico, US or Abroad. The results from the students' response are presented in Tables 11 and 12.

Table 11 PUPR students' university preference options

Puerto Rico	United States	Abroad
UPR-Arecibo	Texas	None identified
	Rochester	
	USF	
	FIU	

Table 12 UPRM students' university preference options

Puerto Rico	United States	Abroad
UPR-Rio Piedras	SCAD Savannan	Madrid Polytechnic
	NY-Poly	Instituto Superior Técnico, Lisboa, Portugal
	University of Michigan	Spain
	University of Central Florida	University of Alberta, Canada
	Columbia University	
	Urbana Champaign, Illinois	
	Georgia Tech	
	Purdue University	
	Renssealaer Polytechnic Institute	

The fourth question was to identify the preference area in Civil Engineering. The listed preferences were: Biomechanics, Materials Science and Engineering, Atmospheric Sciences, Earth Science, Computational Science and Engineering, Geodesy, Geophysics, Project Management, Environmental Engineering, Coastal Engineering, Construction Engineering, Control Engineering, Earthquake Engineering, Transportation Engineering, Water Resources Engineering, Structural Engineering, Structural Engineering at Nanoscale (nanotechnology), Forensic Engineering, Geotechnical Engineering, Municipal or Urban Engineering. In a scale of 1 to 3, where 3 was the most preferred and 1 was the least, students selected a total of three options.

Results reveal that for UPRM students the top three Civil Engineering specialties are: first Structural Engineering (20%), second Geotechnical and Transportation Engineering (15%), and third Project Management (13%). PUPR students' first preference is Transportation Engineering (27%), second is Environmental Engineering (18%), and third is Construction Engineering and Structural Engineering (18%). Combining both universities, results indicate that the top three Civil Engineering specialties were: first Transportation Engineering (21%),

second Structural Engineering (18%), and third Project Management (13%). Figure 17 to 19 present graphs with details of the top three preferences distribution for UPRM, PUPR, and both universities combined.

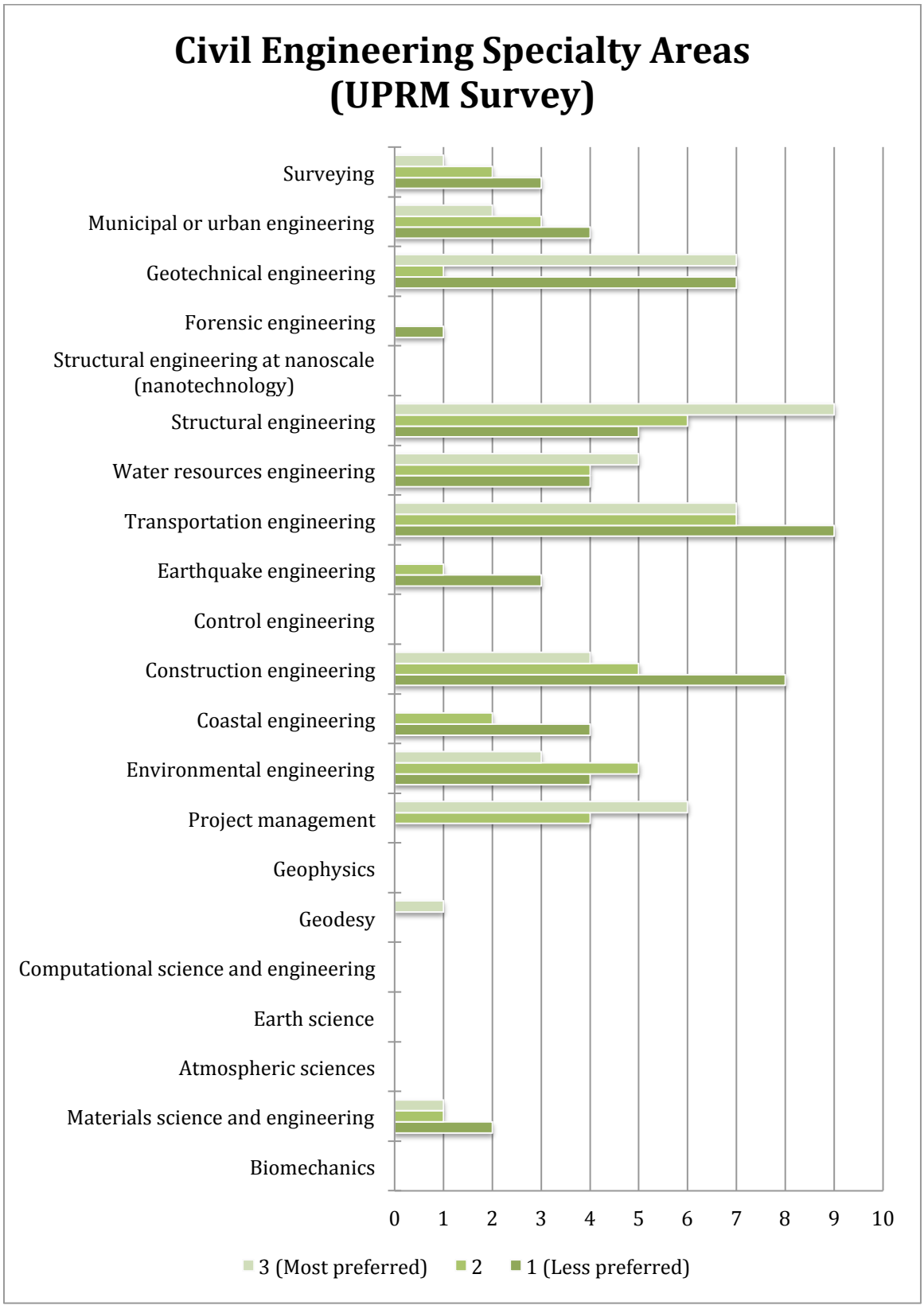

Figure 17 Top three preferred areas of specialty in Civil Engineering for UPRM students

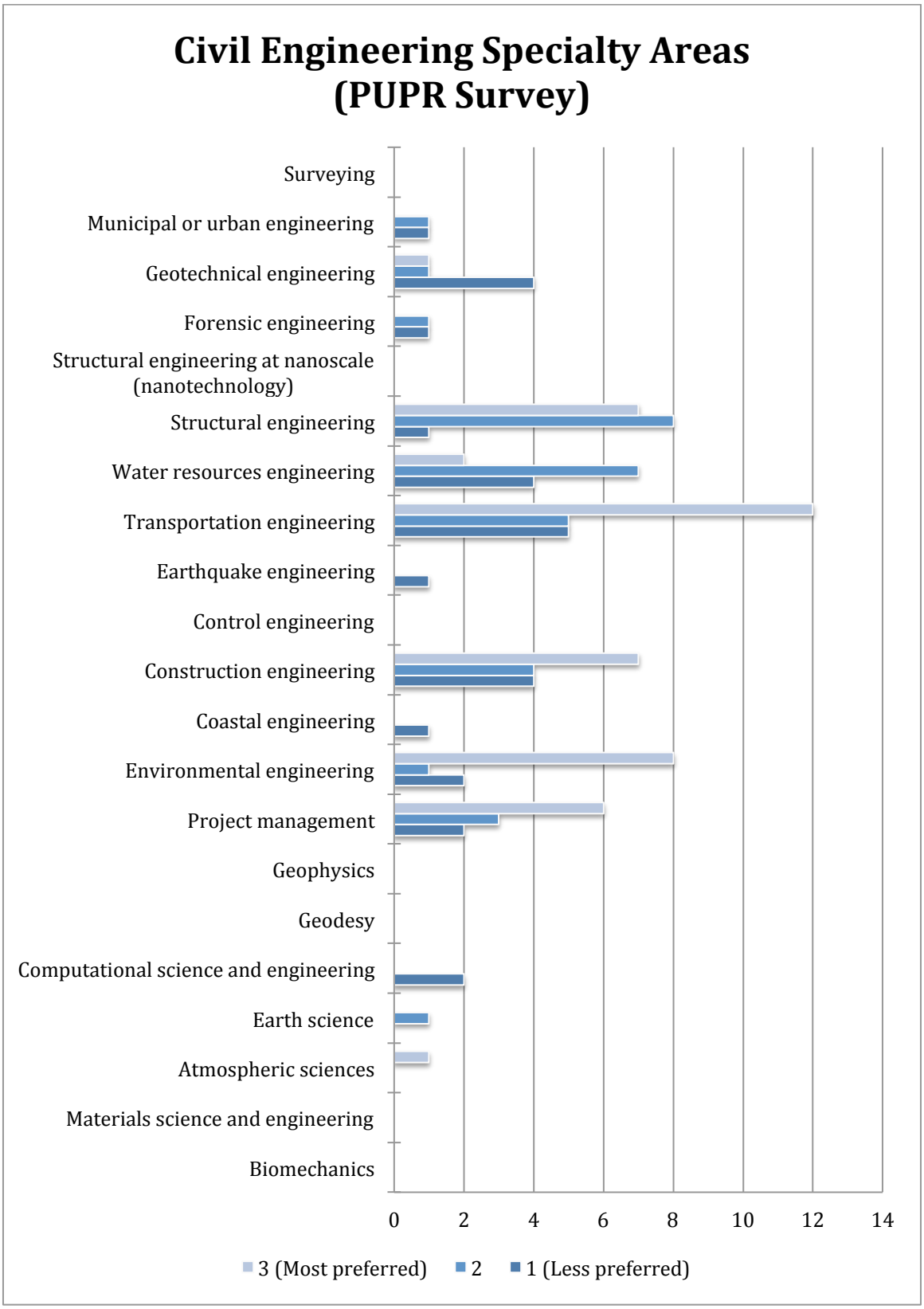

Figure 18 Top three preferred areas of specialty in Civil Engineering for PUPR students

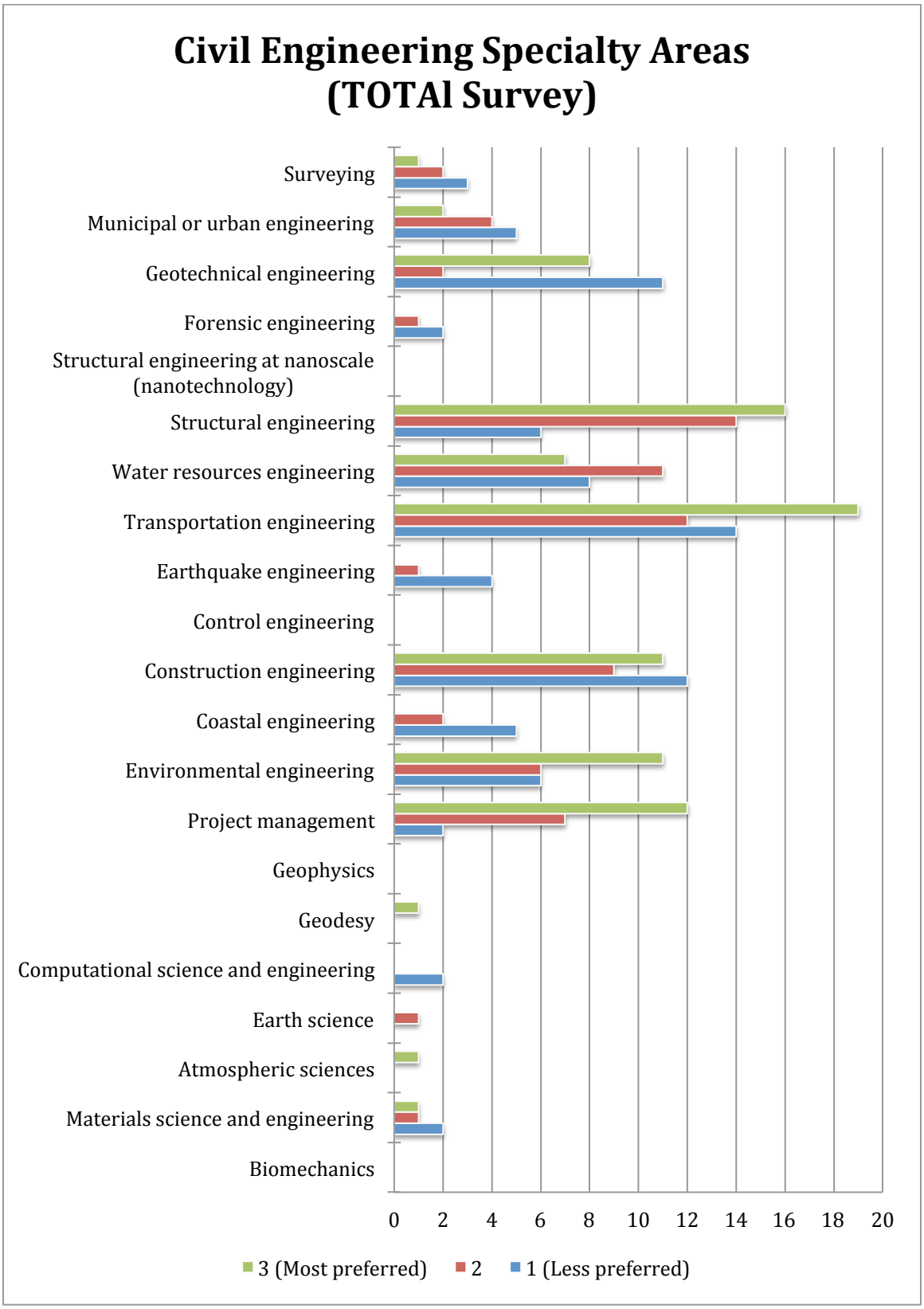

Figure 19 Top three preferred areas of specialty in Civil Engineering for UPRM & PUPR students

The fifth question intended to measure the interest in studying transportation engineering in the next five years. The measure was in a scale of 1 to 7, where 1 was the least interested and 7 indicated a high interest. Results from the survey show that 6% of the students are very interested in studying transportation and 38% are not interested at all. An 8% of PUPR students are very interested in studying transportation and 13% are not interested. Considering both universities the general responses by levels were: 1 – 28%, 2 – 17%, 3 – 13%, 4 –10%, 5 – 15%, 6 –11%, and 7 – 6%. Combining the last three higher levels of interest for transportation, it sums 32% of the general population. This represents about a third (1/3) of the population surveyed with interest in graduate studies (about 32% with level 5 to 7). Indeed, transportation is one of the most preferred areas of focus areas. Details of the results of this question are shown in Figures 20 to 22.

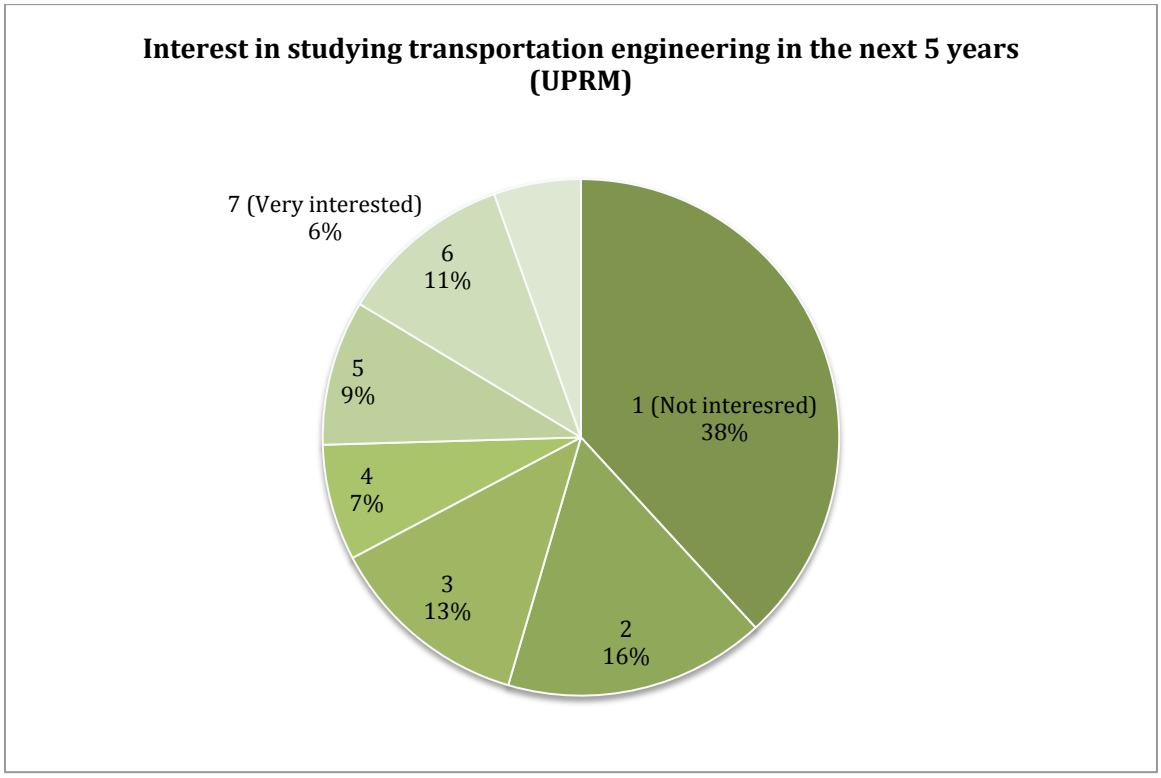

Figure 20 Interest for transportation engineering studies in the next 5 years for UPRM students

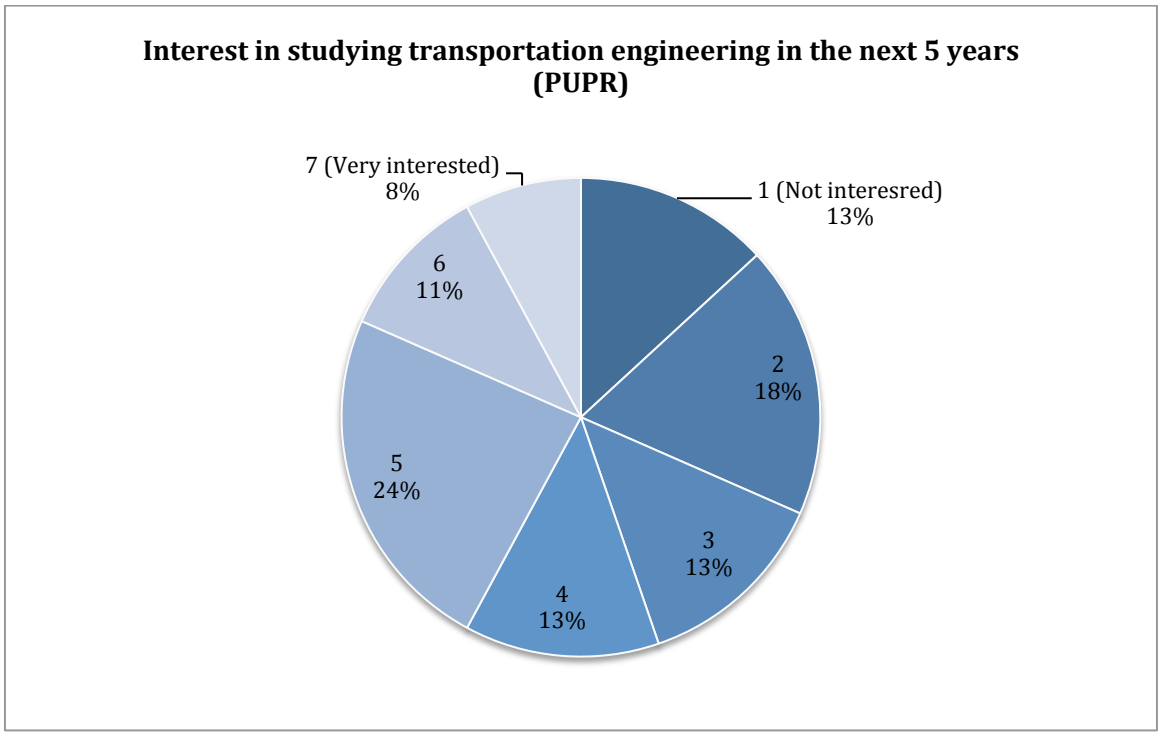

Figure 21 Interest for transportation engineering studies in the next 5 years for PUPR students

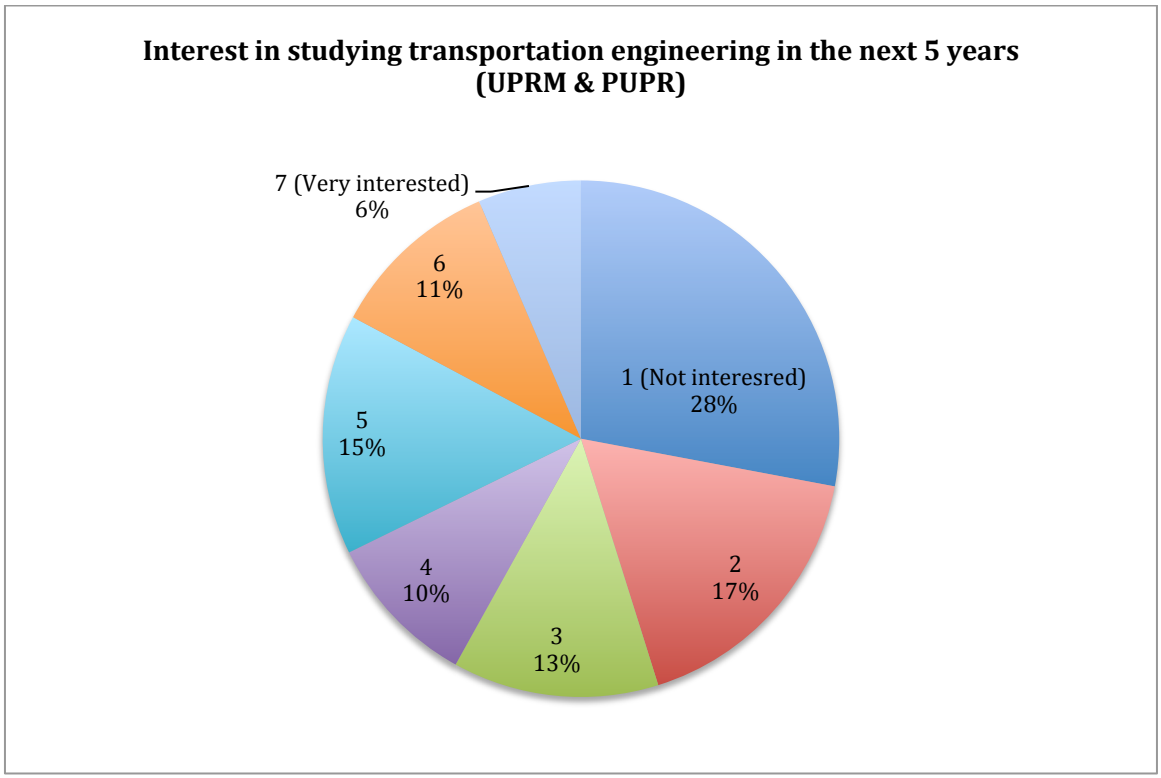

Figure 22 Interest for transportation engineering studies in the next 5 years for UPRM & PUPR students

Students who answered the previous question (interest in studying transportation engineering in the next five years) with a score of 1 or 2, were asked not to answer the following question. The justification is that it was assumed that students, who are not interested in the transportation realm, would generate a bias. If transportation is not a specialty of interest, with high probability the majority of students will score most or all areas with low values of interest and low preparedness. This question has the purpose to obtain the level of interest and perception of preparedness of students who have an interest in the area of 3 to 7.

For the sixth question, students had to indicate their students preference in the listed transportation field specialty areas: Freight, Geometric Design, Infrastructure Management, Traffic Engineering, Urban Engineering, Pavement, Transportation Planning, Rail Systems, ITS, Mass Transportation, Highway Transportation, Sustainable Transportation, Air Transportation, and Maritime Transport. A scale of 1 to 7 was used; where 1 was the least preferred area of specialty in transportation and 7 indicated the highest preferred area.

Highest three scored preferred transportation specialties for UPRM students are: Mass Transportation and Transportation Planning (11%), Sustainable Transportation, ITS, and Urban Engineering (10%), and Air Transportation and Traffic Engineering (9%). Top three preferred transportation specialties for PUPR students are: Transportation Planning and Urban Engineering (12%), Highway Transportation (11%), and Mass Transportation (10%). The highest three preference transportation specialties for both universities students combined are: Transportation Planning and Urban Engineering (11%), Mass Transportation (10%), and Sustainable Transportation (9%).

The least preferred transportation specialty for students at UPRM is Freight (41%), PUPR students is Freight (41%), and both universities combined is Freight (41%). All details of the results distribution are presented in Figures 23 to 33.

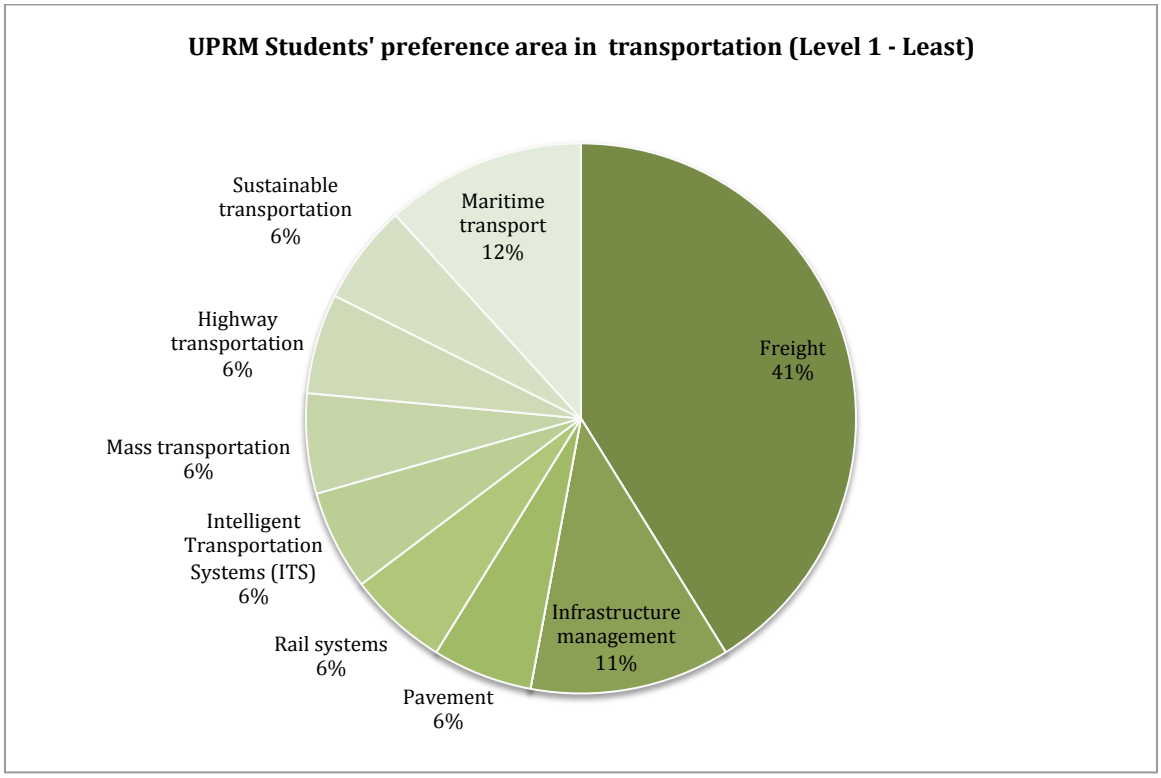

Figure 23 Least preferred specialty areas in transportation for UPRM students (Level 1)

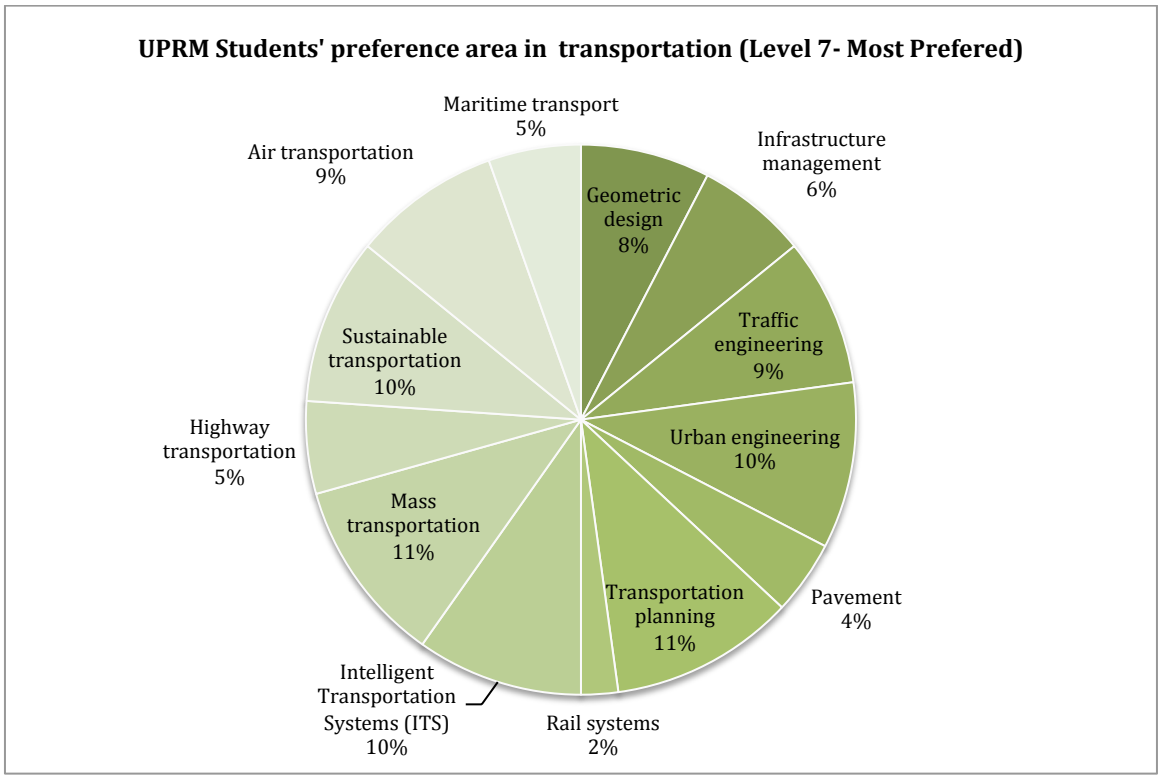

Figure 24 Most preferred specialty areas in transportation for UPRM students (Level 7)

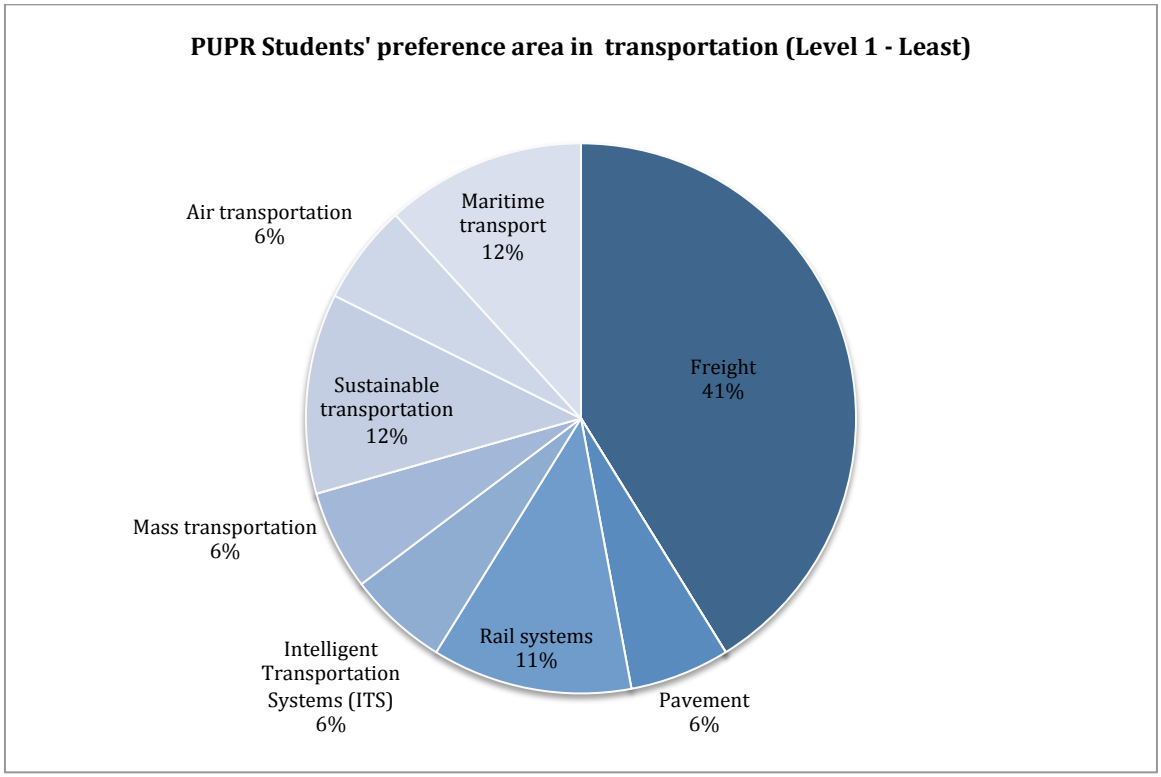

Figure 25 Least preferred specialty areas in transportation for PUPR students (Level 1)

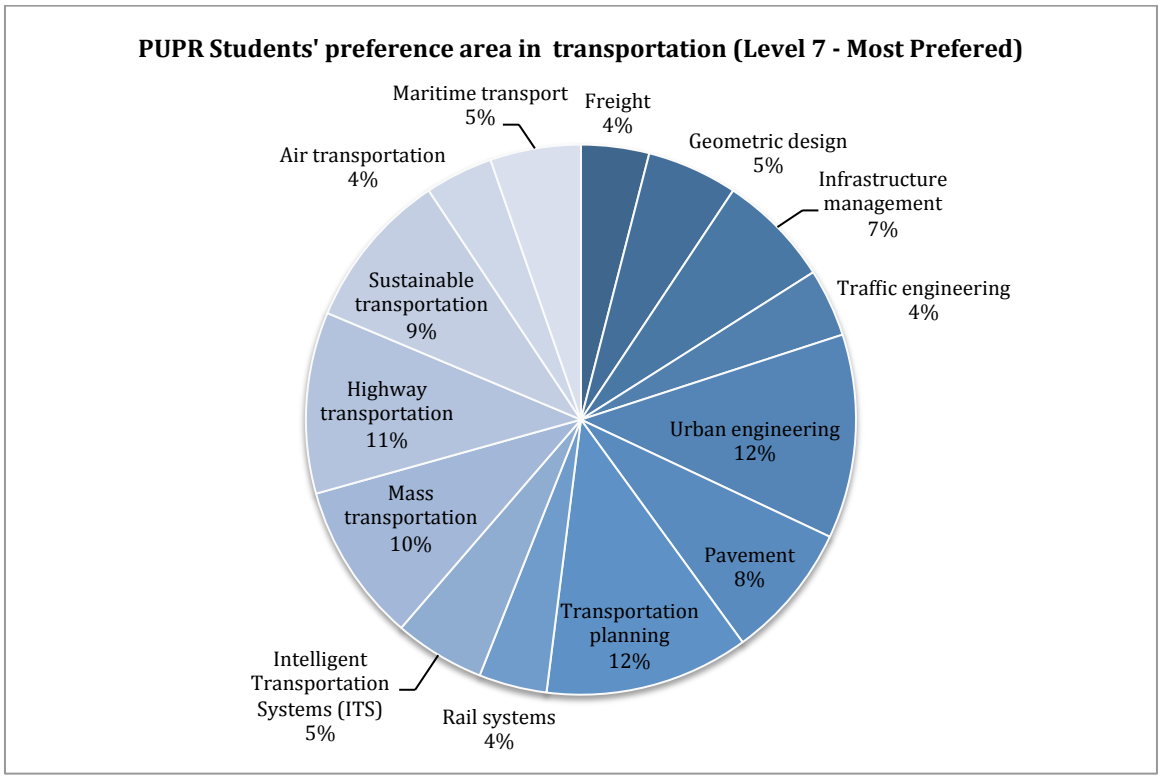

Figure 26 Most preferred specialty areas in transportation for PUPR students (Level 7)

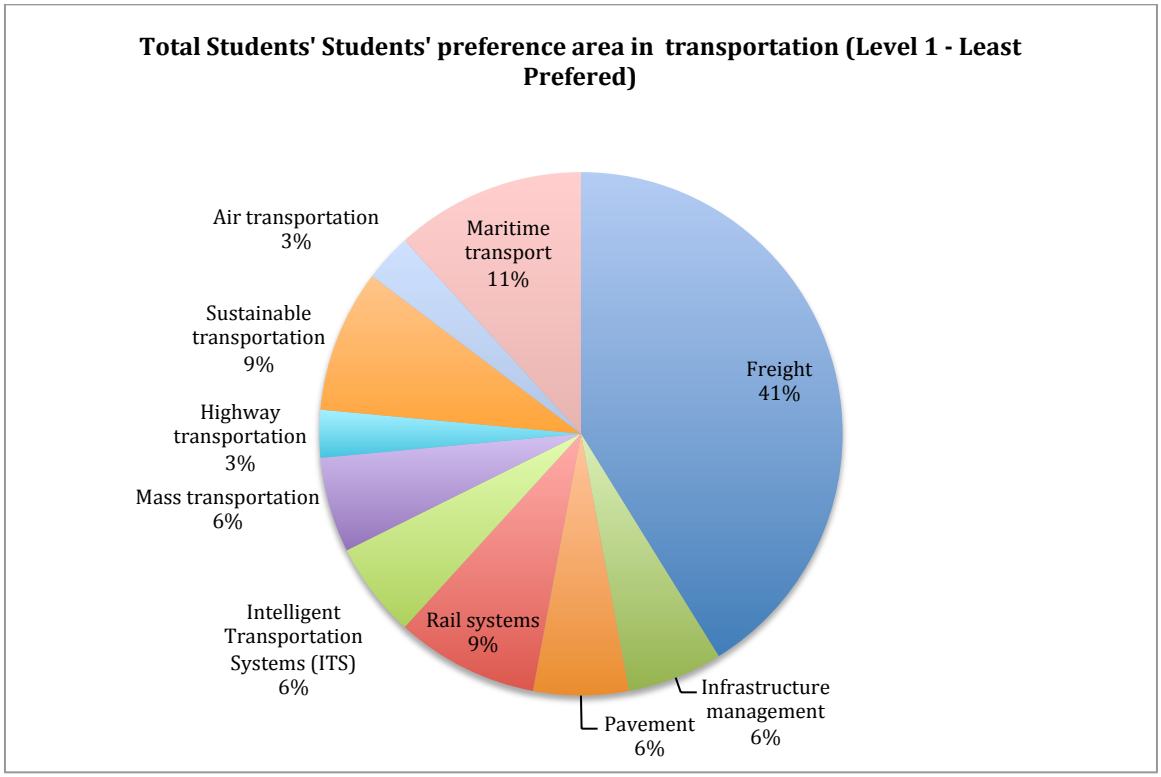

Figure 27 Least preferred specialty areas in transportation for UPRM & PUPR students (Level 1)

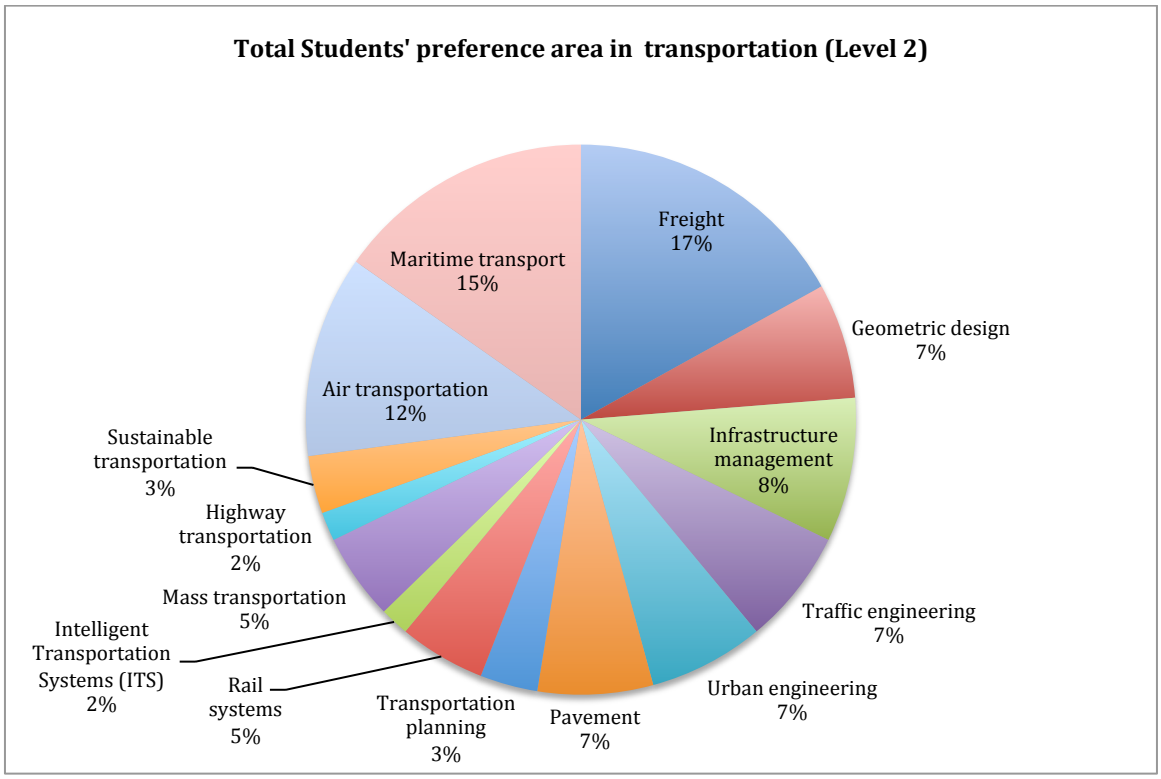

Figure 28 Preference by specialty areas in transportation for UPRM & PUPR students (Level 2)

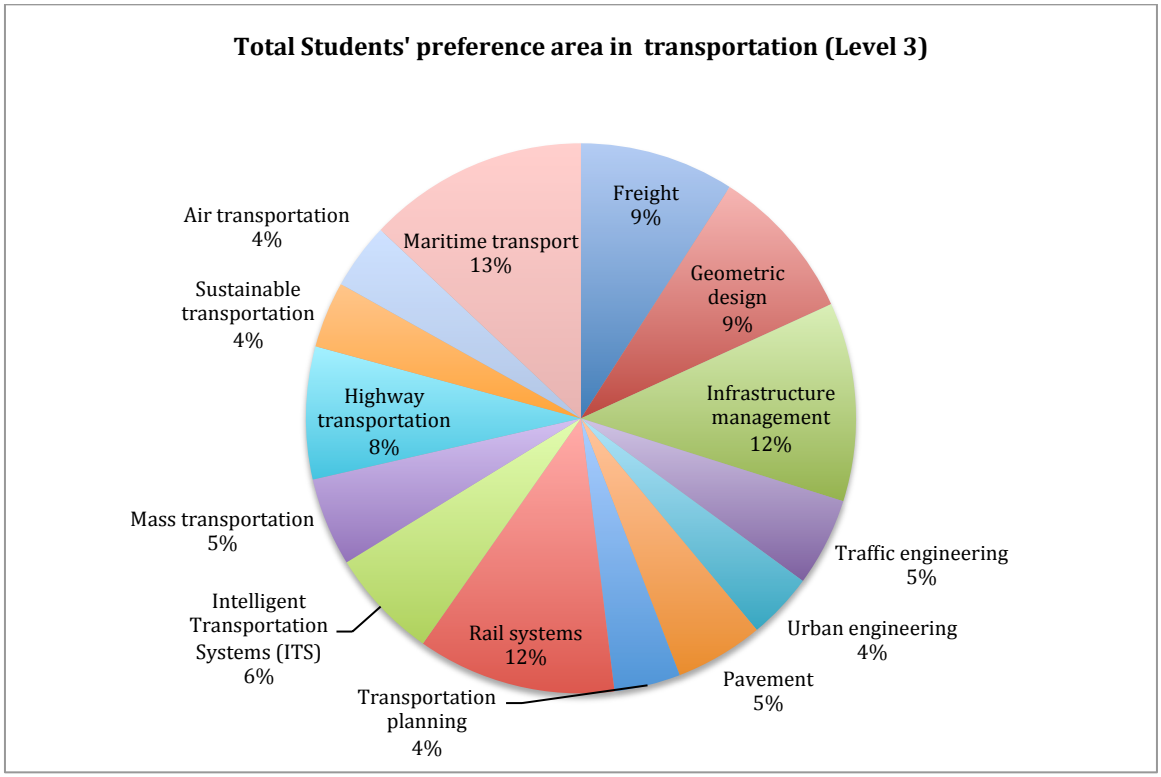

Figure 29 Preference by specialty areas in transportation for UPRM & PUPR students (Level 3)

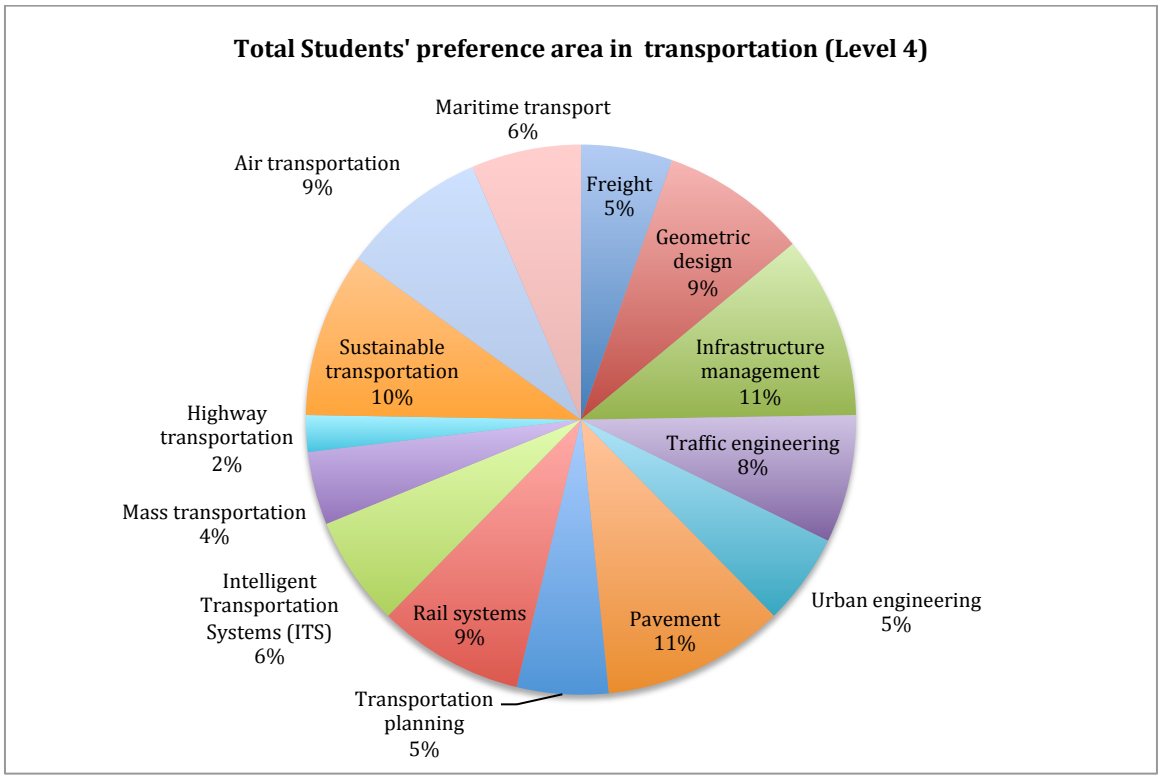

Figure 30 Preference by specialty areas in transportation for UPRM & PUPR students (Level 4)

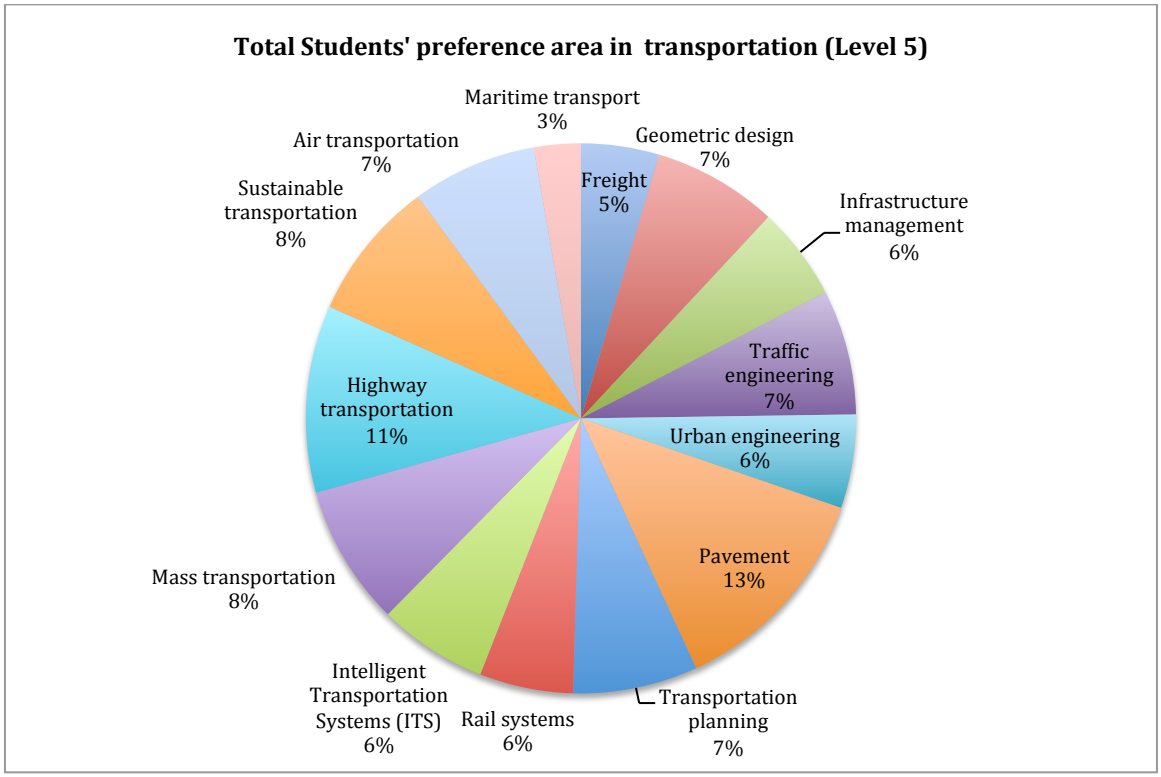

Figure 31 Preference by specialty areas in transportation for UPRM & PUPR students (Level 5)

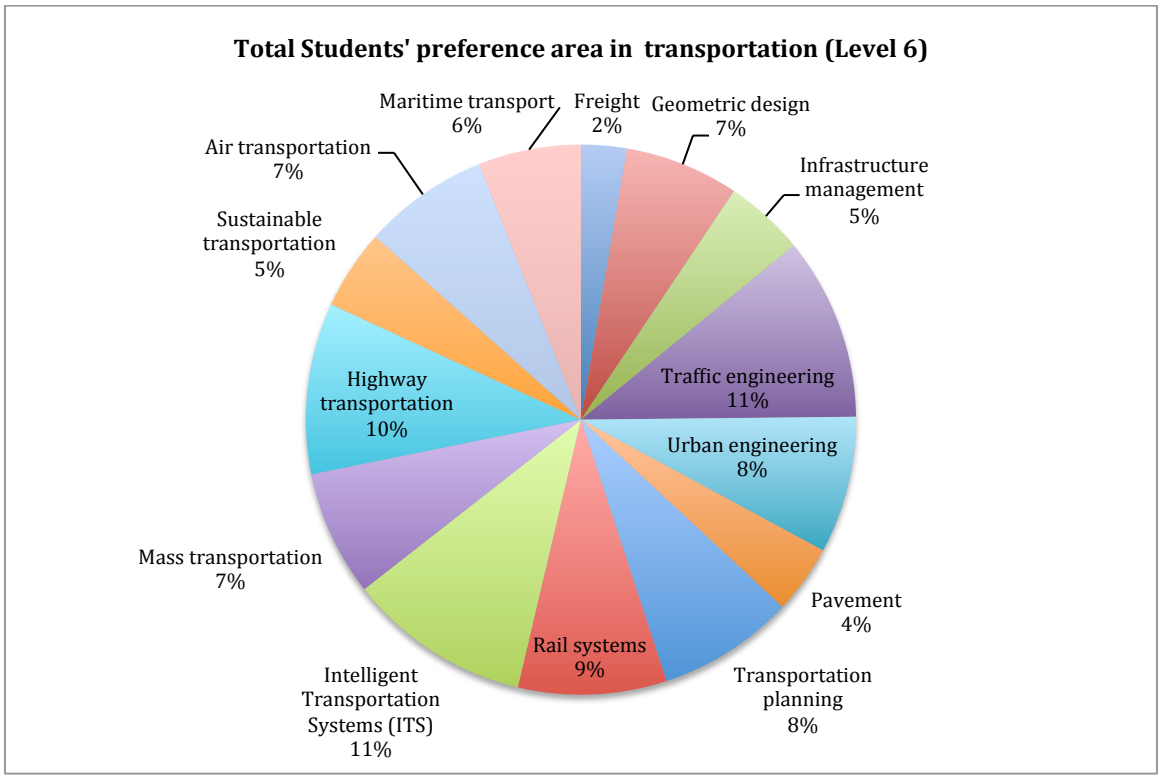

Figure 32 Preference by specialty areas in transportation for UPRM & PUPR students (Level 6)

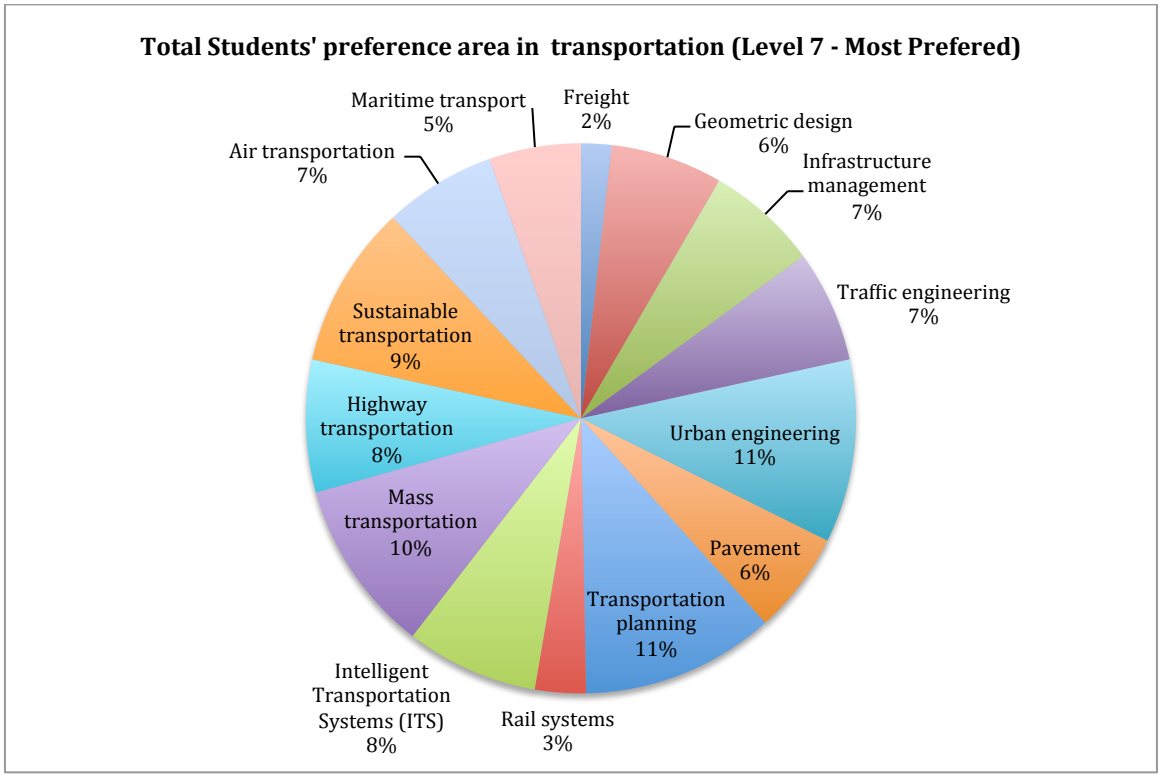

Figure 33 Most preferred specialty areas in transportation for UPRM & PUPR students (Level 7)

The final question was to identify students' perception of their academic preparation. A scale of 1 to 7 was used; where 1 was the least perception of preparedness and 7 indicated a high perception of preparedness. Listed transportation field specialty options are: Freight, Geometric Design, Infrastructure Management, Traffic Engineering, Urban Engineering, Pavement, Transportation Planning, Rail Systems, ITS, Mass Transportation, Highway Transportation, Sustainable Transportation, Air Transportation, and Maritime Transport.

The highest three transportation specialty areas that UPRM students perceive to be best prepared are: Geometric Design, Urban Engineering and ITS (15%), Sustainable Transportation, Mass Transportation and Rail Systems (10%), and Maritime Transportation, Infrastructure Management, Pavements, Highway Transportation and Traffic Engineering (5%). Top three transportation specialties for PUPR students perceived to be best prepared are: Geometric Design and Pavement (15%), Mass Transportation, Transportation Planning and Highway Transportation (11%), and Freight (8%). The highest three score transportation specialties perceived to be best prepared UPRM & PUPR students combined are: Geometric Design (15%), Mass Transportation, ITS and Pavements (11%), and Sustainable Transportation and Highway Transportation (9%).

Students' perceptions of least prepared area in the transportation specialty are: UPRM is Maritime Transportation, Air Transportation and Rail Systems (18%), PUPR is Air Transportation (24%), and both universities combined is Air Transportation (18%). Details of the results of this question are shown in Figures 34 to 44.

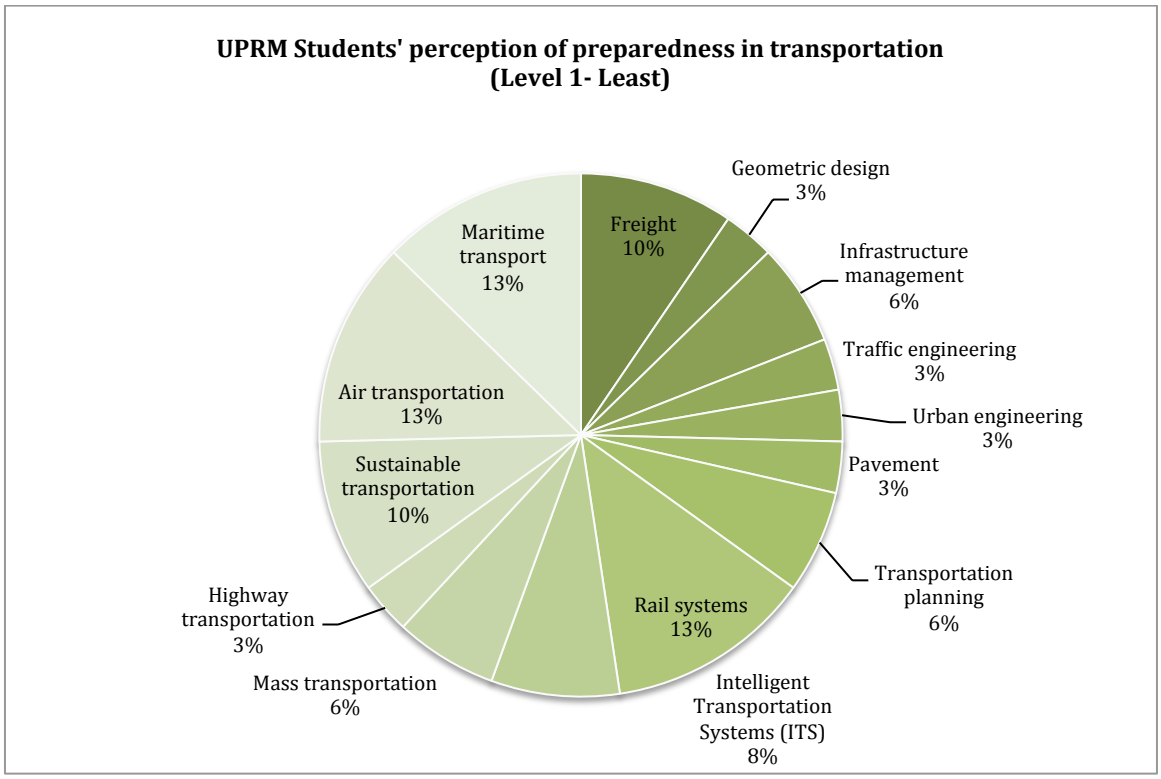

Figure 34 Least perception of preparedness by specialty areas in transportation for UPRM students (Level 1)

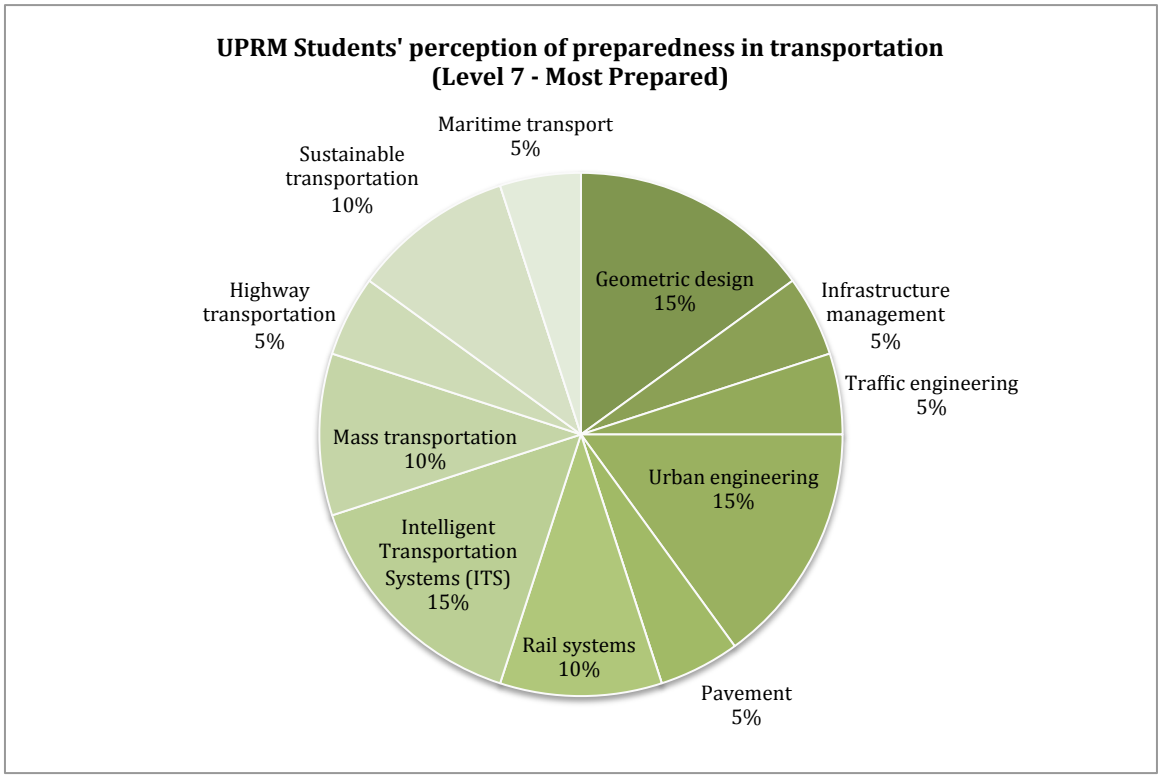

Figure 35 Highest perception of preparedness by specialty areas in transportation for UPRM students (Level 7)

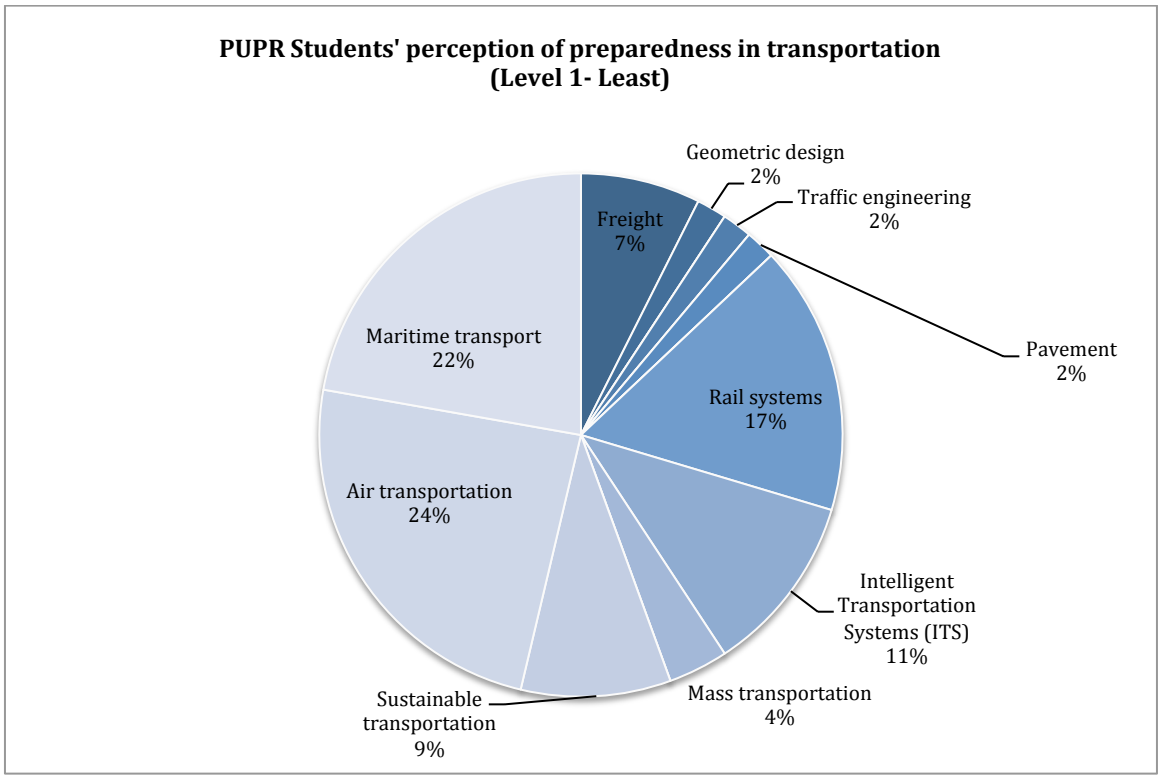

Figure 36 Least perception of preparedness by specialty areas in transportation for PUPR students (Level 1)

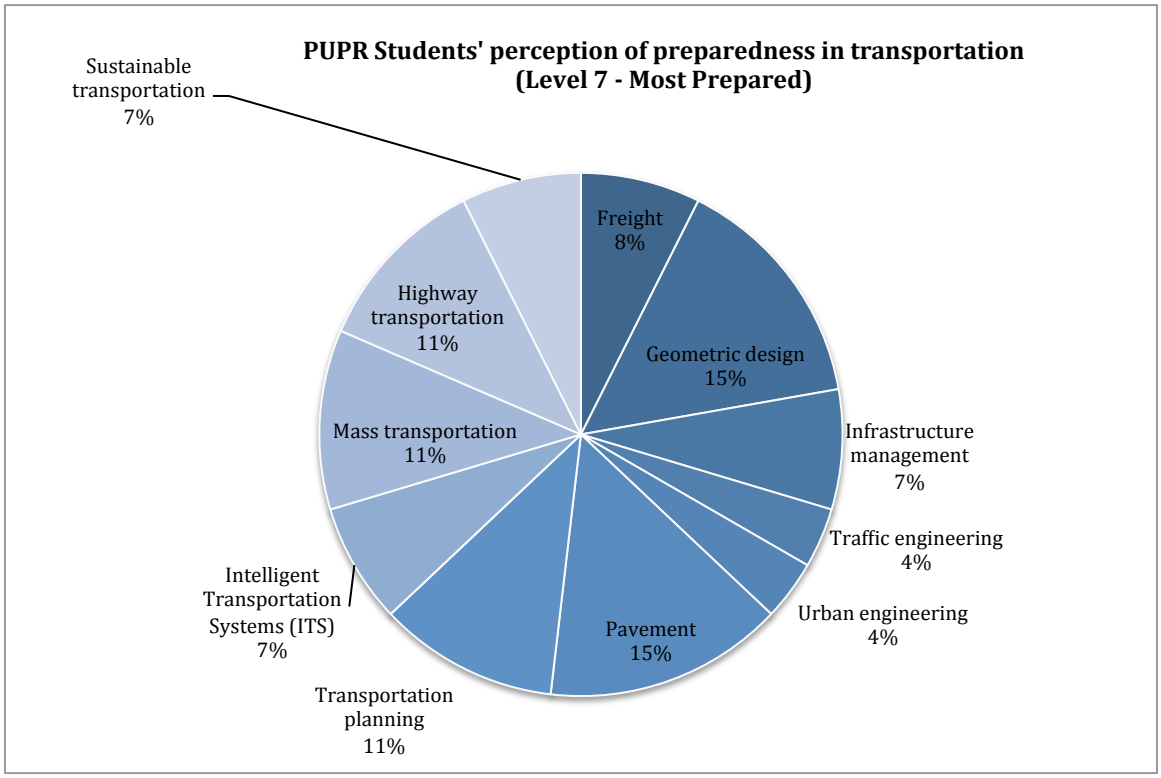

Figure 37 Highest perception of preparedness by specialty areas in transportation for PUPR students (Level 7)

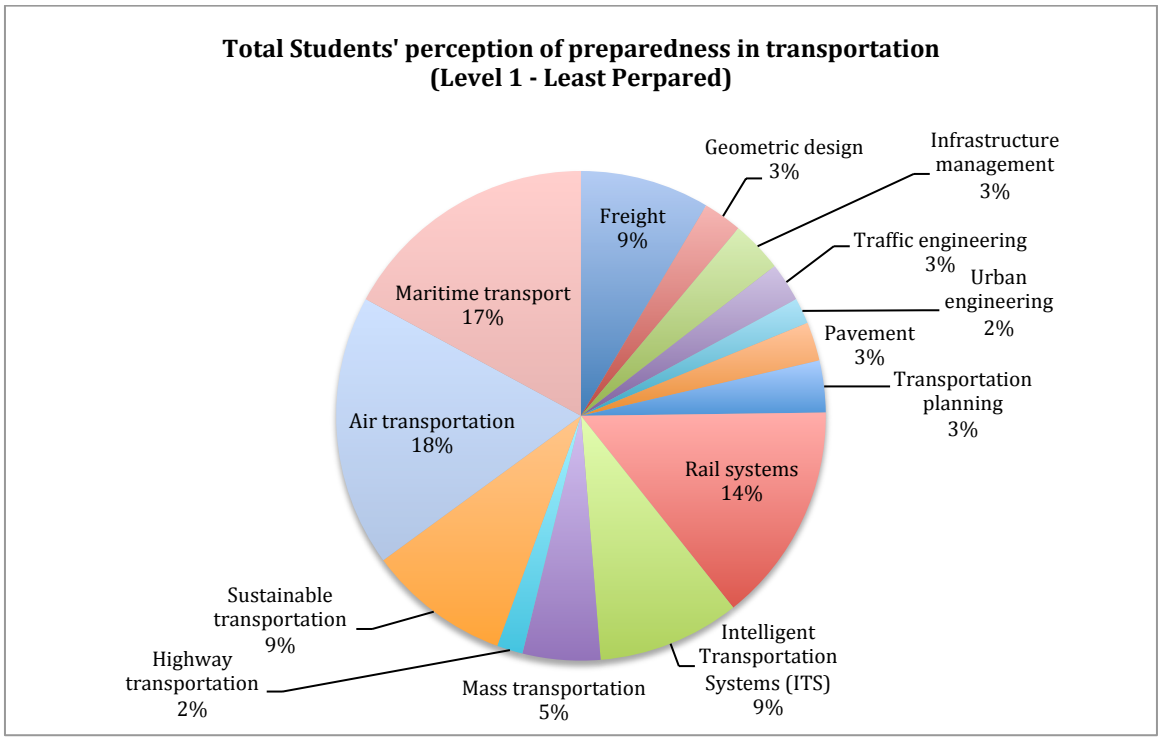

Figure 38 Perception of preparedness by specialty areas in transportation for UPRM & PUPR students (Level 1)

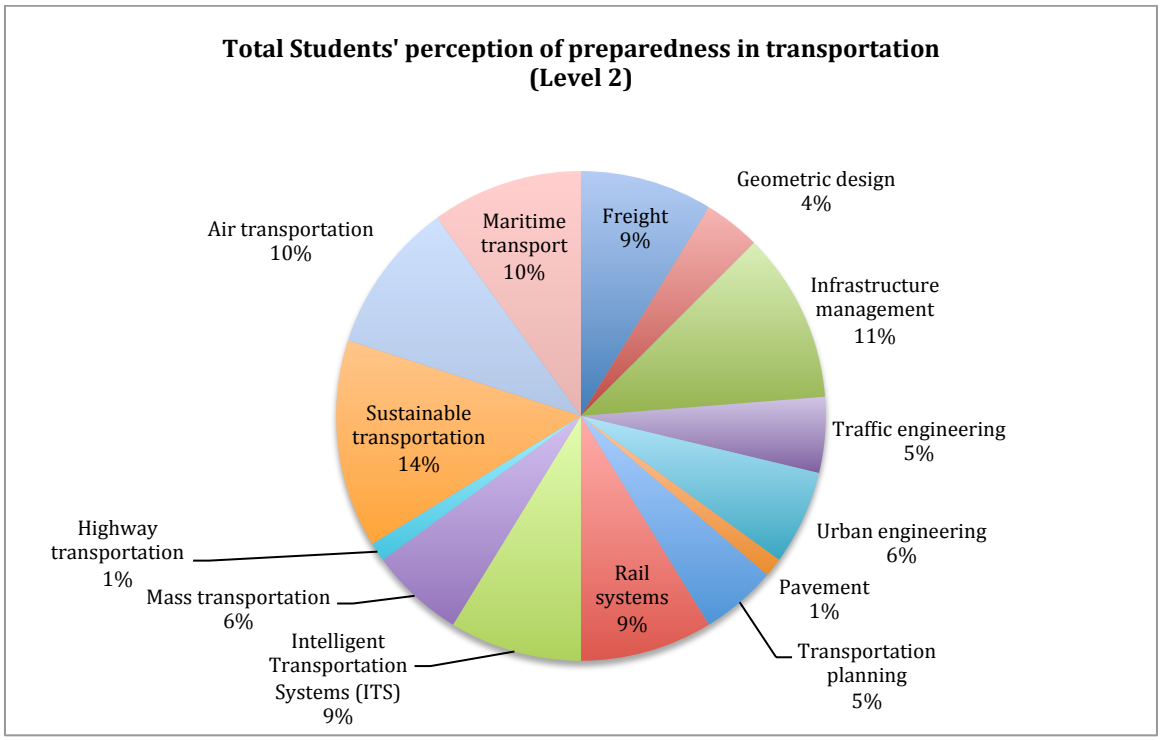

Figure 39 Perception of preparedness by specialty areas in transportation for UPRM & PUPR students (Level 2)

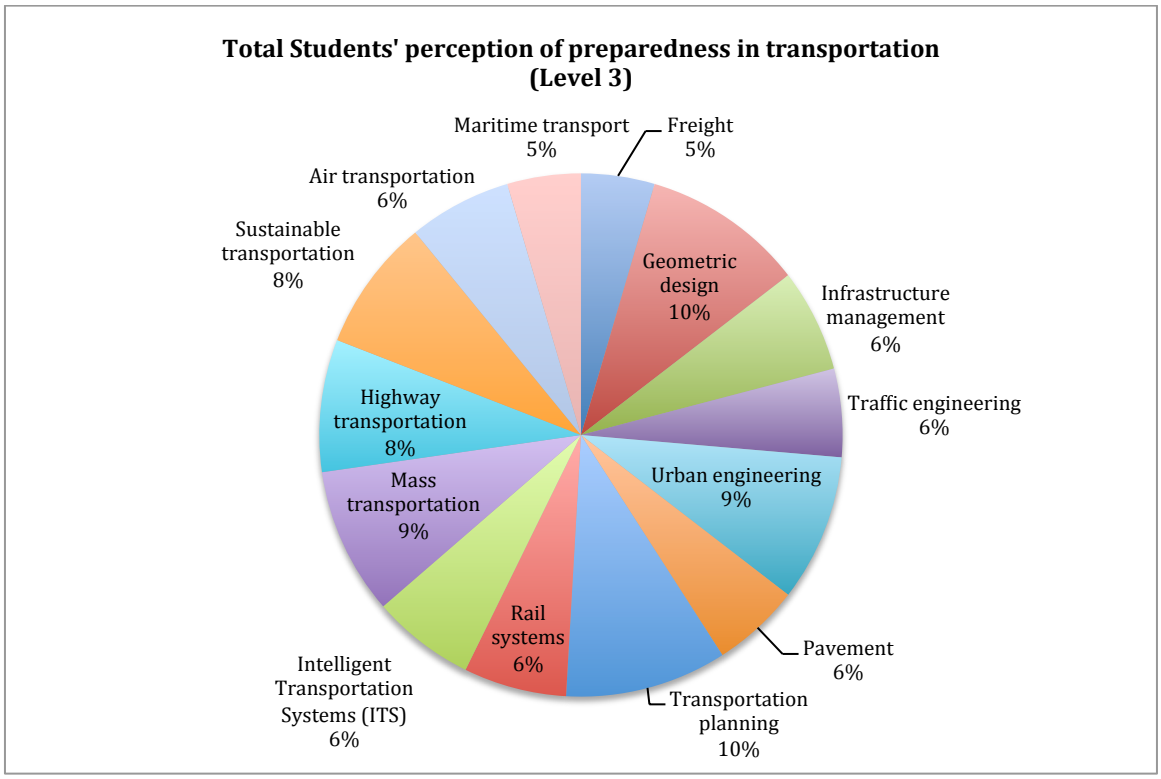

Figure 40 Perception of preparedness by specialty areas in transportation for UPRM & PUPR students (Level 3)

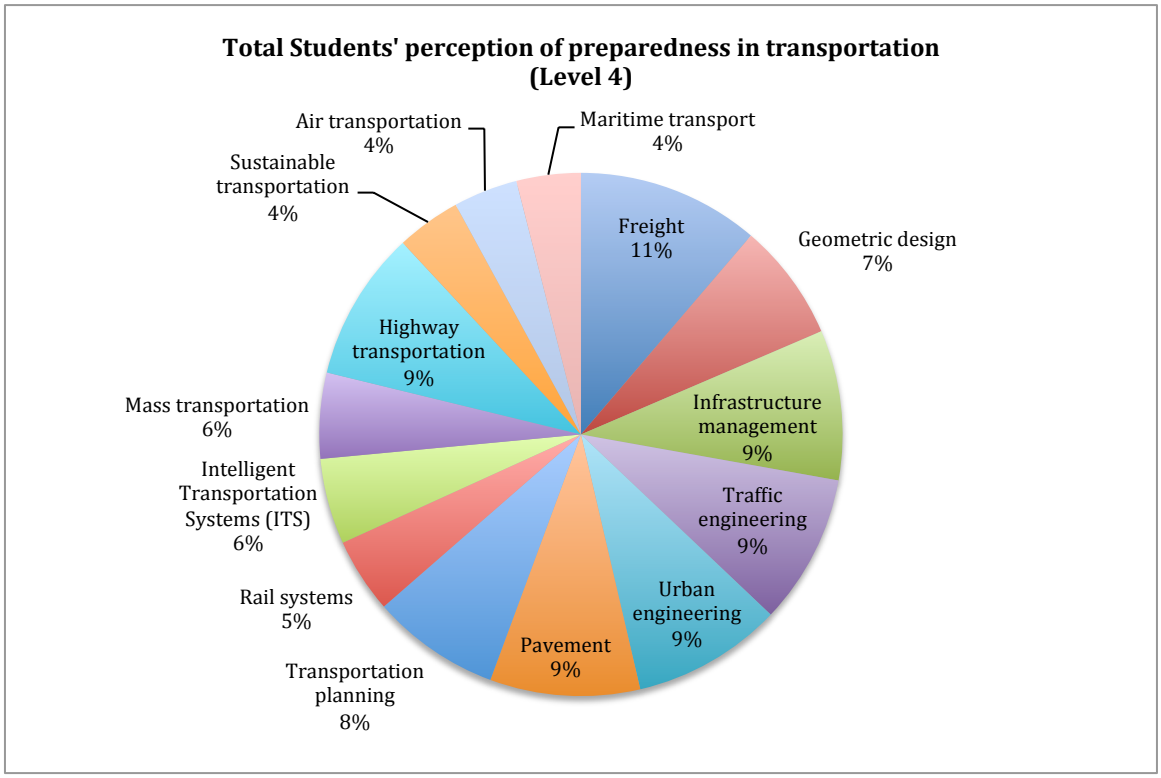

Figure 41 Perception of preparedness by specialty areas in transportation for UPRM & PUPR students (Level 4)

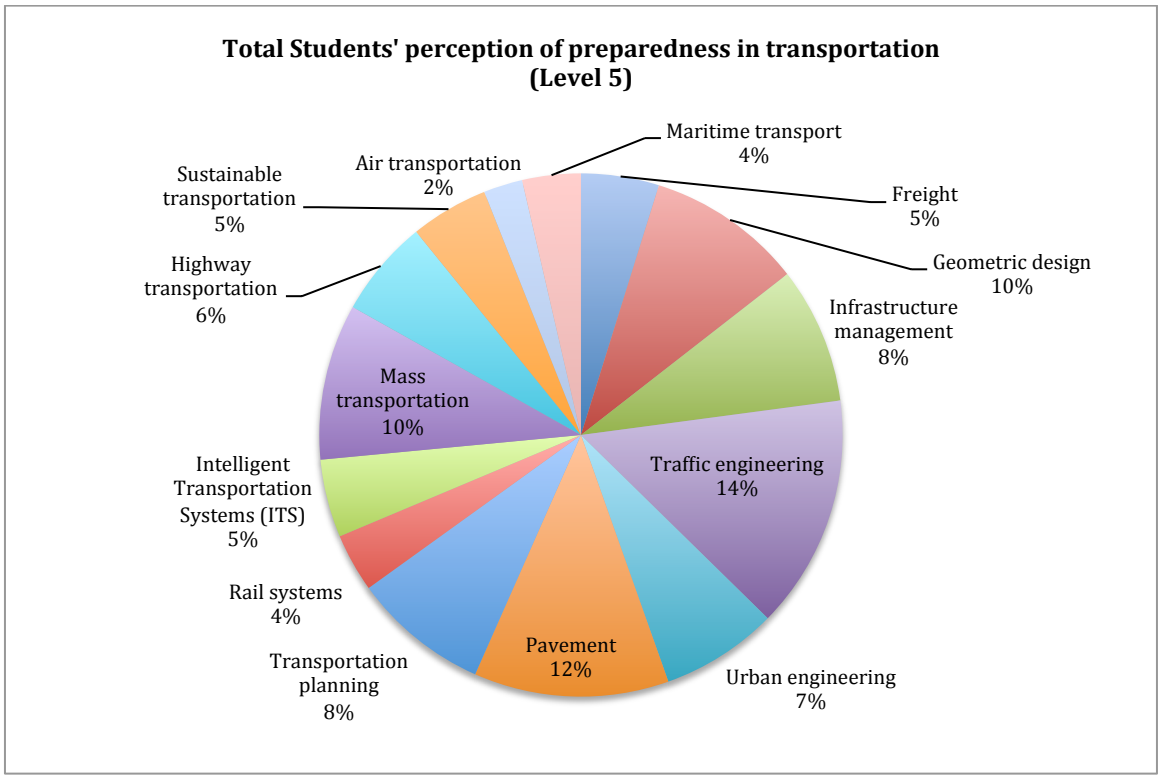

Figure 42 Perception of preparedness by specialty areas in transportation for UPRM & PUPR students (Level 5)

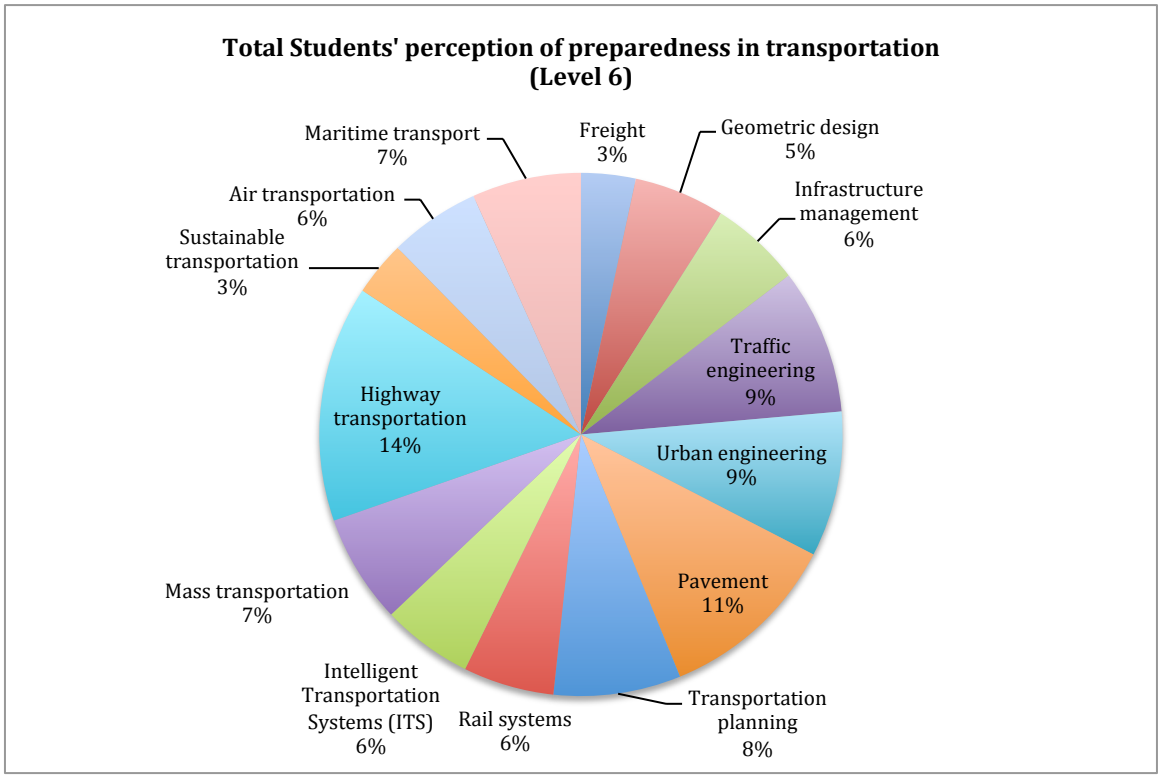

Figure 43 Perception of preparedness by specialty areas in transportation for UPRM & PUPR students (Level 6)

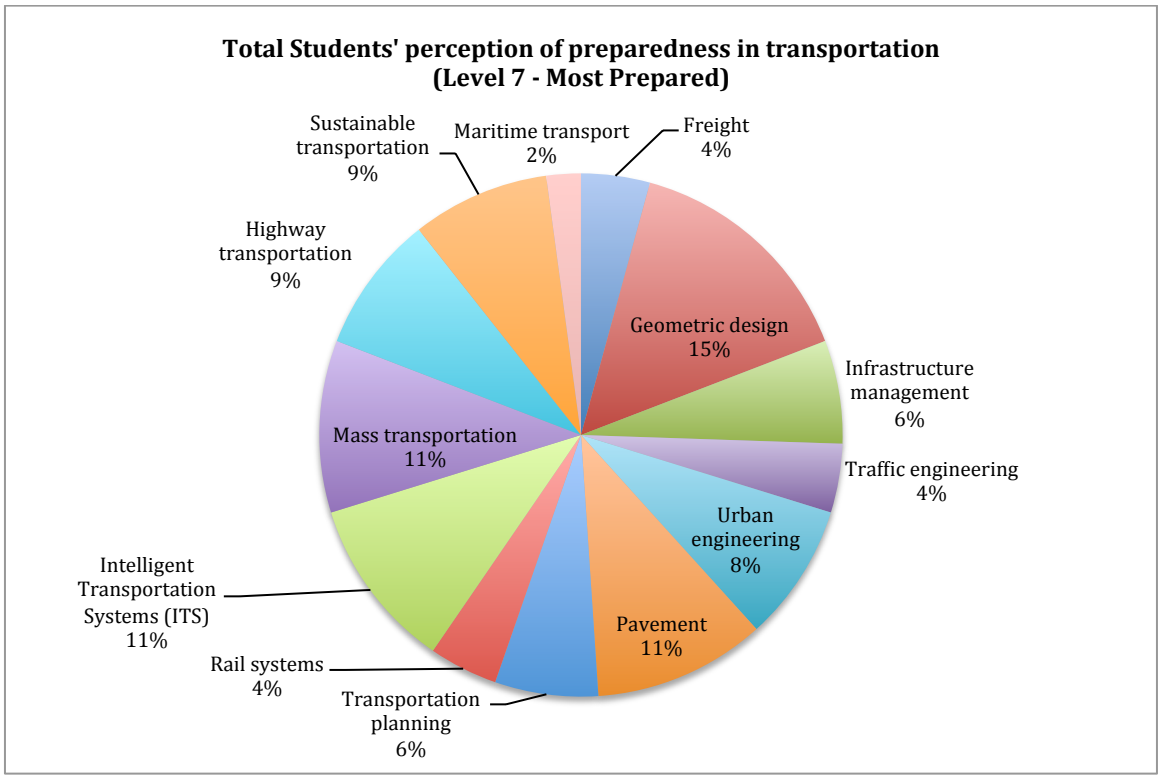

Figure 44 Highest perception of preparedness by specialty areas in transportation for UPRM & PUPR students (Level 7)

Table 13 compares the students' general preferences with their sense of preparedness. It was found that UPRM students' main preference is Mass Transportation and Planning, however they feel more prepared in Geometric Design, Urban Engineering, and ITS. Their least preference is Freight, but consider being least prepared in Maritime, Air and Rail Transportation. PUPR students indicated that their highest preference was Transportation Planning and Urban Engineering, but feel least prepared in Geometric Design and Pavement. Their least preference is Freight and considered to be less prepared in Air Transportation. Considering both universities combined, Transportation Planning and Urban Engineering are the overall preferred specialties and they understand to be best prepared in Geometric Design. The least general area of specialty preferred is Freight and least preparedness is Air Transportation. None of the different areas of preference interact with the area of preparedness. This reflects that students prefer different areas than the ones they are currently been prepared.

Table 13 Comparison of students' preference and preparedness

UPRM		
	Preference	Preparedness
Highest	• Mass Transportation • Transportation Planning	• Geometric Design • Urban Engineering • ITS
Lowest	• Freight	• Maritime Transportation • Air Transportation • Rail Systems
PUPR		
	Preference	Preparedness
Highest	• Transportation Planning • Urban Engineering	• Geometric Design • Pavement
Lowest	• Freight	• Air Transportation
UPRM & PUPR		
	Preference	Preparedness
Highest	• Transportation Planning • Urban Engineering	• Geometric Design
Lowest	• Freight	• Air Transportation

6. INDUSTRY NEEDS

To understand the industry needs it was determined that it was important to identify related studies that provide a perspective of the current needs in the two main fields of transportation: infrastructure and transportation systems. Another important aspect considered was the demand of employers of Civil Engineers professionals with particular skills. Needed skills for employees in Puerto Rico may not be the same as in the US. To address this issue, previous research was performed to identify the need in the US; in Puerto Rico interviews were presented to employers. Finally, a review on the future of transportation in Puerto Rico was performed.

6.1. Related studies

Performing the literature review, three research studies were identified to support the skills required by employers in the industry. The first study identifies the Finland's

transportation plan to face the challenges for 2030. A second and third study provided specific qualities and skills for Civil Engineers specialized in transportation (*Evergreen State College, n.d.)*. The final study identifies attributes companies look when employing Civil Engineers.

6.1.1. Transport 2030: Major challenges, new directions

In Finland the biggest challenges is to keep up with policy and maintain a balance between the climate change countermeasures, better health, cost reduction, efficient transport, maintain competiveness, and innovate (*MTCPS, 2007*). Finland's targets are to provide better transportation for the day-to-day traveling, improve safety, sustainable transport, affordable systems, efficient and innovative networks of transportation, and intelligent systems. These targets were assessed from a local, national, international, and global perspective (*OECD/ITF, 2009)*. The strategies used to accomplish the targets were the incorporation of cooperation, skills, innovation, and efficiency. Some of the measures for infrastructure will be to develop truck networks, themed projects, and infrastructure development. The transportation systems development is mass transport, Transport Management Systems [TMS], transport services, and traffic information services. Although this article is from abroad, in general most of the presented necessities are global ones (*MTCPS, 2007*).

6.1.2. Strategic Transport Infrastructure Needs to 2030

Infrastructure for main international gateways and corridors are seriously required globally, as the need for transportation of people and goods is projected to increase dramatically in the next years. Due to the increase of international commerce, freights are expected to double in 15 years and triple in 20 years (*OECD, 2011*). Private sectors are a key element that could facilitate the finance development of these purposes considering the government limitations for funding. Support for greener transportation is becoming more popular and demanded by various

organizations. Strategies to accomplish this matter should be during the planning and development of the strategies.

6.1.3. Transportation Investment in Our Future

According to an AASHTO's study, current surface transportation systems are becoming old and must be rebuild or replace. In addition, the capacity systems are over the design limits. In the next 20 year mass transportation is expected to double its ridership. Every year increasing costs make transportation more expensive. Global trade is constantly increasing. These are some highlights of the transportation needs at US that require immediate attention. The recommendation related to the interstate transportation system is to preserve current system, enhance its performance, expand the capacity, and reduce highway growth by increasing transit and rail (*AASHTO, 2007*).

6.1.4. Future of Transportation in Puerto Rico

The DTOP and ACT have developed the islandwide Long Range Transportation Plan for 2040. This plan presents the surface transportation planning for the next 27 years, considering challenges at local and global levels, climate changes, and reconfiguration from communities to cities. Some of the objectives are to: improve mobility, accessibility and systems performances in transportation; promote economic growth and sustainability; and reduce congestion. Strategies to incorporate for the completion of the objectives are: develop policy of integrated planning; enhance the public transportation systems; improve and maintain transportation infrastructure; apply complete streets concepts improvement of bicycles and pedestrian facilities; and support Airports, Seaports, and Freight (*Atkins Caribe, 2013*).

This long-term plan is very important for the all agents (government, private industry, academia and students), as this helps to redirect efforts towards the specific direction where the

transportation is been lead. Specific plans provide clear areas to improve in transportation and helps to define the new set of skills that will be needed in the future.

6.1.5. Knowledge for a Career in Civil Engineering

Employers look for Civil Engineers who are capable of planning, designing, and supervise construction projects, including the maintenance of structures and facilities (*MyMajors. n.d.*). Some of the top skills required for Civil Engineers are:

- Complex Problem Solving,
- Coordinating,
- Critical Thinking,
- Financial Management,
- Judgment and Decision Making,
- Listening,
- Mathematics and Sciences,
- Negotiating,
- Orientating,
- Reading Comprehension,
- Speaking,
- System Analysis and Evaluation, and
- Time Keeping.

6.2. Interviews

A strategy implemented in the study to define the industries needs was the employment of an interview to survey governmental agencies and private companies related to transportation. The objective was to survey employers to determine the depth in knowledge, professional and technical skills required for current and future employees for transportation professional careers at their companies. Appendix C presents the guide of questions used to perform the interviews.

To set in perspective the characteristics of the sample companies and governmental agencies assessed, the first part of the interview asked some background information. To maintain the privacy of surveyed companies and individuals, some questions performed were presented in a general form. This study was limited to nine interviews, which were conducted to the following companies and agencies.

- Alternate Concepts, Inc,
- Atkins Caribe, LLP.
- CSA Architects & Engineers, LLP.
- Del Valle Group.
- Highways and Transportation Authority.
- Klein Engineering, PSC.
- Metropolitan Bus Authority.
- Novotren and Transcriollo.
- Streer Davis Gleave.

The first question was of the study was to identify the company's name, and the second question was: What are the services provided in the area of transportation? The following services correspond to the listed companies, respectively.

- Statistics, passenger transit studies, metrics of the system, federal reports, schedules, and supply-demands studies.
- Design and management of highways, bridges and airports projects.
- Design of highways (including structures, lighting, drainage, signs, signals, and others), project management, inspection, and Electronic Toll Collection [ETC] & Open Road Toll [ORT].
- Construction of highways, bridges, and airports.
- Public transportation with the "Tren Urbano" [TU], connections with “TU Conección” (small routs around the TU) and the "Metro Urbano" [MU].
- Engineering design and studies.
- Mass transportation, fix routes (regular), Paratransit Services (disables).
- Consulting DTOP and Caguas municipality for the TransCriollo initiative. Technical areas addressed are transportation plans and economic impact of TransCriollo. Novotren office: consults, provides connections, preserves historic record of the project, and involves in PPP alliances.
- Planning of all transportation modes.

The third question was: How many Civil Engineers do you have in the company/agency? Results suggest three ranges for number of engineers, which could be interpret as the companies and agencies size as: 2 to 5 (Small), 25-30 (Mid) and over 40 (Large). Results indicate that 7 were small size companies, 1 was mid-size, and 1 was a large company.

Forth question was: How many are Transportation Engineers? The answers were from unavailable, 1 to 6, and about 15.

The fifth question was: What are the general working experience requirements for transportation engineers? The following is a compendium of the results and are listed:

- Advance knowledge of English.
- Advance management of Excel.
- At entrance level no experience is required; 2 years for juniors and 10 for seniors; for project administration and supervising is required 3 to 6 years of experience depending of the position; 3-5 years or specialized studies in the area; vast experience.
- Bachelor's degree in Civil Engineering.
- Construction of Highway and Bridges.
- Design and analysis of traffic data.
- Engineering license and collegiate member.
- Experience in highway design (all elements).
- Mass transportation, routes establishment, network analysis.
- Micro, macro and simulation.
- Not-specified.
- Specialty in transportation.
- Up-to-date and knowledge in design codes, regulations, design directives from the Highways and Transportation Authority, and understand the local practice.
- Use of CAD and Civil 3D.
- Vast knowledge in HCM.

Some of these requirements are well addressed in the academia at undergraduate level such as: English, Excel, degree, construction, design and analysis of traffic, highway design, and Civil 3D. Other requirements are offered at graduate level or are acquired during the engineering

work experiences such as: year of working experience, PE license and CIAPR membership, mass transportation design and analysis, simulations, specialties in transportation, design codes, regulations, design directives, and HCM.

The sixth question was to identify the industries' needs for professionals. Companies and agencies were asked: What is the number of vacancies in the transportation area? The responses of the nine employers were that there no employment opportunities currently for Civil Engineers.

A final question was to find the criteria that companies and governmental agencies use for the selection of new employees. Therefore the question was: What criterion (internship, research, study out broad, licenses, certifications, continuous education, etc.) is important for this company/agency in the recruitment of transportation engineers? Answers were varied and are listed below.

- Academic preparation in Civil Engineering.
- Actively involved in professional organizations.
- Additional criteria that are important are: certifications, graduates studies and specialties in the profession.
- At least Master's degree in transportation engineering.
- Engineering license and be certified by the BEE.
- Job experience.
- Management of systems of information and knowledge in Construction Project Management [CPM].
- PE license is not required, because no design is performed in this company, nevertheless is preferred an Engineer in Training [EIT].
- PE license, past worker of ACT and DTOP.

- Prefer EIT.
- Prefer license engineer, nevertheless is more strictly required at mid and senior levels where professional and leading responsibility is greater.
- Projects related to the field.

A second part of the interview was focused in identifying the company's priorities in Civil Engineering and transportation, as well as specific skills relevance, necessity, and level. The first question was to identify the top three (3) specialties in Civil Engineering employers seek for companies and agencies to satisfy current and future needs. Results of current priorities are presented in Figure 45 and future priorities are presented in Figure 46. The top three current priorities with their corresponding percentages of the answers are transportation (26%), project management and computational science/engineering (16%), and Municipal or Urban Engineering and Structural Engineering (11%).

	Current Priority Area in Civil Engineering for Agencies/Companies								
ID	Computational science and engineering	Construction engineering	Environmental engineering	Municipal or urban engineering	Project management	Structural engineering	Structural engineering at	Transportation engineering	Water resources engineering
1	0	1	0	0	1	0	0	1	0
2	1	0	0	0	0	0	1	0	0
3	1	0	0	0	0	1	0	0	0
4	0	0	0	0	0	1	0	1	1
5	0	0	0	0	0	0	0	0	0
6	1	0	1	0	0	0	0	1	0
7	0	0	0	1	1	0	0	1	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	1	1	0	0	1	0
TOTAL	3	1	1	2	3	2	1	5	1
Percentage	16%	5%	5%	11%	16%	11%	5%	26%	5%

Figure 45 Current priorities in Civil Engineering for companies

The future top three priorities according to the results were: transportation (27%), structural engineering (15%), construction engineering and computational science/engineering (12%). The results clearly present that the highest current need is in transportation and the reason is that surveyed companies and governmental agencies are related to the transportation field. Also, applied technology and project management are a current need. The future they see for the industry in Civil Engineering is Construction Engineering and Environmental Engineering.

	Future Priority Area in Civil Engineering for Agencies/Companies											
ID	Coastal engineering	Computational science and engineering	Construction engineering	Environmental engineering	Forensic engineering	Municipal or urban engineering	Project management	Structural engineering	Structural engineering at	Surveying	Transportation engineering	Water resources engineering
1	0	0	0	0	0	0	1	0	0	0	1	1
2	0	1	0	0	0	0	0	0	1	0	1	0
3	0	1	0	0	0	0	0	1	0	0	1	0
4	1	0	0	0	0	0	0	1	0	0	1	0
5	0	0	1	0	0	0	0	0	0	0	1	1
6	0	0	0	0	1	1	0	1	0	0	0	0
7	0	1	1	0	0	0	0	0	0	0	0	0
8	0	0	1	0	0	0	0	1	0	0	1	0
9	0	0	0	1	0	1	0	0	0	0	1	0
TOTAL	1	3	3	1	1	2	1	4	1	0	7	2
Percentage	4%	12%	12%	4%	4%	8%	4%	15%	4%	0%	27%	8%

Figure 46 Future priorities in Civil Engineering for companies

The second question in this part of the survey had the objective of identifying current and future priority areas in Transportation Engineering field for agencies and companies. Results of current priorities are presented in Figures 47 and future priorities are presented in Figures 48. The outcomes revealed that currently mass transportation tops the industry (14%), followed by transportation planning (12%) and tied in third position are traffic engineering, ITS, pavement, and urban engineering (9%).

	Current Priority Area in Transportation for Agencies/Companies													
ID	Air transportation	Freight	Geometric design	Highway transportation	Infrastructure management	Intelligent Transportation Systems	Maritime transport	Mass transportation	Pavement	Rail systems	Sustainable transportation	Traffic engineering	Transportation planning	Urban engineering
1	1	0	1	1	0	0	0	1	1	0	0	1	1	0
2	0	0	0	0	0	1	0	1	1	0	0	0	0	0
3	0	0	0	0	1	0	0	1	0	1	0	0	0	1
4	0	0	1	1	1	0	0	0	1	0	0	1	1	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	1	0	0	1	0	1	1	1	1	1	1	1
7	0	0	0	0	0	1	0	1	0	0	1	0	1	1
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	0	0	1	0	1	0	1	0	1	1	1	1	1
TOTAL	2	0	3	3	2	4	0	6	4	3	3	4	5	4
Percentage	5%	0%	7%	7%	5%	9%	0%	14%	9%	7%	7%	9%	12%	9%

Figure 47 Current priorities in transportation for companies and government agencies

Considering future priorities, the results indicated that these were: infrastructure management and transportation planning (13% each) and mass transportation and rail (11% each). These outcomes reflect that the transportation activity is moving towards planning, collective transportation, and technology.

	Future Priority Area in Transportation for Agencies/Companies													
ID	Air transportation	Freight	Geometric design	Highway transportation	Infrastructure management	Intelligent Transportation Systems	Maritime transport	Mass transportation	Pavement	Rail systems	Sustainable transportation	Traffic engineering	Transportation planning	Urban engineering
1	1	0	1	1	0	1	0	1	1	0	1	1	1	0
2	0	0	0	0	1	0	0	0	0	0	0	0	1	1
3	0	0	0	0	1	0	0	1	0	1	0	0	1	1
4	1	0	0	1	1	1	1	1	0	1	1	0	1	0
5	0	0	0	0	1	0	1	0	1	0	0	1	0	0
6	1	0	0	0	1	0	1	0	0	1	0	0	1	0
7	0	0	0	0	0	1	0	1	0	1	1	0	1	1
8	0	0	0	0	1	0	0	1	0	1	0	0	0	0
9	0	1	0	0	0	0	1	0	0	0	0	0	0	0
TOTAL	3	1	1	2	6	3	4	5	2	5	3	2	6	3
Percentage	7%	2%	2%	4%	13%	7%	9%	11%	4%	11%	7%	4%	13%	7%

Figure 48 Future priorities in transportation for companies and agencies

The results present the current highest priority in the transportation discipline is Mass Transportation and in the future will be in Infrastructure Management and Transportation Planning (13%).

With the objective of identifying particular skills relevance, needs, and level at which are needed, question number 3 in this section of the interview was presented. The instructions were to select the relevance from a list of skills with a scale 1 to 7, where 7 was the most important and 1 as the least important. Also, from the same list the respondents had to select the top five needs and at what level in the profession were they required. Figures 49 to 50 present the results.

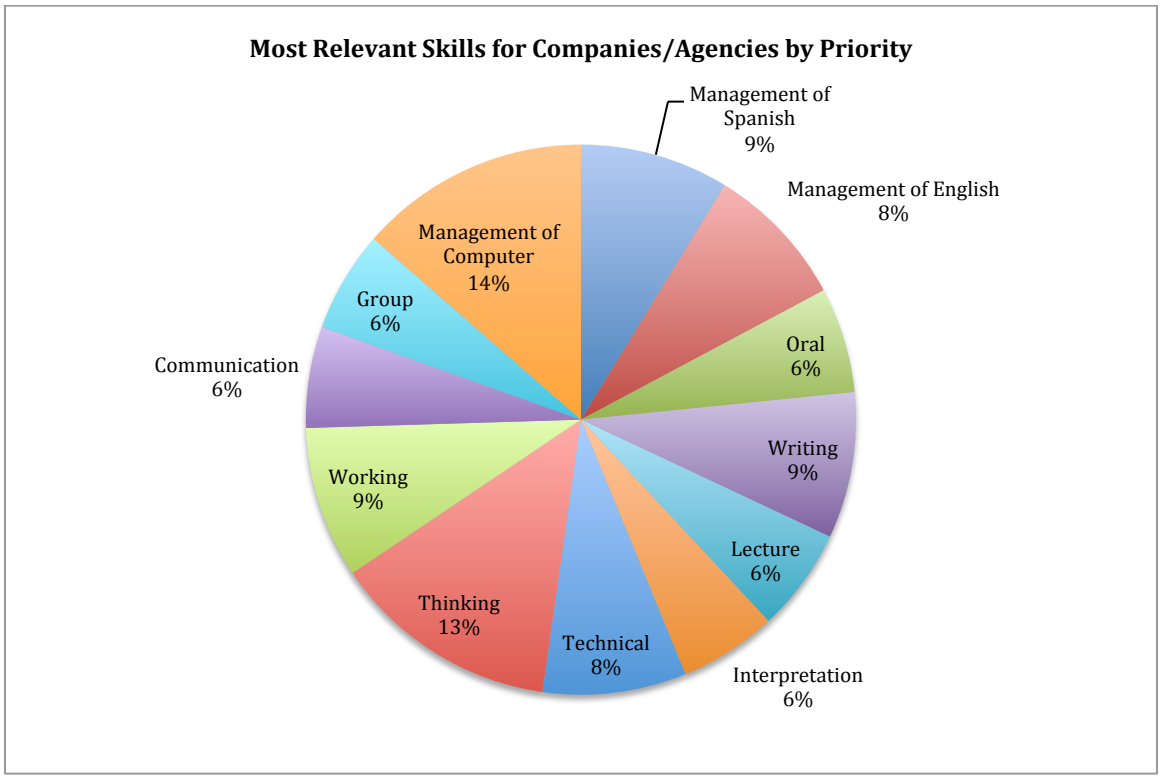

Figure 49 Top relevant skills for companies and agencies

A weight value was assigned to the sum of responses for each level 1 to 7 for each skill, to obtain the top relevant skills required by companies and agencies. The five most relevant skills were: Management of Computer (14%), Thinking (13%), and Management of Spanish, Writing, and Working (9%). The highest skill ranked in the level 7 was Management of Computer.

Considering the same skills listed, companies and agencies were requested to identify the top five (5) skills needed. In a range of 1 to 5, where 1 was the least needed and 5 was the highest need, the results show that the highest skills needed were Management of Computer, Management of English, Communication, and Teamwork, all with a 25%. Figure 50 presents the results distribution.

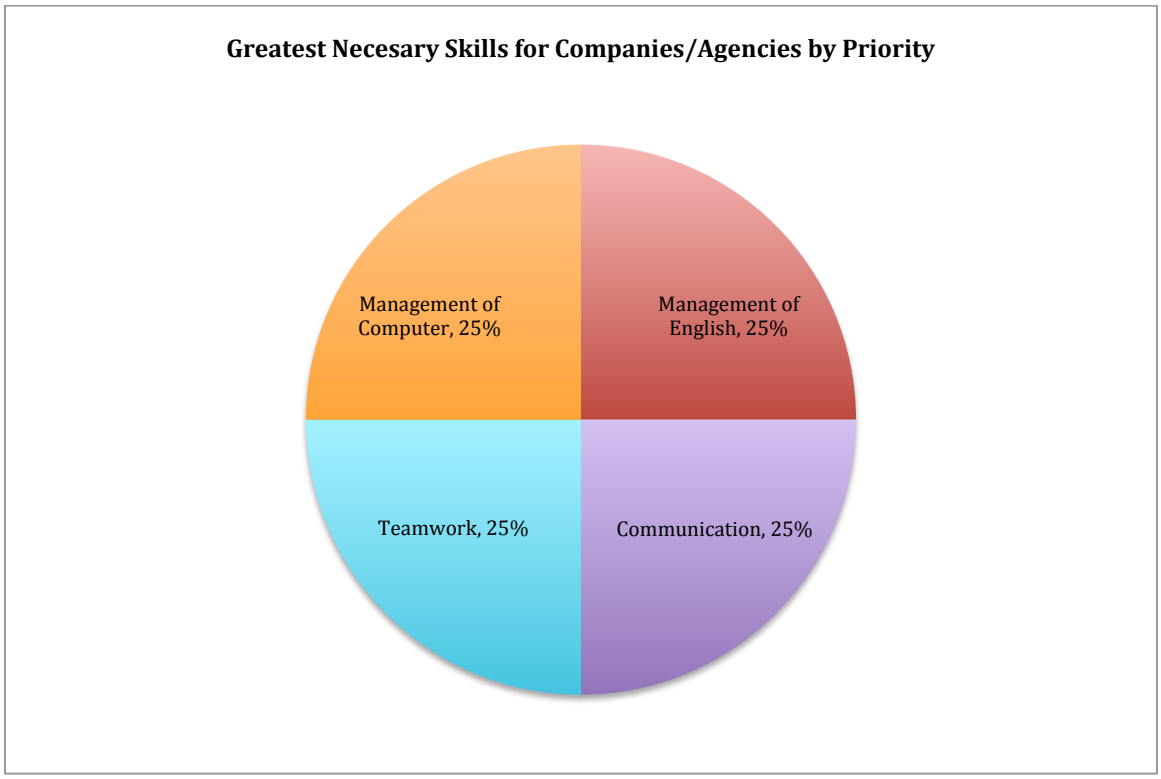

Figure 50 Top needed skills for companies and agencies

The third part of the question number three was to identify the level at which the top skills were required. Figures 51, to 53 present the distribution of results for the top skills previously identified as needed. The results with the highest necessity by level were:

- Entry Level – Management of Computer, Management of English, Communication, and Teamwork, all with a 25%.
- Mid Level – Management of Computer (67%) and Teamwork (33%).
- Superior Level – Management of English (40%), Communication (40%), and Teamwork (20%).

Two of the results were misinterpreted as the answers were all given the same value of need. For analysis purposes these results were not considered in the study. Another two responses to the question of what were their needs was that they had no current need, for such reason they did not respond the question.

Figure 51 presents the necessary skills at Entry level, with a 25% manage English language is one of the four results. Nonetheless, considering that Puerto Rico is an island that commonly communicates in Spanish, the result indicating English is the necessary language is not absolutely correct. English is important for the work development, however Spanish is needed for the daily use.

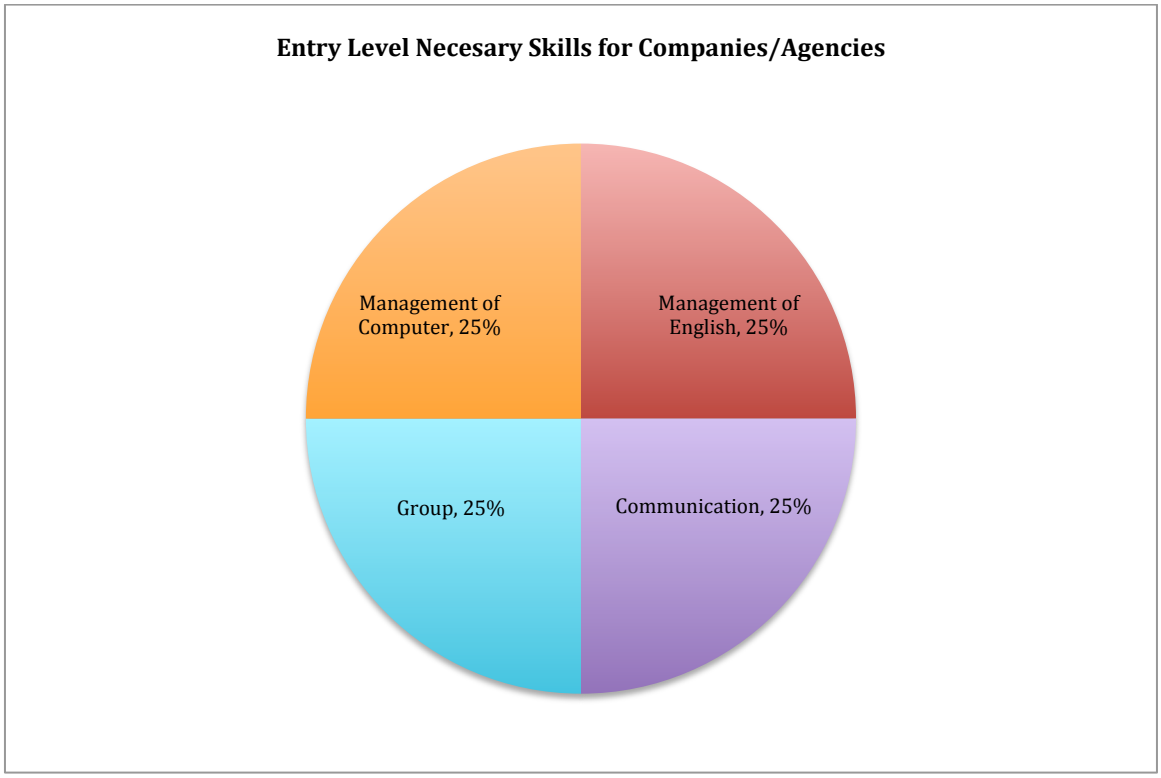

Figure 51 Needed skills for companies and agencies at entry level

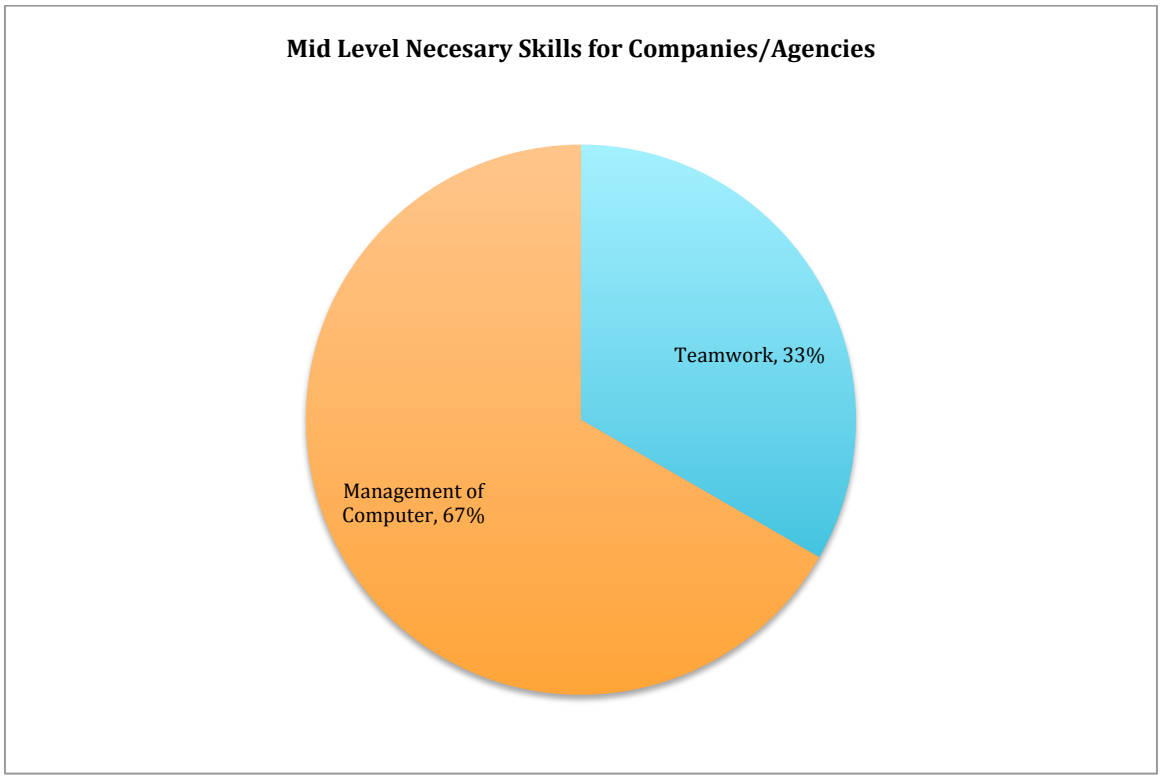

Figure 52 Needed skills for companies and agencies at mid level

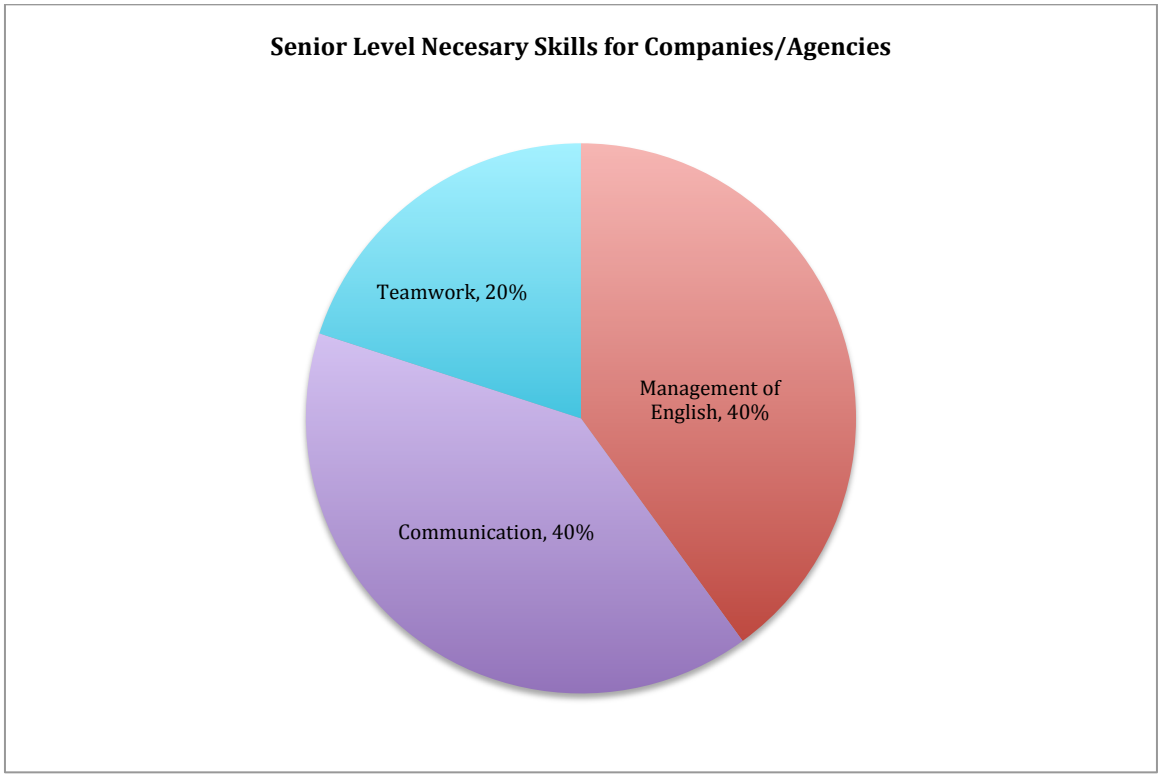

Figure 53 Needed skills for companies and agencies at senior level

Question number four was intended to identify if companies or governmental agencies have environmental factors that affect the communication between transportation engineers and other workers. Two-thirds answer was no environmental factors affect the communication. Other answers were:

- There is a language limitation. In general, engineers' writing in English is limited for the deficiency to express their technical language. Most of the reports are performed in Puerto Rico, but the projects are in mainland, for such reason a technical writing in English is strongly required.
- There is a problem expressing to the public what is ITS and how does it works.
- A factor that affects the communication is the difference in language of employees, drivers, and mechanics.

In question number five employers were to mention projects in which the company/agency has applied sustainability, walkability, planning, ecofriendly, or integration for a transportation project. The objective of this query was to understand the trend for a particular knowledge in diverse areas where green principles are implemented. Knowing the types of projects performed in these areas, it could help to understand the areas of specialty that could be addressed at the undergraduate level due to its demand in the industry. The results for this question in the order that corresponds to the company that worked the project, were the following:

- Reconstruction of runway 10-28, Luis Muñoz Marín International Airport; Concrete was recycled and used as base material.
- Bus Rapid Transit; recycled concrete for the pavement base.

- Master plan of the Sciences City (Ciudad de las Ciencias); Master plan of Bahía Urbana; Transportation Study for Elders at San Juan.
- Vieques bridge feasibility study; ORT & ETC; Metro Urbano, improvements of urban areas; Trocadero / Diverplex.
- Novotren is based on the integration of modes; for that reason TransCriollo operating in the office of the train, because it Integrates transportation to San Juan. This project reduces 7% reduce CO2, which is essential to the region. 1st bike lane (PR-189) from the town center at the University of Turabo, there are 5 universities for advanced studies in the area.
- The bikeway of Piñones is an ecofriendly project; ITS en Mayagüez is an integration of signal network project.
- Recyclable material signals (future project); vehicles (buses) hybrid (diesel-electric).

Question number six was to identify employers' perspective of what type of adaptation or change should be made in the transportation education to supply the current need in the industry, including technology.

- Besides the technical formation, emphasis should be placed in technical writing in English and Spanish; it is very important for the elaboration of proposals and reports.
- Increase the use of latest technology in infrastructure construction area.
- There is a need of professionals well trained in the use of models of micro/macro simulation, with emphasis in calibration and validation of models and the advanced use of excel (macro / Pivot Table).
- Use of technology (i.e., ITS, ETC, ORT), intermodal transportation, financial viability of projects, road safety from the point of integration and human behavior.

- Present politicians the importance and benefits of promoting public transportation systems.
- Graduate students need knowledge of ITS and deepness in the multiple applications such as integrating police, firefighters, incident management, interagency processes and integration of systems, and others.
- Programming and ITS tools.
- Apply the knowledge base of Civil 3D, Synchro, Sidra and other software associated to transportation.
- Programming is necessary in the practice. Studies of traffic in public transport systems.

The seventh question addressed in the interviews was: What are the future technical skills you expect from transportation engineers in the next 5 years? The answers were the following:

- More independence, self-starters, capable of identifying and solve problems simultaneously, multi-tasking, and computer oriented.
- Use of software for modeling infrastructure projects.
- There is a need in managing information geo-referenced, elaboration of maps, use of Port Mapping Protocol [POT], and use of web applications. We need to complete the advance courses with software.
- Use of 3D drawing tools, working with alternative systems such as Microstation (used in other US jurisdictions). Experience in Design-Build procedures, in the areas of risk management and responsibilities.
- Focus on educating on the life center. Cannot forget to bring the center of San Juan the project, when the target is mobility.

- Incident management plan (Atlanta has a PPP).
- Writing and communication with non-technical people.
- Operation of Transportation Management Center [TMC], advance Civil 3D, advanced operational programs, advanced knowledge of the green book, Manual on Uniform Traffic Control Devices [MUTCD], HCM.
- Programming is vital, data converting algorithms, optimization of spaces and systems, rehabilitation, and maintains of infrastructure.

Question number eight was: What should be the focus of the transportation courses, with the objective to provide better professionals that comply with the needs of your company or governmental agency. The answers were:

- Focus in providing additional courses in AutoCad and Microstation. Today many engineering plans are developed in Bently Microstation V8i.
- Optimization of elements in projects of infrastructure (pavements, concretes).
- Provide high skills in traffic models, Geographic Information System [GIS], financial analysis of highway infrastructure projects (consider systems P3).
- Graduates students should be aware of the design guidelines, directive and manuals used in Puerto Rico.
- It is fundamental that the profession must be integrated to the practice.
- More laboratories. Bring the theory to the practice.
- More skilled in the design, analysis and evaluation of public transport systems.
- Fundamentals and advanced use of computational tools.
- Subdivide by specialties: public transport, private, marine, etc. But always keeping some basic courses in common.

The ninth question was to identify how important do employers consider that partnerships with the academia would prepare better transportation professionals?

- Extremely important. Those alliance help the student to make a transition sooth and effectively to the labor world by the end of their academic career.
- Not so important if an updated curriculum is followed.
- Partnerships are vital to have professionals ready to join the real world of labor.
- Very important.
- It is fundamental; the profession must be integrated to the practice.
- It is highly important.
- Very important to establish Coop strategies.
- Very important.
- Extremely important. One thing is theory and practice is another. Promote professional training. PUPR program is privileged by the practical application to the academic offers.

7. COMPARISON OF INDUSTRY'S NEEDS VS. ACADEMIC OFFERINGS AND STUDENT'S OUTCOME

To accomplish the objectives of this project to identify the technical skills desired for transportation engineer professionals in the 21th century it was essential to compare the current required skills in the practice with the current academic offer that addresses those skills.

A total of 49 listed technical core skills are required by the industry; approximately 37% are offered at the undergraduate level, 8% at the graduate level, 18% is offered in other courses, and 37% are not offered. In general, the courses not available are in the areas of construction,

tolls, reports and administration, rails, intermodals, and maintenance. At the graduate level some of the skills covered are Highway Safety Manual [HSM], planning, systems, and safety. Examining the results this could represent additional material that could be covered at the transportation courses, additional courses for specialization, or provide them at graduate level. Table 14 shows details of the technical skills required in the industry. Some are addressed on the courses and others are not included in the curriculum.

Table 14 Technical skills required in the industry vs. academic offer

Covered Technical Skills	New Technical Skills
Green Book	Computational sciences and engineering
MUTCD	Design-built process
Transit transportation	Design, analysis and evaluation of public transportation systems
Design codes, regulation, design directives, and local practices	Electronic Toll Collection
Traffic Engineering	Environmental friendly projects in transportation
Modeling systems and infrastructure	Human factors
Construction of highways, bridges, airports, and general projects	Incident management
Structural	Infrastructure management
Transportation Planning	ITS
Pavement	Maintenance, rehabilitation and reconstruction
General Transportation	Open Road Toll
Project management	Optimization of spaces and systems
Finance feasibility	Paratransit systems
Design of highway structures, lighting, drainage, signs, signals, and others	Passenger studies
Safety	PPP
Design and analysis of traffic	Prepare schedules
Metrics of systems	Rail transportation
Urban Engineering	Transit Route Design
Administration of highways	Transportation Management System
Construction engineering (latest technology)	Write federal reports
Intermodal planning	
HSM	
Supply-demand studies	

Professional skills are difficult to measure because of their subjectivity. The resources used to identify if these skills were encouraged were the syllabus and opinions of professors in the area. Table 15 shows all of the professional skills addressed in the transportation courses or

in other courses at both universities. There are no available techniques identified that could quantify the level at which each of the skills are provided, besides providing students surveys that could help in developing metrics for these.

Table 15 Professional skills addressed in the courses

Skill
Advance English
Advance Spanish
Advance excel
Technical Writing
Lecture
Technical
Thinking
Communication
Management of Computers
Interpretation

Twenty first century skills not only involve the latest knowledge of advances in transportation systems and infrastructure, but also the newest available technological tools to provide feasible solutions to complex problems in shorter periods. An example of this is the performance of traffic counts. In the past, multiple persons were required to make a traffic count at intersections. For more precise projects with multiple transportation modes, it is required additional staff. Today, one person can do a traffic count from any smart device. Figure 54 presents the TurnCount application. This software is a technology that facilitates the traffic counts, and this could be an example of a technology that a Transportation Engineer should be capable of using or even developing.

Figure 54 TurnCount Application for smart devices

From 19 different software and technologies needed in the industry, only 2 are currently provided in the academic offerings at UPRM. This represents a significant disadvantage for newly graduates, as they are intellectually capable to perform this type of task; however they are not practical for having limitations in managing transportation engineering software and technology. See Table 16 for details on the available technological skills that can be addressed on transportation courses.

Table 16 Software and technology management requisites in the transportation industry

Software and Technologies
AutoCAD
Bentley Microstation
Civil 3D
Database management
Electronic Toll Collection [ETC]
GIS
Highway Capacity Software [HCS]
ITS
Macro/Micro
Modeling
Open Road Toll [ORT]
POT (Mapping)
Programming
Sidra
Simulation
Synchro
Systems P3 (financial analysis)
Traffic Count
Transportation Management System [TMS]

NOTE: The "X" represents the software and technological skills provided in the transportation courses at UPRM.

Some additional general requisites employers request are: bachelors degree in Civil Engineering, engineering license PE/EIT and CIAPR membership, working experiences, active with professional organizations, certifications, graduate studies, independent worker, self-starter, problem solver, multi-tasking.

Comparing the students' developed skills at the academia, with the ones required by the practice, the results demonstrated that the top areas of specialties in transportation students prefer are: Transportation Planning and Urban Engineering. Their perception of preparedness was in the areas of Geometric Design. However, industry today is focusing in Mass Transportation. The projection focus in the near future is in the areas of Infrastructure Management and Transportation Planning. Overall, the main areas to focus are Planning, Mass Transportation and Technology. Main difference is that students prefer different specialties compared to the

industry needs. Students prefer Planning and Urban Engineering; nevertheless the future of transportation tends to be in Mass Transportation. It is important that students, who seek to specialize in transportation, be directed to the needed areas of interest for the industry. Strategies should be developed to attract these students into these areas.

8. CONCLUSIONS AND RECOMMENDATIONS

Technological advances in transportation have increased considerably in the last decade. With it new minimum sets of skills are required. Currently, mobility has been compromise for the increasing demand of transportation; effect of population growth and globalization. This results in higher infrastructure deterioration and more financial investment. Transportation systems are vital for the economic growth of a nation, thus is important to keep updated infrastructure and integrate proven technologies to enhance the transportation. Nevertheless, research and development of the field has been limited due to governmental funding reductions, resulting in unskilled and less competitive engineers. In addition, the massive emigration of young professionals from Puerto Rico to the Mainland US endangers the future of local transportation. Notwithstanding these issues, it is fundamental that universities remain at the vanguard of engineering education in providing high quality engineers.

Results from the surveys reveal that 67% of students are interested in obtaining a Master's Degree and 15% a Doctorate Degree in the next 10 years, and 1 out of 3 is interested in the transportation realm from 21 specialties considered. This denotes that there is a high-expected demand in the US industry until 2024 and there is an available offer for recent graduate engineers specialists in transportation. Nevertheless, the available work opportunities in Puerto Rico are scarce or null, as the industry assessment demonstrated that, at the time of performing

the interview, no civil engineering positions with specialty in transportation were available. This evidently result in the massive migration of young professionals to the continental US (*Velázquez, 2013*). Important attention should be taken by the academia to provide qualified engineers for the local and national industry. This requires tempering the curriculum to the reality that many students are considering leaving the island after obtaining their degree.

Industry looks for engineers with outstanding professional skills such as: Managing English, Technical Skills, and Communication and Interpretation. In the near future the industry's priorities will focus in: Mass Transportation, Transportation Planning, and Urban Engineering.

Several topics not covered in the current academic offerings were identified and recommended to be included. The topics that are not feasible to incorporate to current general undergraduate transportation courses should be incorporated to new technical electives or graduate courses. Great care should be taken when incorporating new topics to the current curriculum, as trying to enhance the transportation program could result in risking quality. Evaluation techniques such as exams, quizzes, participation, and projects allow students to develop their professional and technical skills. Written reports should be requisite to be in English language; helping students to enhance their technical language in English. Syllabus should be updated with the presented new topics; this will help to accommodate the skills required by NCEES and the transportation industry.

UPRM and PUPR academic offering are relatively similar with some difference in the topics covered. PUPR offers a laboratory with focus on topics applied to the engineering practice such as: Volume Studies, Intersection Counts, Parking Studies, Public Transportation Studies, Transportation Planning Data, Traffic Control Devices, Arrivals and Departures,

Intersection Delay, and Saturation Flow Measurement. UPRM transportation courses should benefit from having a separate laboratory course that is focused on practical transportation applications, software and studies, as those are skills that the industry seeks for engineers. Transportation is a broad discipline that requires specialists. More graduate programs are currently been needed and PUPR should develop a graduate program in Transportation Engineering and address areas not yet exploited.

Enough information could not be found to relate the Civil Engineering courses that address particular skills in accordance to the industries' needs. However, this study was not intended to focus on the design of courses. In addition, it is understood that the necessary expertise level to deepen into this objective was not encountered. It is recommended that a specialist in education develop a future study to address this objective; this study could be used as base for that research.

ABET's curriculum requirements are met in both universities in Puerto Rico. In the transportation courses, students are exposed to material, projects, and lectures that allow them apply their knowledge, perform experiments, analysis and interpret results, and design systems. In addition the students' outcomes A to K are met with the development of projects and presentations. NCEES exam evaluation topics are partially presented in the transportation courses. The particular topics that are missing and should be covered so that students are fully capable are: pedestrian facilities, diver behavior and/or performance, geometric design of intersections, and traffic safety.

Evaluating the curriculums of the top, mid, and low ranked universities it was found that most US universities provide students the opportunity to specialize in a particular area of interest within the Civil Engineering curriculum or let students take courses in various areas to obtain a

General Engineering degree. UPRM could consider providing a flexible curriculum that allows students decide if they want to specialize in a particular area in Civil Engineering. Students can benefit for specializing in an area of interest as they can focus on a matter that they are comfortable with, and this could allow them to create their own path for their career. However, basic courses on all areas should remain part of the minimum requisites for the degree. In addition, UPRM should consider the development of a study to identify the desirability to reduce the academic curriculum from 5 years to 4 years. Also, topics addressed at US universities should be integrated to UPRM's curriculum as a large percent of young professionals are migrating to the continental US and is expected from them to have knowledge in mitigation techniques, intersection and interchange design, parking design, multilane highway design, bicycle and pedestrian facilities design and analysis, passenger and freight transportation systems, rail, mass and airport transportation, ITS, policy, maintenance, and familiarity with the latest transportation software programs.

A strong recommendation provided by the industry is the need for integration of the academia to the professional practice. Such initiative provides a smooth transition from the theoretical world to the practical world. Also, it helps to relate the theory with the practice and apply the knowledge to current global projects. Students could be ready to join the labor workforce right after graduation. Specific details of the knowledge depth required by the industry could not be identified with the survey; nevertheless the general knowledge expected is design and analysis of mass transportation, planning, and traffic engineering.

Another recommendation is to integrate the skills required by the practice by considering adjustments to undergraduate and graduate programs. Some essential elements that should be considered to integrate to the transportation courses based on the results are the following topics

construction, tolls, rails, internodes, maintenance, administration, and development of reports. In addition to the results, some of the hot topics at local level that must be attended immediately are roundabouts, transit, freights, and safety. Emphasis in these areas is also needed in the courses.

From the survey performed to UPRM and PUPR students, the top areas of preferences in the transportation discipline are: Transportation Planning, Urban Engineering, and Mass Transportation. The industry demands Infrastructure Management, Planning, Mass and Rail Transportation, Technology, ITS, Pavement, Urban Engineering and Traffic, while the academia is offering Geometric Design, Urban Engineering and Pavement. Comparing the four agents (government, private industry, academia, and students) it can be concluded that the preference of students concurs with the industries' needs; however the academic offering at undergraduate level does not prepare General Civil Engineers for the current and future needs. Constant adjustments to the curriculum should be made to emphasis on topics that future professionals will need, as well as to satisfy the current and future needs of the industry.

Taking into account that Puerto Rico is an island; the academia should consider expanding their academic offering to other specialty areas such as maritime and air transportation. This could influence the interests of students to consider a career in transportation. Students demonstrated no interest in those areas of transportation because the experiences to which they have been exposed in their academic environment have been limited.

From the results of this study some recommendations to improve the transportation courses are to focus the courses in the industries' needs from Puerto Rico and US, to integrate the courses with most of the topics listed in Tables 10 and 13, and to assign students projects to that could allow them to develop the required professional and technical skills. One of today's most important skills in the transportation discipline is the use of technology. In the real world,

advances in technology provide efficient tools for the design, construction, analysis, maintenance, and administration of transportation systems and infrastructure, which provides enrichment of their careers and improvement of performance. It is then recommended that transportation courses include in their curriculum tools that represent current and latest advances in technology.

One of the current weakness of the academic programs is that prepares professionals for an area that has numerous needs, but has no working opportunities. The fours agents should develop or improve their liaison and develop alliances, scholarships, fellowships, work-study, Coops, partnerships, collaborative agreements, and future project notices to direct efforts in one direction. It is important that local transportation specialists be prepared to face today's employment challenges. There is a need for work to be performed, but the issue is how can it be achieved. An effort that the government and the academia should incorporate as a strategy in order to face the challenge that is unemployment, is to orient and train future professionals so they can be able to develop private consulting business, Corporate Partnerships, and Cooperatives. An example of an effective strategy managed by the four agents was the coordination of efforts by the government and private sector on the arrival of Lufthansa (Europeans largest aircraft company) and the creation of the School of Aeronautics in Puerto Rico.

There are many opportunities in transportation for all agents. Private industry is the entity that has the potential of investing in the construction, maintenance, and operation of the transportation infrastructure and systems. Academia has the opportunity to develop more research with the government and private sectors, and students can benefit from the opportunities to develop specialized knowledge, technical, professional and technological skills, while gain experience and get exposed to the latest topics in transportation.

The academia has the challenge to maintain updated transportation programs to supply the demand of the industry of high quality professionals, and attract students to specialize in the areas that the industry needs. At local level, industries face the challenges to work on innovative projects, which have not been developed before in Puerto Rico, ensure to have qualified professionals with new sets of skills, and keep up with technology. Local companies face more competition with foreign companies that have vast experience, resources, and expertise. The government is expected to provide a safe, accountable, flexible, and efficient transportation infrastructure. However, the greatest challenges faced by the government are to preserve aging transportation systems and develop new projects, with the highest financial deficit in history. Meanwhile, traffic congestion increases, maintenance costs increase, environmental impacts increase, institutions become more outdated, and more human intellectual and greater financial support is needed. Students have the challenge to develop specialized knowledge, develop the technological and technical skills required by the industry, and solve Puerto Rico's issues in the future.

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APPENDIX A

Letter of Approval

Committee for the Protection of Human Subjects in Research

Comité para la Protección de los Seres Humanos en la Investigación
CPSHI/IRB 00002053
Universidad de Puerto Rico – Recinto Universitario de Mayagüez
Decanato de Asuntos Académicos
Call Box 9000
Mayagüez, PR 00681-9000

6 de agosto de 2013

Sr. Kenneth X. Vélez Rodríguez
Depto. de Ingeniería Civil y Agrimensura
Recinto Universitario de Mayagüez
P.O. Box 9000
Mayagüez, PR 00681-9000

Estimado Señor Vélez Rodríguez:

El Comité para la Protección de los Seres Humanos en la Investigación (CPSHI) consideró la versión más reciente de la Solicitud de Revisión y demás documentos sometidos para el proyecto titulado *Destrezas técnicas requeridas para los profesionales de Ingeniería en Transportación*.

En vista de que su proyecto cualifica para un proceso expedito de aprobación y ha incorporado las recomendaciones que se le hicieron, el CPSHI gustosamente le otorga su aprobación con una vigencia de un año a partir de hoy, esto es, desde el 6 de agosto de 2013 hasta el 5 de agosto de 2014. Sólo quisiera indicarle que todo participante debe recibir copia de la hoja del consentimiento informado aunque no la solicite, para que así tenga la información de contacto por cualquier cosa.

Recuerde que deberá someter al CPSHI un informe anual con un resumen de los resultados de su proyecto, incluyendo la identificación de efectos adversos que, en el proceso de desarrollo de este proyecto, hayan padecido o estuviesen en ese momento padeciendo los sujetos humanos participantes de su investigación.

Cualquier cambio al protocolo o a la metodología deberá ser revisado y aprobado por el CPSHI antes de su implantación. El CPSHI deberá ser informado de inmediato de cualquier efecto adverso o problema inesperado que surgiera con relación al riesgo de los seres humanos, de cualquier queja sobre esta investigación y de cualquier violación a la confidencialidad de los participantes.

Agradecemos su compromiso con los más altos estándares de protección de los seres humanos y le deseamos éxito en su proyecto. Queda de usted,

Atentamente,

Rosa F. Martínez Cruzado

Rosa F. Martínez Cruzado, Ph.D.
Presidente
CPSHI/IRB
UPR - RUM

Teléfono: (787) 832 - 4040 x 6277, 3807, 3808 – **Fax:** (787) 831-2085 – **Página Web:** www.uprm.edu/cpshi
Email: cpshi@uprm.edu

APPENDIX B

Student's Survey

Universidad de Puerto Rico
Recinto Universitario de Mayagüez
Departamento de Ingeniería Civil y Agrimensura

Consentimiento Informado

Estimado(a) estudiante:

Le suscribe Kenneth Vélez, estudiante graduado en Ingeniería del Departamento de Ingeniería Civil y Agrimensura del Recinto Universitario de Mayagüez (RUM). Como parte de los requisitos para completar el grado de maestría, estoy llevando a cabo una investigación la cual se titula *Identificación de Destrezas Técnicas Requeridas para los Profesionales de Ingeniería en Transportación*. El objetivo del estudio es identificar las destrezas desarrolladas por los estudiantes durante su formación académica y el interés de éstos en realizar estudios graduados, en especial en el área de Transportación. Si desea colaborar, su participación consistiría en completar un cuestionario el cual consiste de preguntas sobre sus datos demográficos e interés en la Ingeniería de Transportación.

La información obtenida a través de este estudio será mantenida bajo estricta confidencialidad y cualquier información que le identifique no será divulgada. Los cuestionarios completados estarán almacenados bajo llave y, una vez termine el estudio, los cuestionarios serán destruidos en su totalidad.

Contestar el cuestionario podría tomarle de 15 a 30 minutos y el riesgo es mínimo. Esta encuesta es totalmente voluntaria y usted tiene el derecho de negarse a contestar, dejar preguntas en blanco, descontinuar su participación o retirar el consentimiento para la participación en cualquier momento sin incurrir en penalidad alguna. Si desea copia de este consentimiento solicite el mismo al momento de someter la encuesta. De usted tener preguntas o dudas sobre los derechos de participar o sobre los resultados de la investigación se puede comunicar enviando un correo electrónico a kenneth.velez1@upr.edu o a la Dra. Ivette Cruzado (ivette.cruzado@upr.edu) o a través de teléfono al (787) 265-3815.

Atentamente,

_____
Kenneth Vélez Rodríguez

Yo _____, he leído el procedimiento
(letra de molde)
descrito en la parte superior. El investigador me ha explicado el estudio y ha contestado mis preguntas. Voluntariamente doy mi consentimiento para participar en el estudio de Kenneth Vélez.

_____	_____	_____
Firma del participante	Número de ID	Fecha

Universidad de Puerto Rico
Recinto Universitario de Mayagüez
Departamento de Ingeniería Civil y Agrimensura

Perfil del Estudiante e Interés para la Carrera Profesional en Ingeniería Civil

Número de Estudiante: _____

Datos Demográficos

1. Seleccione el género con el cual usted se siente más identificado:
   O Masculino O Femenino O Otro _____

2. Seleccione su rango de edad:
   O 15 – 19 O 20 – 24 O 25 – 29 O 30 – 34 O 35 – 49 O 50+

3. Seleccione la respuesta que describe su estado civil:
   O Soltero(a)/nunca casado(a)
   O Casado(a)/vuelto a casar
   O Convivo con alguien
   O Estoy separado(a)
   O Divorciado(a)/viudo(a)

4. Seleccione el número de niños que tiene dentro del rango:
   O 0 O 1-2 O 3-4 O 5-6 O 6+

5. Seleccione el número de créditos totales completados hasta el momento, incluyendo los generales:
   O 41 – 60 O 81 – 100 O 121 – 140
   O 61 – 80 O 101 – 120 O 141+

6. ¿Cuál es su concentración(es)?
   O Ingeniería Civil O Ambiental O Agrimensura O Otra: _____

7. Marque todos los cursos de transportación que ha completado:
   UPRM
   O INCI 4007 – Diseño y Trazado de Carreteras
   O INCI 4137 – Introducción a la Ingeniería de Transportación
   O INCI 4026 – Ingeniería de Carreteras

   PUPR
   O CE 3310 – Localización de Rutas y Diseño Geométrico
   O CE 3320 – Ingeniería de Carreteras
   O CE 3320 – Laboratorio de Carreteras e Ingeniería de Transportación
   O CE 3330 – Ingeniería de Transportación y Planificación Urbana

8. Seleccione el rango de su actual índice académico de graduación (GPA, por sus siglas en inglés):
   O 4.00 – 3.50 O 3.49 – 3.00 O 2.99 – 2.00 O 1.99 – 1.00 O 0.99 ó menor

Universidad de Puerto Rico
Recinto Universitario de Mayagüez
Departamento de Ingeniería Civil y Agrimensura

Intereses Para una Carrera Profesional

1. En una escala del 1 al 7 circule cuál es su interés en estudios graduados.

Nada interesado(a)						Muy interesado(a)
1	2	3	4	5	6	7

2. En los próximos 10 años, ¿cuál es su meta académica? Terminar o comenzar:

O Bachillerato **O** Maestría **O** Doctorado **O** Postdoctorado
O Ninguna de las anteriores

3. ***De haber marcado 1 ó 2 en la pregunta 1 no necesita contestar la siguiente pregunta ya que es sólo para las personas que estén interesadas en realizar estudios graduados. Por favor pase a la pregunta 4.***
Identifique en una escala del 1 al 5 la universidad de preferencia donde desea realizar sus estudios graduados. El número 5 será su mayor preferencia y 1 su menor preferencia.

____ UPRM
____ PUPR
____ Otra en Puerto Rico: _____
____ Otra en Estados Unidos: _____
____ Otra en el extranjero: _____

4. ¿Cuál es su área de preferencia en el área de ingeniería?
(En una escala del 1 al 3 seleccione hasta 3 opciones en orden de preferencia, donde 3 es la mayor preferencia y 1 es la menor preferencia).

_____ Biomecánica
_____ Ciencia de los Materiales en Ingeniería
_____ Ciencias de la Atmósfera
_____ Ciencias de la Tierra
_____ Ciencias e Ingeniería Computacional
_____ Geodesia
_____ Geofísica
_____ Gerencia de Proyectos
_____ Ingeniería Ambiental
_____ Ingeniería Costera
_____ Ingeniería de Construcción
_____ Ingeniería de Control
_____ Ingeniería de Terremoto
_____ Ingeniería de Transportación
_____ Ingeniería en Recursos de Agua
_____ Ingeniería Estructural
_____ Ingeniería Estructural a Nano Escala (Nanotecnología)
_____ Ingeniería Forense
_____ Ingeniería Geotécnica
_____ Ingeniería Municipal o Urbana
_____ Topografía

5. ¿Cuán interesado(a) está en estudiar ingeniería de transportación en los próximos 5 años?

Nada interesado(a)						Muy interesado(a)
1	2	3	4	5	6	7

***** SI SELECCIONÓ EN LA PASADA PREGUNTA 1 Ó 2, POR FAVOR NO CONTINÚE CONTESTANDO Y DE POR COMPLETADO ESTE CUESTIONARIO*****

Universidad de Puerto Rico
Recinto Universitario de Mayagüez
Departamento de Ingeniería Civil y Agrimensura

EN LAS SIGUIENTES DOS PREGUNTAS EVALÚE CADA PUNTO SEGÚN LA ESCALA MOSTRADA

Nivel de Interés						
Nada	**No**	**No mucho**	**Neutral**	**Regular**	**Bastante**	**Muy**
1	**2**	**3**	**4**	**5**	**6**	**7**

6. En la escala de 1 a 7 circule su preferencia de especialidad en cada una de las siguientes áreas del área en transportación.

Nada interesado(a)						Muy interesado(a)	CAMPO
1	2	3	4	5	6	7	Carga
1	2	3	4	5	6	7	Diseño Geométrico
1	2	3	4	5	6	7	Gerencia de Infraestructura
1	2	3	4	5	6	7	Ingeniería de Tráfico
1	2	3	4	5	6	7	Ingeniería Urbana
1	2	3	4	5	6	7	Pavimento
1	2	3	4	5	6	7	Planificación de Transporte
1	2	3	4	5	6	7	Sistemas de Rieles
1	2	3	4	5	6	7	Sistemas de Transporte Inteligente (ITS)
1	2	3	4	5	6	7	Transportación Colectiva
1	2	3	4	5	6	7	Transportación por Carreteras
1	2	3	4	5	6	7	Transportación Sostenible
1	2	3	4	5	6	7	Transporte Aéreo
1	2	3	4	5	6	7	Transporte Marítimo

7. En la escala de 1 a 7 circule su percepción sobre su preparación académica para especializarse en cada una de las áreas de ingeniería de transportación.

Nada preparado(a)						Muy preparado(a)	CAMPO
1	2	3	4	5	6	7	Carga
1	2	3	4	5	6	7	Diseño Geométrico
1	2	3	4	5	6	7	Gerencia de Infraestructura
1	2	3	4	5	6	7	Ingeniería de Tráfico
1	2	3	4	5	6	7	Ingeniería Urbana
1	2	3	4	5	6	7	Pavimento
1	2	3	4	5	6	7	Planificación de Transporte
1	2	3	4	5	6	7	Sistemas de Rieles
1	2	3	4	5	6	7	Sistemas de Transporte Inteligente (ITS)
1	2	3	4	5	6	7	Transportación Colectiva
1	2	3	4	5	6	7	Transportación por Carreteras
1	2	3	4	5	6	7	Transportación Sostenible
1	2	3	4	5	6	7	Transporte Aéreo
1	2	3	4	5	6	7	Transporte Marítimo

APPENDIX C

Guide Questions for Industry Interviewing

Universidad de Puerto Rico
Recinto Universitario de Mayagüez
Departamento de Ingeniería Civil y Agrimensura

Preguntas Guías para Entrevista

Empleadores de Profesionales de la Transportación

Objetivo: Identificar los conocimientos técnicos y profesionales actuales y futuros necesarios para los ingenieros de Transportación.

Empresa / Agencia de Información:

1. Empresa / Nombre de la Agencia:
   _____
2. ¿Cuáles son los servicios que presta en relación a Transportación?
   _____
   _____
3. ¿Cuántos ingenieros civiles hay actualmente en la empresa / agencia?
   _____
4. ¿Cuántos de estos ingenieros son del área de Transportación? _____
5. ¿Cuáles son los requisitos de experiencia de trabajo en general para los ingenieros del área de Transportación?
   _____
   _____
6. ¿Cuál es el número de vacantes en el área de Transportación? _____
7. ¿Qué criterio (internado, investigación, estudiar en el exterior, licencias, certificaciones, educación continua, etc.) es importante para esta empresa / agencia en la contratación de ingenieros de Transportación?
   _____
   _____
   _____

Universidad de Puerto Rico
Recinto Universitario de Mayagüez
Departamento de Ingeniería Civil y Agrimensura

Guía de preguntas:

1. De las siguientes especialidades de ingeniería civil, indique 3 que son prioridad para su agencia / empresa con el fin de satisfacer las necesidades actuales (lado izquierdo) y 3 que serían necesarias en un futuro cercano (lado derecho).

Presente	Sub-disciplina	Futuro
_____	Ciencias Atmosféricas	_____
_____	Biomecánica	_____
_____	Ingeniería Costera	_____
_____	Ciencia e Ingeniería Computacional	_____
_____	Ingeniería de Construcción	_____
_____	Ingeniería de Control	_____
_____	Ciencias de la Tierra	_____
_____	Ingeniería de Terremoto	_____
_____	Ingeniería Ambiental	_____
_____	Ingeniería Forense	_____
_____	Geodesia	_____
_____	Geofísica	_____
_____	Geotécnica	_____
_____	Ciencia e Ingeniería de Materiales	_____
_____	Ingeniería Municipal o Urbana	_____
_____	Gestión de Proyectos	_____
_____	Ingeniería Estructural	_____
_____	Ingeniería Estructural en Nano Escala (Nanotecnología)	_____
_____	Topografía	_____
_____	Ingeniería de Transportación	_____
_____	Ingeniería de Recursos de Agua	_____

2. Por favor, indique cuál de las siguientes áreas de transportación son prioritarias para su agencia / empresa con el fin de satisfacer las necesidades actuales y futuras.

Presente	Sub-disciplina	Futuro
O	Ingeniería de tráfico	O
O	Diseño geométrico	O
O	Transportación colectiva	O
O	Transportación sostenible	O
O	Sistemas de Transportación Inteligente	O
O	Pavimentos	O
O	Carga	O
O	Transportación marítima	O
O	Transportación aérea	O
O	Sistema de rieles	O
O	Transportación por carreteras	O
O	Manejo de infraestructura	O
O	Planificación de transportación	O
O	Ingeniería urbana	O

3. Por favor circule para cada una de las destrezas a continuación, en una escala de 1 a 7, donde 7 es el más importante y 1 es el menos importante, el peso de relevancia para su empresa/agencia. De estas destrezas, indique las 5 necesidades máximas en su empresa / agencia. Para las cinco necesidades seleccionadas, indique a qué nivel profesional son necesarias (Entrada - **E**, Medio - **M**, Superior - **S**).

Destreza	Peso de relevancia	*Necesidad*	Nivel
Manejo del Español	[1 2 3 4 5 6 7]	____	_____
Manejo del Inglés	[1 2 3 4 5 6 7]	____	_____
Destrezas orales	[1 2 3 4 5 6 7]	____	_____
Destrezas escritas	[1 2 3 4 5 6 7]	____	_____
Destrezas de lectura	[1 2 3 4 5 6 7]	____	_____
Interpretación	[1 2 3 4 5 6 7]	____	_____
Destrezas técnicas	[1 2 3 4 5 6 7]	____	_____
Destrezas de pensamiento	[1 2 3 4 5 6 7]	____	_____
Destrezas de trabajo	[1 2 3 4 5 6 7]	____	_____
Destrezas de comunicación	[1 2 3 4 5 6 7]	____	_____
Destrezas de grupo	[1 2 3 4 5 6 7]	____	_____
Manejo de la computadora	[1 2 3 4 5 6 7]	____	_____

4. ¿Esta agencia / empresa cuenta con factores ambientales que pueden afectar la comunicación con los ingenieros del área de Transportación?

   _____
   _____

5. ¿Podría mencionar algunos de los proyectos en los que su empresa/agencia ha aplicado sostenibilidad, peatonalización, planificación, eco-amigable, o la integración de proyectos de transporte?

   _____
   _____

6. ¿Qué tipo de adaptación o cambio usted cree que se necesita en la educación del área de Transportación para que esta esté en acorde acuerdo con la profesión actual, como por ejemplo en la parte tecnológica?

   _____
   _____

7. ¿Cuáles son las futuras habilidades técnicas que usted espera de los ingenieros de Transportación en los próximos 5 años?

   _____
   _____

8. ¿En qué usted cree que se deben enfocar los cursos de ingeniería en Transportación con el fin de proporcionar mejores profesionales que cumplan con las necesidades de su empresa / agencia?

   _____
   _____

9. ¿Cuán importante considera usted las alianzas entre el mundo académico y su agencia/empresa de manera que preparen mejores profesionales del transporte?

   _____
   _____