SUSTAINABLE DEVELOPMENT AND TRANSPORTATION DECISION MAKING: EMBEDDING COMMUNITY PREFERENCES IN VISUALIZATIONS

by

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ABSTRACT

Transportation systems play a vital role in the development and prosperity of human beings, but can also negatively affect the environment and society, particularly if the interests of communities are disregarded. To advance Public Involvement in the transportation project development processes, a participatory decision-making technique focused on early public participation and the use visualizations was studied. A corridor located in the community of "Dulces Labios" in Mayaguez, Puerto Rico was used as case study for a hypothetical redevelopment project. Design criteria were selected from the literature, ranked based on public preferences, and translated into five fly-through animations. Finally, the visualizations were presented to the public for feedback. The results demonstrated that the visualizations were highly effective to embody and convey the original preferences, and are easy for people to understand and to discuss, empowering the whole process of public involvement.

Resumen

Los sistemas de transporte desempeñan un papel importante en el desarrollo y la prosperidad del ser humano. Esta interrelación trae consigo una expansión constante de la infraestructura y servicios que, a su vez, generan consecuencias negativas sobre grupos minoritarios. La presente tesis constituye un esfuerzo para alcanzar niveles de participación ciudadana más efectivos durante la evaluación de proyectos de inversión pública. La metodología propuesta se basa en la participación del público desde una etapa temprana en el ciclo de vida del proyecto, así como en la comunicación de las ideas de diseño a través de visualizaciones. El proceso incluyó la elaboración de una lista de criterios, la jerarquización de los mismos en base a las preferencias del público, y el diseño y evaluación de las visualizaciones del proyecto. La reconstrucción hipotética de un corredor vial ubicado en la comunidad de "Dulces Labios" en Mayagüez, Puerto Rico, es utilizado como caso de estudio y se generaron diferentes alternativas de diseño. Los resultados demuestran que las visualizaciones son un medio efectivo para la comunicación de las preferencias de diseño en un econtexto de toma de decisiones participativa. El proceso a su vez resultó fácil de entender y fue bien recibido por el público generando mejores niveles de discusión con respecto a las alternativas y por ende un mejor ámbito para la toma de decisiones participativas.

I would like to dedicate this thesis…

To God,

To my mother, Carmen Hurtado Atayupanqui and my father, Hilario Chacón Chávez for being model examples of determination in life,

and to my sister, Vanesa Chacón Hurtado, for being my greatest friend and tireless supporter.

To Yarelí,

To my friends in Puerto Rico, Katia, Carlos, Marianna, Omar, Joan, Ollantay, Karen, Sofia, Oscar, Ulises, Karenly, Erika, Jairo, Andres, Yaileen, Dafne and many others … who have become a family, and especially to Ana Aparicio who has taught me the priceless value of friendship.

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List of Acronyms

AHP	Analytical Hierarchy Process
AIJ	Aggregation of Individual Judgments
AIP	Aggregation of Individual Priorities
AMIS	Analytic Minimum Impedance Surface
ARRA	American Recovery and Reinvestment Act
AT	Appropriate Technology
AVI	Audio Video Interleave
CAVE	Case wise Visual Evaluation
CI	Consistency Index
CR	Consistency Ratio
CSD	Context Sensitive Design
CSS	Context Sensitive Solutions
D.A.D.	"Decide, Announce, Defend" approach
DTPW	Department of Transportation and Public Works of Puerto Rico
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
GDM	Group Decision Making
GDP	Gross Domestic Product
GLM	General Linear Models
HUD	United States Department of Housing and Urban Development
ISTEA	Intermodal Surface Transportation Efficiency Act
MPOs	Metropolitan Planning Organizations
NEPA	National Environmental Policy Act
OECD	Organization for Economic Co-operation and Development
PC	Personal computer
PM	Performance measures
PPGIS	Public Participatory GIS
SAFETEA-LU	Safe, efficient Transportation Equity Act: A Legacy for Users
SD	Sustainable Development
ST	Sustainable Transportation
TEA-21	Transportation Equity Act for the 21st Century
USDOT	United States Department of Transportation
VIF	Variance Inflation Factors

1 INTRODUCTION

The prosperity and well-being of people, for both developed and developing countries, are influenced by a reciprocal relationship between the economic growth and transportation. The transportation sector constitutes the backbone of global economy (World Bank, 2011). For example, transportation accounts for 10 to 12% of the Gross Domestic Product (GDP) of the United States (RITA, 2012). However, the increasing demand and supply of transportation infrastructure and operations also brings great pressure on the environment and society. The transportation sector accounts for nearly 30% of the global air pollution and greenhouse gases (CEE, 2011). In addition, transportation systems in many countries fail to resolve the issues of mobility, accessibility, and safety (Stanley and Lucas, 2013; Toleman and Rose, 2008).

Among transportation agencies, there is an increasing emphasis on the concept of sustainability (Toleman and Rose, 2008). Along with other sustainable development components, social aspects have been integrated as a principle of transportation agencies (Jeon and Amekudzi, 2005). In fact, many transportation agencies, such as the Department of Transportation and Public Works of Puerto Rico, have assimilated the three components of sustainability (social wellbeing, economic development, and environment protection) into their visions.

One important sustainability component is Public Involvement, with many agencies recognizing it as a vital component along the different stages of a project's development; especially on the early stages. However, many situations can be found in which, even with the commitment to improve social conditions and to accomplish mandates of public input, the interests of communities, environment, and economic development are incongruent. Thus, the requirements defined by the literature for Sustainable Development (SD) and Appropriate Technology (AT) are not satisfied. Currently, the literature presents many efforts at different levels and locations in order to reach sustainable transportation systems. Nevertheless, the integration of public involvement remains very challenging for the transportation community (FHWA 1996). The literature presents the existence of a gap between awareness and action on public involvement (Bailey et al., 2011; Sheppard, 2006).

Methodologies and techniques for Public Involvement range from face-to-face interviews to virtual reality (FHWA 1996; Environment Canada 2008). At the present time, technology allows the exploration of new approaches and techniques (Bailey et al., 2007; Grossardt et al., 2001) that are changing the communication processes (Center for Computational Research, 2009). However; the application of enhanced techniques are still limited to some context and conditions and its implementation requires further research.

This research explores visualizations as a tool for participatory public involvement. Visualizations constitute an alternative to convey design aspects in an easy and effective way (Hixon III, 2006). Visuals are constructed based on the expression of the community members' preferences with respect to predefined criteria. This research study was developed in four stages: the selection of design criteria based on Sustainable Transportation indicators, the hierarchization of grouped indicators, the generation of 3-D fly-through roadway design visualizations based on the grouped indicators, and the presentation of the visualizations to the community in order to get their opinions and feedback. The study does not intend to establish a list of criteria to be used in the generation of project alternatives; rather, it intends to explore the use of visualizations of conjoint features in reflecting community preferences. This research employed a hypothetical redevelopment of a roadway segment of highway PR-102, located next to the community of “Dulces Labios” in the Municipality of Mayagüez, Puerto Rico, as a case study for using public participation and identifying the community preferences.

1.1 Motivation

Public involvement is an indispensable component of any infrastructure project initiative. It has been part of the transportation decision-making process for various decades, but it has taken a greater importance recently. Emerging concepts such as “Sustainability”, “Context Sensitive Design”, and “Appropriate Technology” have contributed to this effort. These concepts provide principles, fundamentals, and guidelines for the development of projects that are in harmony with the surroundings, including physical elements as well as cultural and socio-economic aspects. The consideration of these concepts, at the governmental and non-governmental levels, have resulted in new perspectives about the visions and missions of agencies, and more importantly, in a shift in the role of professionals.

Still, there is evidence that these “well-known” principles are superseded by incompatible priorities. In fact, many of the principles imparted by these approaches are more discussed in theory rather than put into practice. This phenomenon has been mentioned in literature of diverse areas of study. The author believes that one of the main difficulties of changing traditional procedures and paradigms of public involvement is the lack of “ready-for-implementation" techniques for practitioners. In the realm of public involvement a common way to incorporate public input is thought Public Hearings, but in many cases, the results are insufficient. Public Hearings might not reach key stakeholders who are not be able to attend the meetings due to limitation in time and resources, or simply because they may feel intimated by the process. Nevertheless, their opinions and needs remain valid and important. The latter may cause conflict of interest when stakeholders become involved at the end of the project development process when most design decisions have already been made. As a result, many well-intended efforts are abandoned resulting in wasted time and resources, and more importantly, the credibility and legitimacy of decisions are diminished. Many practitioners lack an adequate background or education to allow them to confront the endeavor of community involvement, and challenging situations such as community opposition. Thus, new techniques and methodologies to assist transportation professionals in the early stages of a project development are needed.

The motivation of this study is to contribute to the state of the art for public involvement techniques while exploring a different approach. Unlike the traditional approach (such as the D.A.D. explained in Chapter 2), particular emphasis was given to the early involvement and customized design trying to incorporate recommendations of CSD/CSS, AT, and SD. The author believes this initiative could serve as a benchmark for future roadway projects in Puerto Rico and other regions, by integrating community values and needs as an important input in the decision making process. The author also restates the importance of engineering practices in community well-being, which constitutes the ultimate goal and the reason to be of engineering. Finally, this study also aims to constitute a potential source for the development of new knowledge in the realm of public involvement.

1.2 Objectives

This study looks to advance the process of participatory decision making processes for transportation projects. A different approach that promotes early involvement of stakeholders and the use of visualizations as a mean of communication is presented. The specific objectives of the study are:

- Establishment of a participatory decision-making approach
- Evaluate the effectiveness of visualizations as a tool for public involvement

1.3 Expected Benefits

This thesis contributes to bridging the gap between theory and practice in the realm of sustainable transportation and public involvement. The approach to include public input from the *inception* of the design idea, and to communicate with the public through visualizations is very appealing for practitioners, researches, and the public. Additionally, the early public involvement through visualization approach demonstrated in this project could initiate a change in future preferred practices. However, further details and strategies may be required for future implementations. This, in turn, might create opportunities for additional research and case study developments. The implementation of an appropriate public involvement approach is very challenging and raises many questions that go beyond the scope of the thesis. For example, the strategies to reach adequate levels of public engagement, the standards for visualizations design, the tradeoffs analysis among design alternatives, and how to ensure the appropriateness of designs in time and community context. Although this thesis does not aim to answer these questions, it does lay the foundation for answering them thought interdisciplinary approaches. This research could also serve as a ready-to-practice example for projects in similar contexts, particularly in Puerto Rico.

1.4 Organization of Thesis

This thesis is composed of seven chapters. Chapter 2 present the literature review performed for the thesis describing the main topics that are needed to understand and interpret the intention of the study. Concepts of sustainable development, appropriate technology and Context Sensitive Design are briefly explained. Also, an overview of public involvement and available techniques is presented in the chapter, ending with the presentation of the concept of visualizations as a tool for public involvement.

Chapter 3 outlines the methodology followed in the present study. It also explains the context where the case study is developed. Chapter 4 analyses in detail the process of selecting the design criteria. It also includes the process of hierarchyzation and the final criteria output. Finally, the chapter discusses the relationships found between ODDs of selecting a criterion as important for the transportation project design process and the explanatory variables gathered in a survey by interpreting the results of a Logistic regression.

Chapter 5 explains the procedure followed for the construction of the PR-102 roadway design visualizations. Subsequently, the visual preference questionnaire made in the Dulces Labios community is described, and the results of the study are presented.

Chapter 6 presents the conclusions of the study, summarizing the main findings, with an explanation of the learning and reflections about the present study, and possible future research studies. Finally, Chapter 7 corresponds to the appendixes.

2 THEORETICAL BACKGROUND

2.1 Sustainable Development

The widely acknowledged definition of Sustainable Development (SD) was expressed in 1987 by the United Nations Commission presided over by Gro Harlem Brundtland. The commission's report, published by the Oxford University Press, defined SD as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 8). This definition encompasses two key factors: the concept of *needs* and the idea of *limitations* (CEE, 2011), that were also considered in earlier definitions (Du Pisani, 2006). The Brundlant definition implicitly established links with current global issues such as poverty, equity, environmental quality, overpopulation, and many others (Heijungs et al., 2010).

These issues can be framed in different ways. One approach is the "triple P" or P3: People, Planet, and Profit or Prosperity (Heijungs et al., 2010). The United Nations in 1992 stated that the objectives of SD are based on the consideration of the three aspects: Environment, Economy, and Social Prosperity or Social Well-being (United Nations Division for Sustainable Development, 1992) (FIGURE 1).

These considerations, also known as the *three pillars* of SD, are graphically represented using columns of a structure with three pillars in parallel giving the idea of three independent concerns. Another representation that differs the common notion of elements in parallel, considers a nested hierarchy of concentric circles where the environment or natural systems provide the resources and services (life-support) that are essential for the well-functioning of human systems (social systems), which in turn is critical for the productivity of economic systems (CEE, 2011) (FIGURE 2). These definitions of SD are still ambiguous because of the broad aspects and complex relationships between dimensions that should be taken into account (Mori and Christodoulou, 2010; Parris and Kates, 2003), especially when many of them lead to divergent conclusions. The definition of SD proposed in 1987 could be seen as anthropocentric (Méndez and Piaggio, 2007) which is also reflected in the Principle 1 of the Rio Declaration of 1992 stated that "Human beings are at the center of concerns for sustainable development" (UN Division for Sustainable Development 1992).

Among the different concepts and definitions of SD, the Board on Sustainable Development of the National Research Council (1999) recognized key differences regarding to the emphasis given to what is to be sustained, what is to be developed, the links between these entities, and the period of time envisioned. These aspects are summarized in what is entitled the "Taxonomy of Sustainable Development Goals" (Parris and Kates, 2003), shown in Table 1. Regarding to what is to be sustained, Nature, Life Support and Community are the main categories. The first one aims to preserved nature because of its intrinsic riches, as is Biodiversity and Ecosystems. On the other hand, an anthropocentric view of life consider the nature as the support of life, where the most important life to be supported is human (Board on Sustainable Development, National Research Council, 1999). The nature is seen as a source of resources that should be kept, the nature is the Environment and the features are the Ecosystem services. Similar to the conservations of biological species, cultural species should also be conserved, and constitute the third category. Regarding to what is to be developed; most emphasis is given to economy, which provides employment, earning and consumption. It also supports the financing for environmental maintenance. The other two categories are referred in terms of “quantity” and “quality” of life for humans and Society respectively. The fisrt one includes for example, survival of children, education, and life expectancy. The second one includes well-being and social ties and community organizations (social capital) (Board on Sustainable Development, National Research Council, 1999).

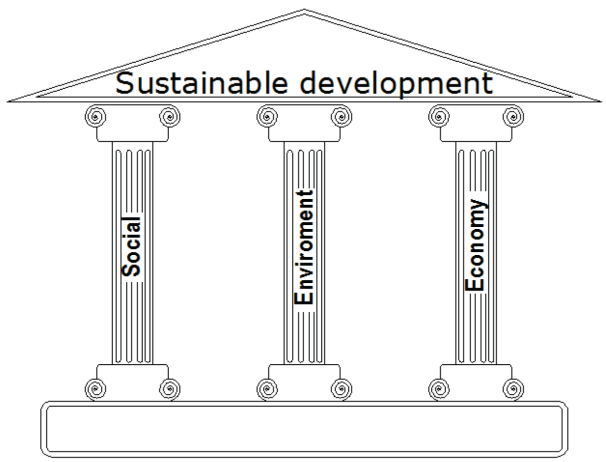

FIGURE 1 Three pillars of sustainability (Heijungs et al. 2010).

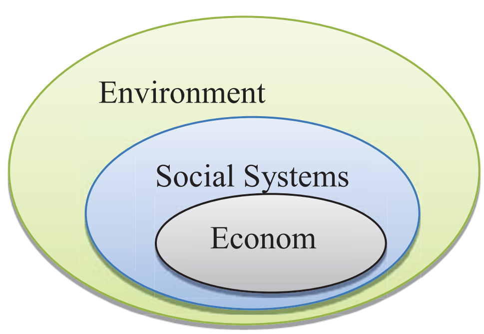

FIGURE 2 Dimensions of sustainability (CEE 2011).

The relationship between what is to be sustained and what is to be developed implies a degree of negotiations and tradeoffs. A common relationship is to sustain the environment while developing the economy and society. However, this is only one way of envisioning this links. Finally scope in time of this relationship should be also considered, since the value of sustainable development relies on its intergenerational scope. Even though the time period stated by the Bruntland commission is widely accepted *(now and the future*), almost any kind of developments seems to be sustainable within a short period of time, but if maintained for a long period of time those developments might become unsustainable (Board on Sustainable Development, National Research Council, 1999).

TABLE 1 Taxonomy of Sustainable Development Goals (Parris & Kates 2003)

What is to be sustained	What is to be developed
Nature	People
Earth	Child survival
Biodiversity	Life expectancy
Ecosystems	Education
	Equity
	Equal opportunity
Life support	Economy
Ecosystem services	Wealth
Resources	Productive sectors
Environment	Consumption
Community	Society
Cultures	Institutions
Groups	Social capital
Places	States, Regions

2.1.1 Sustainable Transportation

Sustainable Transportation (ST) has also various definitions, but most address the following issues: mobility, accessibility, safety, ecosystem health, limited emissions, renewable resources, economic growth, and alternative modes, among others. This broad spectrum of ST components is sometimes taken narrowly (Litman, 2007), and as with SD in general, ST is advocated to some specific aspects, e.g. reduction of air pollution, but without capturing the comprehensive impact on all dimensions of sustainability (Jeon et al., 2010). A holistic analysis can explore connections among issues and opportunities (Litman, 2007).

The Organization for Economic Co-operation and Development OECD (1997) mentioned that "the expression of sustainable development within the transportation sector" is Sustainable Transportation. OECD defined, in turn, the term environmentally sustainable transport as:

"*Transportation that does not endanger public health or ecosystems and meets mobility needs consistent with the use of renewable resources at below their rates of regeneration and the use of non-renewable resources at below the rates of development of renewable substitutes*" (OECD, 1996)

Another definition of ST is provided by the Centre of Sustainable Transportation (as cited by Black 2005), which is accepted by other experts (see Jeon 2010; Oswald & McNeil 2010; Litman 2007; Jeon & Amekudzi 2005; EPA 2011), stating that:

"a sustainable transportation system is one that a) allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and

ecosystem health, and with equity within and between generations; b) is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy; and c) limits emissions and waste within the planet's ability to absorb them, minimizes consumption of nonrenewable resources, reuses and recycles its components, and minimizes the use of land and the production of noise"

According to Amekudzi et al. (2011), important efforts have been taken to promote and pace the incorporation of sustainability into the transportation policy in the US. For instance, the Transit Investments for Greenhouse Gas and Energy Reduction grant program, which is part of the American Recovery and Reinvestment Act (ARRA), and the Livable Communities Partnership (EPA, USDOT, HUD) and the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). The latter mandates environmental streamlining and stewardship.

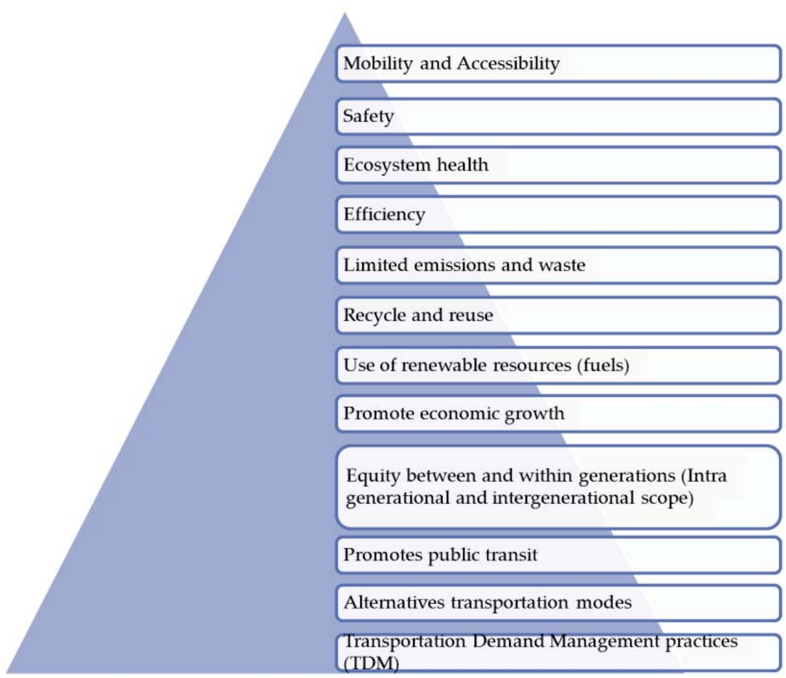

FIGURE 3 Components of sustainable transportation.

The Department of Transportation and Public Works of Puerto Rico (DTPW), as the governing agency , inherently establishes into its mission several of the ST components shown in FIGURE 3. Its mission is as follows: “Drive economic development in Puerto Rico by providing an efficient, safe and environmentally responsible transportation system and by providing innovative and exceptional service” (Translated from DTOP 2010). However, no particular information was found about the initiatives or strategies taken for the execution of this mission is unavailable or at least not aparent requirements of sustainability. On the other hand, other agencies have developed their own system to measure sustainability thought rating systems. For instance, the New York’s DOT presents the “GreenLITES” system and the FHWA presents the “INVEST” system.

2.1.2 SD indicators and performance measures

An important step in the evaluation of transportation systems is the identification of a mechanism that quantifies the degree in which an objective or goal, e.g., reduction of water pollution, is being achieved. According to Sinha and Labi, “performance measures (PM) represent, in quantitative and qualitative terms, the extent to which a specific function is executed” (Sinha and Labi, 2007, p. 21). PM’s are necessary to evaluate the effectiveness of a system, organization, or effort in relation to a set objective (Falcocchio, 2004; Organisation for Economic Co-operation and Development, 2001), therefore can directly influence the design criteria to be considered. They become the basis to define our criteria to evaluate an alternative with regard to the accomplishment of a specific objective and to determine whether to proceed or find another alternative (Ramani et al., 2012). The process of selecting

PMs is a key step to ensure that they reflect the goals and objectives of all stakeholders. These become especially useful when applying new approaches such as Context Sensitive Solutions (CSS).

Falcocchio (2004) classified the PMs in three types: input, output, and outcomes. Input PMs are related with the resources assigned to an initiative. Output PMs are associated to the "products" provided by the system, e.g., bike lanes added to a transportation network. Outcome PMs are used to describe consequences of the outputs, e.g., the number of bike lane users or reduction in car ridership because of the bike lanes. Additionally PMs can be classified as natural or constructed, direct (outcomes) or indirect (outcomes) (Falcocchio, 2004; Winterfeldt, 2000). Natural PMs can be applied directly to a feature, e.g., total length of bike lanes added, meanwhile, constructed PMs are elaborated to measure some specific characteristic such as level of public acceptance using a scale from 0 to 9, or based on other natural PMs, such as the index of expected reduction in car ridership per bike lane added to the system. The direct and indirect PMs are associated with an "end" objective and "means" objective.

According to Falcocchio (Falcocchio, 2004), the implementation of an action has to be evaluated from different points of view called scenarios or domains. Domains are a group of factors that need to be considered in the evaluation of a system, and consequently in setting the performance measures (FIGURE 4). This adds complexity to the simple fact of having different stakeholders, because each interested group might have a different perspective over the same domain. This fact was also mentioned by Sinha & Labi (2007), as shown in TABLE 2.

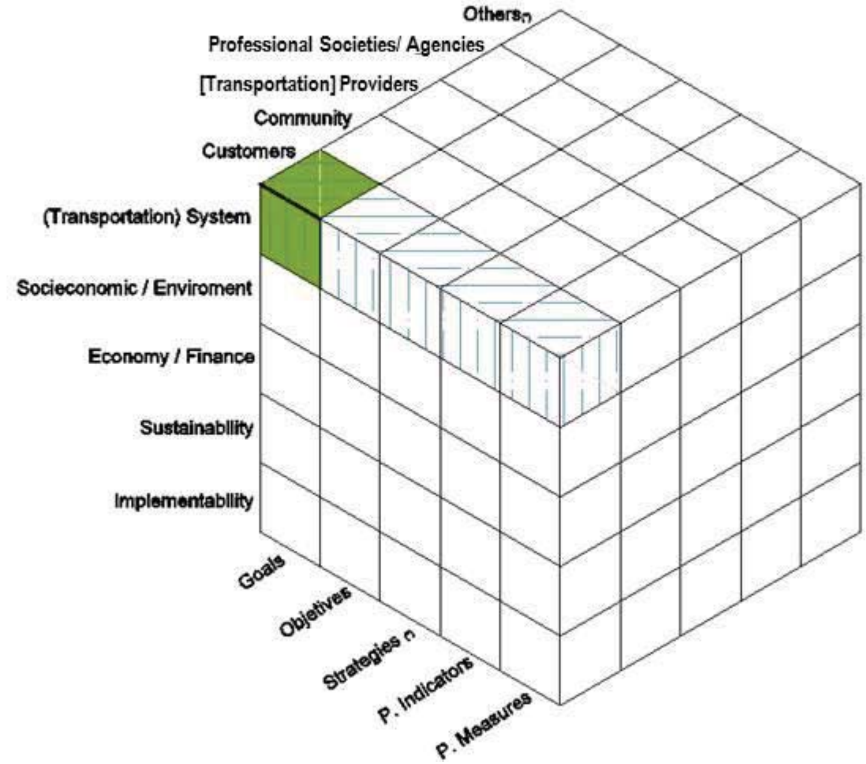

FIGURE 4 Organizing framework for analysis of transportation Performance Indicators [PI] and Performance Measures [PM] (Falcocchio 2004).

TABLE 2 Suggested Relationships Between Project Impact Categories and Dimensions. Adapted from Sinha & Labi (2007)

Impact Category	Parties that are directly concerned or affected											
	Users			Community			Agency / Operator			Governmental		
Technical Scope of the evaluation	ST	MT	LT	ST	MT	LT	ST	MT	LT	ST	MT	LT
Technical (Operational effectiveness and System preservation)	P	P	P				P	P	P			
Environmental				P,C	C,R	C,R				C,R	C,R	C,R
Economic efficiency	P	P	P				P	P	P			
Economic development				C,R,N		P,C				C	C,R	C,R,N
Safety and security	P	P	P	P,C	P,C	P,C	P,C	P,C	P,C	C	C,R	C,R
Quality of life / sociocultural				P	P,C	P,C,R						

ST: Short term, MT: Medium term, LT: Long term, C: Corridor, P: Project, R: Regional, N: National or global

The establishment of PMs for the evaluation of impacts of transportation systems has also been a concern of the government, in that sense, as part of the Intermodal Surface Transportation Efficiency Act (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21), it is encouraged and, under some circumstances required, the development of systems focused in performance. Nevertheless, very few Metropolitan Planning Organizations (MPOs) capture the comprehensive impact of transportation systems and land use changes on the economy, environment, and social quality of life, which are commonly considered the essential three dimensions of sustainable transportation systems (Jeon et al. 2010).

For the purpose of this study, the importance of the Indicators and Performance Measures is that they become the basis to define our criteria to evaluate an alternative with regard to the accomplishment of a specific objective. Ramani et al. (2012) as part of the NCHRP Report 708, state that PMs "Help evaluate, compare, prioritize, and select among alternatives and options in terms of sustainability considerations and determine whether to proceed with a proposed action or to select among alternatives". These criteria can be used for both the traditional development of projects and for new approaches such as the Context Sensitive Solutions (CSS) from the Federal Highway Administration.

2.2 Appropriate Technology

The concept of appropriate technology (AT) was first introduced by economist Ernst Friedrich Schumacher in the 1960's. The concept was promoted at a conference in the

University of Oxford in 1968, and became popular with the publication of the book "Small is Beautiful: A Study of Economics as if People Mattered" in 1973. In this book the term "appropriate technology" is used interchangeably with intermediate technology (i.e. technology that intermediates between innate and modern technology) (Frey et al., 2012; Willoughby, 1990).

AT is difficult to define and its development and implementation have generated debate (Tharakan, 2010). According to Willoughby (1990), as many interested groups and individuals at different levels and with different objectives used the term, its usage becomes loose and confusing. The same author cites applications that range from philosophical definitions and ideologies to technical hardware and even anti-technology activities. There are two basic approaches to defining AT: the general-principles approach and the specific characteristic approach. The first one states formal and broad definitions of what AT is, while emphasizing appropriateness to a given context However, it is criticized by its vagueness and lack of criteria and parameters. The second approach, more than a concept, gives a normative an empirical statement. It adds operational criteria and functionality to the definition (Willoughby, 1990). This thesis adopts a definition that belongs to the first approach:

"[Appropriate Technology is] technology tailored to fit the psychosocial and biophysical context prevailing in a particular location and period" (Willoughby, 1990, p. 15).

The term AT has two parts. The first refers to technology per se, and according to (Practical Action, 2012) is sometimes wrongly interpreted as only some kind of physical tool or hardware. However, it also involves techniques, methodologies, skills, products and goods, and organization of processes, among others. The first technologies (fire, club, and spear) were developed to satisfy the basic needs of people and to ensure their survival (Tharakan, 2008). In fact, traditional technologies (e.g., fishing, cooking) show a high degree of consistency across societies (Practical Action, 2012). This human-technology relationship has been evolving in a complex loop, where advances in technology stimulate development in society and the latter leads to advances in technology (e.g., the technological advances in agriculture, the industrial revolution, and the generation of new technologies in other areas such as transport(Practical Action, 2012). In current contexts, the discussion of strategies for economic development and public policy at different level relies critically on technology (Edoho, n.d.). However, despite broad advances in technology, many people do not show such levels of development (e.g., 1.3 billion people do not have access to electricity, i.e. one out of five people globally). Moreover, some (underlying) assumptions of the traditional human-technology relationship are considerably debated. The notion that the needs and socioeconomic difficulties are similar in all countries, both developed and developing, and can therefore be addressed with the same strategies (production and management technologies) is questioned (Castro-Sitiriche et al., 2012; Edoho, n.d.). This is also known as the "Modernization theory". In this theory, it is supposed that simple introduction of (northern) technology, regardless of the local circumstances, will automatically lead to development to (southern) countries (Practical Action, 2012).

In this framework, the term "appropriate" gives the first notion that there should be an awareness that countries are subject to different constrains and that there exists uniqueness. Since the perspective of the general-principles approach, the term appropriate means that something (technology) is suitable, proper or applicable to a specific end or purpose (dictionary definitions as cited by (Willoughby, 1990). Technology that does not take into account socio cultural, and economic circumstances is certain to fail (Practical Action, 2012). Moreover, even a technology might be appropriate to a specific need, the local skills of recipients and infrastructure may not be ready to house that technology (Edoho, n.d.). However, the intention in the term seems to be incomplete since it does not imply what is appropriate for. Then, technology could be appropriate for "something", regardless of the possible absurdity of the "something" (Willoughby, 1990). This thesis considers that a technology will be appropriate if it "advances the well-being and flourishing of the community" (Castro-Sitiriche et al., 2012, p. 2).

There are many terms and concepts related to AT (Castro-Sitiriche et al., 2012; Willoughby, 1990) including: alternative technology, community technology, soft technology, humanized technology, humanitarian engineering, peace engineering, and engineering to help, among others. Each term or concept reflects a particular point of view and incorporate aspects from other disciplines.

The characteristic of Appropriate Technology (AT) can be enclosed in standard principles developed through decades of discussion about what constitutes AT (Frey et al., 2012; Tharakan, 2010), these principles are:

- Context consideration: meaning accordance with the social, cultural, and economic circumstances (Practical Action, 2012). Addressed itself to unique characteristics of the surrounding community. This is also known as Aptness (Edoho, n.d.).

- Simplicity and employs labor in intensive rather that capital intensive. (Edoho, n.d.)also denominates Scale, meaning that technology is small and rural based.
- Decentralization in context and time. (Edoho, n.d.) denominated to this sustainability.

AT is also criticized. (Frey et al., 2012; Willoughby, 1990) mention that since AT is open to different interpretations, they are not adequately evaluated and may be disused, they may not be affordable for every people. It is also argued that any group could adopt the rhetoric of AT without really practicing. Emmanuel (as cited by(Edoho, n.d.) considers that AT is an "impoverished" technology that will keep developing countries as underdeveloped. In the same vain, DeGregory (as cited by (Edoho, n.d.) states that technology cannot be either appropriate or inappropriate. This researcher claims that technology runs its own evolutionary course and that the AT seems to be a retreat from science and technology. Also, regarding to the characteristics of AT showed above, Terpstra and Davis (as cited by (Edoho, n.d.) state that regardless of the source, complexity or scale technology is appropriate if it is environmentally feasible, stable, and resilient, and open to revision.

The assessment of technology being appropriate raises the issue about the socio-technical systems in societies. Socio-technical systems (STS) include institutions, facilities and organized knowledge (science and technology brainpower, e.g., engineers, scientifics, technologists, managers, etc.) in society. It includes the interactions and networks of relationships among them (Edoho, n.d.; Frey et al., 2012). STS can be divided into components that reflect local values and that are essential one to each other. Adequate understanding of the STS is prerequisite for the success Appropriate Technology.

Besides the compatibility of technology and the socio-technical systems, AT furthers the dictionary definition by considering the development of the community (i.e. for what technology is appropriate). This is related to the capabilities approach introduced by Amatyta and Martha Nussbaun (Frey et al., 2012). In this approach, the leading goals for project development are not to address the needs, desires of the community, but rather the leading goals focus on the capabilities of people (i.e. “What is this person able to do or be?) (Nussbaum as cited by (Frey et al., 2012) to transform them into active and functioning. Castro and Papadopoulos (as cited by (Frey et al., 2012) gave an example that the increase in supply of electricity (technology) could improve affiliation (capability) between the members of a community. It provides illumination in the evenings (conversion factor) that furthers the opportunities for social activities and interaction between those members (real functioning).

2.3 Context Sensitive Design (CSD) /Context Sensitive Solutions (CSS)

CSS is defined as:

“Collaborative, interdisciplinary approach that involves all stakeholders in providing a transportation facility that fits its setting. It is an approach that leads to preserving and enhancing scenic, aesthetic, historic, community, and environmental resources, while improving or maintaining safety, mobility, and infrastructure conditions” (CTE, 2007)

CSS does not constitute a novel approach. In fact, its core principles were already known by many transportation professionals back in the 1960’s and 1970’s (CEE, 2013). Nevertheless, the 1969 NEPA Act constitutes the first milestone for CSS by providing federal mandate of its main principles. Subsequent legislation and guidelines continued to lay down the foundation of CSS, including: ISTEA in 1991, FHWA Environmental Policy statement in 1994, National Highway System Designation Act in 1995, TEA-21, and the FHWA Flexibility in Highway Design guide in 1998. The workshop "Thinking Beyond the Pavement: National Workshop on Integrating Highway Development with Communities and the Environment while Maintaining Safety and Performance", hosted by the Maryland DOT in 1998, provided the first definition of CSS and identified the qualities for excellence in design and the main barriers for implementation. CSS was later reinforced by the Executive Order 13274 that promotes environmental stewardship, and by SAFETEA-LU that authorized DOT's to take into account CSS. Currently, MAP-21 states that CSS "will continue to involve structuring a planning, design, and implementation process that is collaborative and creates consensus among stakeholders and the transportation agency" (Moore, 2012).

The "traditional" way in which projects are developed comprises a three-step process, as shown in FIGURE 5. This process is known as the "Decide, Announce, Defend" approach (D.A.D.) (ICF International et al., 2009). The D.A.D. approach implies that the projects are developed by a technical group, typically experts and officials in the government. Moreover, these experts and officials often do not coordinate or consult with each other sufficiently about design aspects, taking separate decisions from each specialized area. Subsequently, the final design is presented to the public for consideration; nevertheless, most of the primary project decisions have been already made (FHWA, 2009).

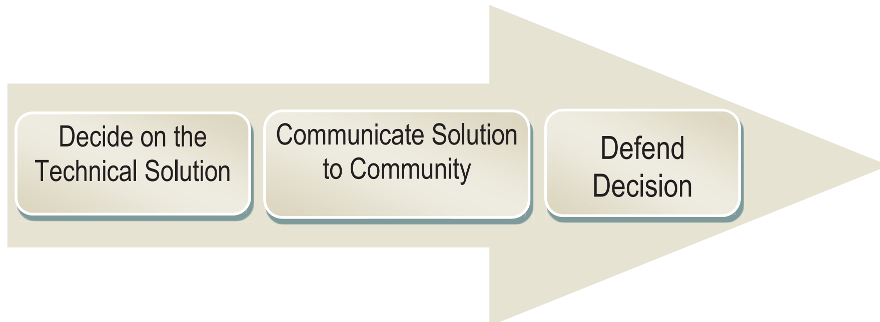

FIGURE 5 The D.A.D. approach (FHWA 2009)

In the traditional approach the level of public involvement increases with the advancement of the project. At the initial stages public participation is very scarce and thus most of the project-related issues remain undiscovered until the NEPA process is performed. As more information about the project becomes available, more people become aware and the unattended issues become prominent. This could result on project delays or even cancellations. In either case, time and resources are wasted (ICF International et al., 2009).

On the other hand, in the CSS approach the issues to be addressed arise very early in the project development process. By involving a broader range of stakeholders and investing more time in the problem definition, better alternatives can be proposed. CSS relies in a series of incremental decisions that address stakeholders' priorities and values, rather than one unique decision (ICF International et al., 2009). In this effort, transportation officials have been looking to solve transportation issues taking into consideration economic and environmental goals, which require working collaboratively with public (FHWA, 2009). These three aspects also constitute the pillars of Sustainability. FIGURE 6 shows the process of selecting the recommended alternative for both the D.A.D. and CSS approaches. In the

D.A.D. approach the selection is done under a high degree of uncertainty because of the existence of many unaddressed issues and concerns. Meanwhile, in the CSS approach the selection of the alternative occurs after many of the issues and concerns have been already considered. Additionally, the CSS approach considers a range of options or alternatives that could be extended beyond the transportation problem itself (FHWA, 2009).

CSS is guided by four core principles or strategies (FHWA, 2005):

- Strive towards a shared stakeholder vision to provide a basis for decisions.
- Demonstrate a comprehensive understanding of contexts.
- Foster continuing communication and collaboration to achieve consensus.
- Exercise flexibility and creativity to shape effective transportation solutions, while preserving and enhancing community and natural environments.

Additionally, The FHWA (FHWA, 2009) mentions twelve characteristics of the CCS process. One of them is related to the scope of this study stating that: “Full range of communication and visualization tools are used to engage stakeholders.”

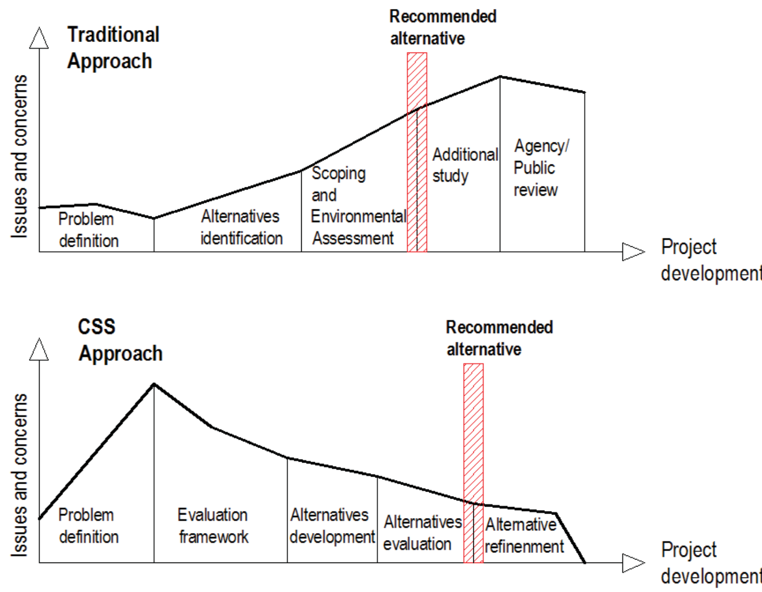

FIGURE 6 Comparison between the D.A.D. and CSS approach (ICF 2009)

The word "Context" in CSS assumes that any project has a surrounding environment and activities that must be considered in the design. A suggested inventory of elements is shown in TABLE 3.

TABLE 3 Example of elements to be considered in the context of a project (FHWA, 2009)

Area	***Elements***
Natural environment	Rivers, landscape, animal habitat, etc.
Social environment	Demographic and socioeconomic characteristics of people in the area. Stakeholder's perception of community.
Economic environment	Uses of the area, business and activities that might be affected
Cultural characteristics	Features and aspects that define or are important to the community
Transportation behavior	Modes and travel patterns
Transportation facility	Function and design of the transportation facility and expected users

Each aspect might be seen differently for each stakeholder. For that reason, "neutrality" has to be ensured in the description of each one. These aspects correspond to the scenarios or domains described in FIGURE 4 and TABLE 2. Additionally, each stakeholder group possesses needs and qualities that are unique. The core task behind any agreement is to reach consensus around common and particular aspects. Each member of the community is encouraged to accept a decision, even though it does not fully satisfy his/her personal requirement. This tradeoff process constitutes an important part of the CSS (ICF International et al., 2009), in which stakeholders must be satisfied with not only the outcome, but also with the process. Some of the main benefits from CSS are summarized in TABLE 4.

TABLE 4 CSS benefits (CEE, 2013; FHWA, 2009, 2005; ICF International et al., 2009)

CSS component	Benefit
Better value for agency and users	Improvement of project scoping and budgeting could reduce cost and time by the avoidance of opposition and facilitation on the EIS process. Provides opportunities not only for shared decision-making, but also for shared financial responsibility. Additionally, objectives for economic development can also be addressed.
Tailored solutions and environmental stewardship	Sometimes standards do not fit the requirements and a tailored approach is required. It looks for optimal solutions that minimize the impacts while keeping the efficiency and safety. The overall impact to human and natural environment is minimized. Walkability, bikeability, multimodal transportation, and safety are increased.
Customer satisfaction	CSS brings consensus and rallying points for community. The agency also improves its credibility through better relationship with public and stakeholders. It also increases stakeholders' ownership and interest for participation.
On-time delivery	Early understanding of issues helps to streamline the design process and reduce the likelihood of further redesign or big changes. Involvement of relevant agencies allows the early fulfillment of requirements for permits and thus approvals are faster and simpler. CSS can expedite the EIS process, and only a FONSI could be required. It also improves the predictability of project delivery and minimizes construction related disruptions.

On the other hand, there are challenges to the implementation of CSS. CSS projects will require more time and effort in the early stages of development with the time rewards not emerging until later phases. Public liability is also a factor to consider when adopting “non-traditional” designs. Finally, there might also be some natural resistance to change in the practice and use of older perspectives and inflexible design standards (FHWA, 2009).

Additionally, The FHWA (FHWA, 2009) mentions twelve characteristics of the CCS process. One of these characteristics especially relates to the scope of this study states that: “Full range of communication and visualization tools are used to engage stakeholders.”

2.4 Community involvement

The involvement of community as a partner in the process of decision-making has taken a renewed importance since it has been recognized as an empowering agent of the project development process. It fosters the identification of issues, concerns and ideas, but also promotes essential goals such as sustainability, human well-being, and social legitimacy. Depending on the scope and the realm of the application, a useful common measurement of the quality of involvement is performed through Arnstein’s ladder of citizen participation proposed in 1969 (Bailey et al., 2011). In this ladder (FIGURE 7), the degree of involvement varies from Manipulation in one extreme to Citizen Control in the other extreme. The first level of Manipulation does not include any kind of real participation and is limited to “educate” the participants. The fifth level of Placation allows the participants to have a voice and the decision-makers are encouraged to hear from them. However, there is no guarantee that their opinions are going to be considered as a preponderant element for the final decision. The last group of levels, Citizen Power, introduces the “Partnership” as a tradeoff level, meaning that all stakeholders will negotiate with each other by recognizing that the interests or needs in some cases are incompatible. The ultimate level of citizen participation, called Citizen Control, is when a large part of the decision is dictated by the citizens. At this stage, it is assumed that depending of the scenario, the heterogeneous groups of citizens might have a mechanism to reach an agreement among their own interest (Arnstein, 1969). Some organizations (Environment Canada, 2008; International Association for Public Participation, 2007) adopted a similar scale of public participation based on five levels: Inform, Consult, Involve, Collaborate and Empower.

The interaction between two of the main actors (agency and community) of project development describe a synergic/dependence relationship where agencies require public involvement to have sound and successful project developments and where people claim to have a voice in transportation decision making (FHWA 1996).

Community involvement has been difficult to implement into the typical project development process. Moreover, the literature and practice show a gap between knowledge and pro-environmental behavior (Sheppard, 2006). The existing gap in public involvement was denoted the “Arnstein Gap” (Bailey and Grossardt, 2006), by explaining the difference between the desired and actual level of public participation. As it was stated by Holgate (Ball, 2002, p. 82) “there is a big difference between an issue being on the agenda and a mechanism for that issue to be addressed”.

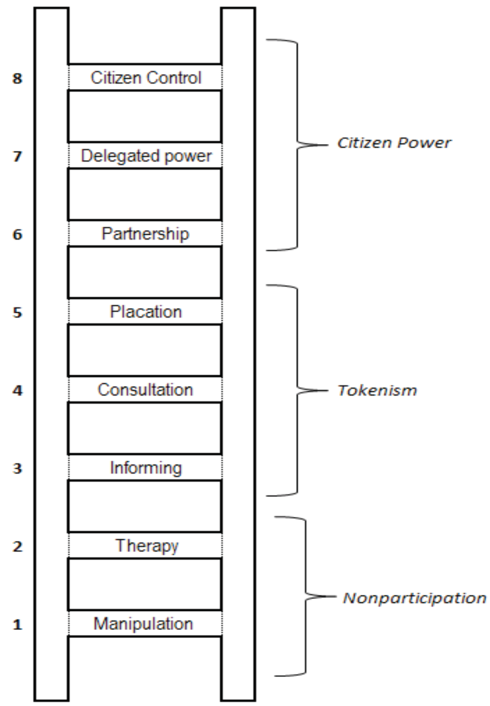

FIGURE 7 Eight rungs on the ladder of citizen participation (Arnstein, 1969)

Public involvement has been required in transportation project development since the inception of the 1969 National Environmental Policy Act (Bailey and Grossardt, 2006), and the Council of Environmental Quality gave guidelines for its implantation. In order to comply with these mandates, FHWA issued the regulation 23 CRF § 771 and the Technical Advisory T.6640.8A. The FHWA NEPA process states that "Public involvement and a systematic interdisciplinary approach are essential parts of the development process for proposed actions" (FHWA, n.d.). Public involvement continued to evolve, and the Intermodal Surface Transportation Efficiency Act (ISTEA) envisioned an open decision-making process (Federal Highway Administration, n.d.). It stated that the far-reaching effects of transportation investments may affect community values that should be considered, and that all interested parties should be provided with reasonable opportunities to comment. By the 1990's, a movement connected to the 1960 Right's Movement (FHWA, n.d.) addressed the issue of inequity affecting certain groups of society. As a result, the Executive Order 12898 Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations was signed in the year 1994 FHWA, in turn, gave the Order 6640.23 (replaced by Order 6640.23A in 2012) so as to comply with the E.O. 12898 and avoid to cause disproportionate high or adverse effects on minority and low income groups (FHWA, n.d.). TEA-21 of 1998 and SAFETEA-LU of 2005 continued to expand these opportunities. The Moving Ahead for Progress in the 21st Century of 2012 (MAP-21) placed Public Involvement as a "hallmark of the transportation planning process" (FHWA, 2013).

2.4.1 Public Involvement Techniques

There are many available techniques to get in contact with the community (FHWA, 1996; International Association of Public Participation, 2006). These include person-to-person interviews, direct mail, video techniques, multimedia, and virtual reality presentations. Each method has advantages and drawbacks depending on the objective, stakeholders, and context, and especially on the desired level of public engagement. These methods can be grouped by taking into account the level of participation reached (Environment Canada, 2008; International Association for Public Participation, 2007). In one extreme, media strategies such as Radio spots and brochures ensure that people get informed; in the other, techniques such as Task Forces and Design Charretes might ensure collaboration. Public involvement is a two-way pathway (FHWA, 1996), meaning that it is necessary not only to disseminate information, but also to receive the feedback from people. Some techniques favor only one way of communication (e.g., brochures, web questionnaires) and some of them need to be combined in order reach adequate levels of involvement. Furthermore, public involvement can vary based on two factors: its scope and level of engagement. The scope is wider when the process itself or the technique allows for reaching the most interested parties, e.g., neighborhoods, ethnic groups, cycling groups, or people with disabilities. The second factor is related to the level of involvement of each participant into the process. Participants could only receive information or actively participates in the discussion. Ideal public involvement possesses an appropriate scope, and facilitates participation. These depend on organization and well-planned outreach (FHWA, 1996).

The advent of sophisticated technologies, such as computer image generation, originated from military applications (Hughes, 2004), allows the use of special techniques to improve the public involvement process. Enhanced techniques are not aimed to replace traditional "ways" of communication; rather they must be carefully integrated into the processes without alienating the natural communication (FHWA, 1996). The use of enhanced techniques might attract more people to participate and encourage people to not only discuss issues, perspectives and opinions, but also understand the agency's vision and strategies (FHWA, 1996). These techniques include interactive television, computer presentations, simulations, teleconferencing, listservers, and e-mail, Computer Based Polling, World Cafes, Visualizations, Interactive modeling, among others (FHWA, 1996; Hixon III, 2006; International Association of Public Participation, 2006).

2.4.2 *Visualizations*

Visualization techniques are the visual representation of an idea in order to communicate different characteristics of objects at appropriate and understandable scales (John A. Volpe Center 2009). They may correspond to a project design alternative or a change in existing infrastructure. Visualizations have a great potential because they are universally understood, overcome the barrier of spoken languages and illiteracy, and help to introduce discussion of substantial issues and concerns (FHWA, 1996). Scientific research has shown that human beings are inherently visual (Al-Kodmany, 2001; Center for Computational Research, 2009) and visual information possess cognitive advantages over written or verbal information (Sheppard, 2006).

Visualizations have been used to enhance the transportation project development process, and more specifically the communication among interested groups (John A. Volpe Center 2007). Beginning with the geographical representation of Napoleon's Campaign in Russia (a map showing the movement, size of troop, and fatalities during the journey) (Hixon III, 2006), physical models continued to evolve in forms of plans and mock-ups. During the 1950's and 1960's a new era of computer assisted graphs began and the first computer software was denominated "SkecthPad". This software was primarily used for designing mechanical parts; however, because of the availability and cost of computers, only the automotive and aerospace companies were able to use it. In fact, these companies, along with Universities in the US and Europe, played an important role in the development of the next generation of CAAD software and hardware. The advent of high capacity and small sized computers enabled the development of CAAD programs by a variety of providers and the development of 2D and 3D models became the domain of more than only the automotive and aerospace companies (Hixon III, 2006). In the present day, visualizations include realistic 3D graphics, 4D animations; renderings, drive/fly/walk-through capabilities, among others, that can be constructed with different available software (TABLE 5). There are many successful applications ranging from corridor alternatives to land development scenarios (Center for Computational Research, 2009; John A. Volpe National Transportation Systems Center, 2007).

The common use of visualizations has been to communicate the final project idea or design alternative. However, visuals should not only be understood as imagery showing how a proposal will look, but rather they should effectively convey how things operate (Hughes, 2004). Visualizations are considered a vehicle for collaboration and a way to reach consensus among the public, agencies and any other stakeholder (John A. Volpe National Transportation Systems Center, 2007). Moreover, visualizations are not only high resolution images or animations. They are a way to communicate how the proposed alternative will help achieve basic community values and the values of the design (Hughes, 2004). Hughes also stated that "No amount of increased resolution, scene content, or animation can serve to convince the user of the value/benefit of the proposed design, if the design is not consistent with the core values of the user" (Hughes, 2004, p. 173).

Visualizations are also affected by issues related to the use of sophisticated technologies and the requirements of specialized staff. This may be time consuming and costly (FHWA, 1996; Hixon III, 2007, 2006). Unlike other engineering tools such as CAAD, visualizations still lack common standards (Hixon III, 2007). Also, minorities such as ethnic groups, low-income groups, or poorly educated people may feel uncomfortable with the use of new technology (FHWA, 1996). Finally, during the earliest stages of visualizations (e.g., maps, makeups), its elaboration was commissioned to artists and the design characteristics were subjects to their point of view (Hixon III, 2006). Currently, there is still discussion about the implicit or explicit bias of preferences or opinions when elaborating visualizations; and neutrality must be guarantee based on ethical considerations (Sheppard, 2006).

TABLE 5 Types of Visualization (Adapted from Hixon III 2006)

Type of Visualization	*Description*
Hand Rendering	Elaboration of visualizations by hand, also known as "*pen and paper*". An important advantage of this method is that it can be used interactively in public in "open houses" to draw directly people's ideas (*on-the-spot sketching*). Quick and inexpensive. However, it may require the assistance of a graph specialist or an artist. Also, lacks precision.
2D/3D Representations	Most used in meetings, public presentations, and printed mediums. It may use vectors and/or raster graphics. Photo montages belong to this group. Method of activities location that used paper maps and physical models (mock-up) can be included in this group.
3D Modeling and Computer Renderings	Computerized creation of buildings in three dimensions using specialized software. Its use has increased because of the availability of low-priced and high-performance platforms. Renderings add realism to 3D models based on color, textures, lighting, reflectivity, and shadows. Renderings are easily performed with the assist of computer software. Nevertheless, it is very time-consuming. Additionally, there are the 3D-GIS models that help to spatially communicate the implications of project designs. However, it requires plenty of data and expert's assistance. An example is the planning software "Community Viz ®".
Photo-Simulation (Photo and Photorealistic)	Incorporation of photographs to 3D models through photo-editing-packages. Results are composite images that provide a great sense of realism. Easy to understand and very helpful when comparing options. Nonetheless, it only offers a single point of view. Currently, it is the most used technique.
Computer Animation	A subfield of computer graphics and animation. Consist of creating moving images using computers. Movement is created by a succession of renderings. It could be very time consuming and requires high computer processing capacity.
Real-Time Simulation	Interactive navigation based on virtual reality constituted by a graphical database. Started as flight simulators in the U.S. military sector. It streamlines the planning and design phases by allowing the visualization of multiple plans and elevations. It also can be linked with other databases such as GIS, which in turn allows analyzing various types of information interactively. The main advantage is that, as database, it can be expanded, modified and updated. There are different levels of users ranging from designers, who can make changes to the database, to lay people, who would be able to walk thought a virtual neighborhood using a device that allows them to "jump" into the virtual model.

Type of Visualization	*Description*
Web Development	The internet can be used as a powerful tool to convey and share information. It is used for promotional purposes, as a mean to exchange project information within and between stakeholders. It empowers the efforts for public outreach. Its low-cost and public familiarity made it an adequate platform to share and combine with other visualization technologies.
Multimedia and Hypermedia Development	Use of more than one medium of expression to communicate information. Include text, images, audio, animations, and interactive tools, among others. Hypermedia, also known as interactive multimedia, is the combination of these mediums in an associative format. It allows the user to interact with the content in contrast to linear progressions.
Video Production	The project design is represented using a combination of photo-simulation, computer generated graphics, 3D modeling, and animation. The greatest advantage is that it can be projected multiple times in different locations and thought different means of communication.
Hand Rendering	Elaboration of visualizations by hand, also known as "*pen and paper*". An important advantage of this method is that it can be used interactively in public in "open houses" to draw directly people's ideas (*on-the-spot sketching*). Quick and inexpensive. However, it may require the assistance of a graph specialist or an artist. Also, lacks precision.

3 METHODOLOGY

3.1 Overview of the Research Procedure

The research for this study is divided in three stages in response to the specific objectives of the project. The inputs are constituted as a series of indicators, metrics, and community preferences. The output is constituted by a group of fly-through corridor animations and the preference given by community members over each one. Criteria, and therefore visuals, aim to reflect community values in the form of corridor alternatives. The research methodology is shown in FIGURE 8.

Stage 1: Criteria selection

Based on the literature review with emphasis in Sustainable Transportation, selected metrics and indicators were evaluated and grouped to obtain a range of options, broad enough to cover most of the aspects related to sustainable transportation, but small enough to be handled in the next stages of this job. A subset of eleven criteria was identified from this process and was considered to streamline the pairwise comparison for stage 2. Because the literature presents a vast quantity and variety, the criteria that could be used in this process is not limited to what is listed in this study. Moreover, the author believes that the criteria must be adapted to each situation in order to reflect the local community needs and values. The sources for the chosen criteria used were based on rating system (FHWA, 2011), and literature of local and global indicators (Litman 2009, 2007), and (Sinha and Labi, 2007). More details can be found in chapter 4.

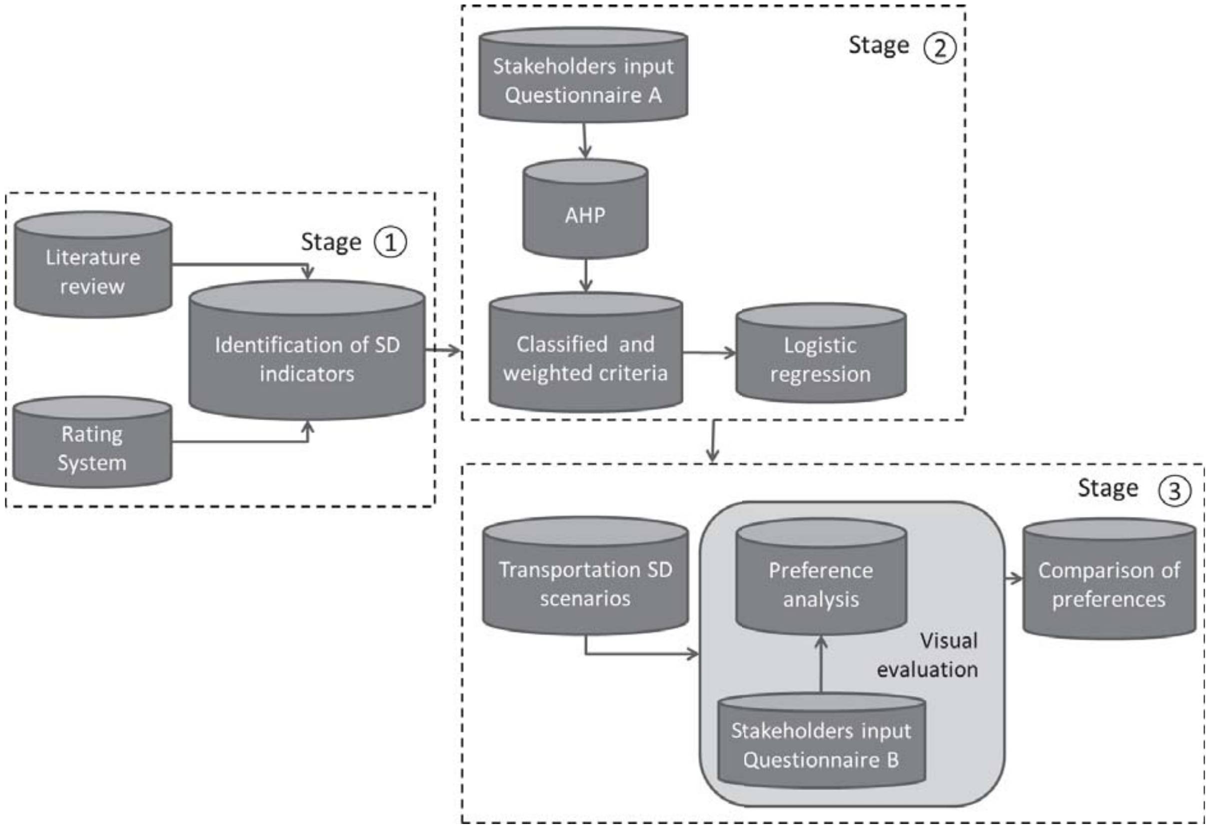

FIGURE 8 Research methodology process

Stage 2: Questionnaire Development and Hierarchization

A survey questionnaire "A" was developed to collect the community members' preference with regard to the selected criteria. More detailed information is provided in Chapter 4. The survey was conducted using a non-probabilistic sampling method based on interviews with 114 members of the community. The survey included a pairwise comparison between of the criteria, and relevant information about the people's mobility and awareness of the process of decision making was also collected.

The technique Analytical Hierarchy Process (Saaty and Vargas, 2000) (see chapter 4) was used to create a hierarchy of the preferences expressed in the survey. Within this analysis, the Aggregation of Individual Judgments (AIJ) methodology was chosen in which a matrix Arithmetic mean, Geometric mean, Harmonic mean, and Percentile 75, 80, and 90 were created and compared based on the Consistency Ratio (CR). CR is dependent on the maximum eigenvalue of the matrix of aggregated values, the dimension of that matrix, and a tabulated Random Index. The Arithmetic mean, Geometric mean, Harmonic mean, and Percentile 75, 80, and 90 were evaluated. The final output of this stage is constituted by a set of eleven criteria ordered from the most preferred to the less preferred based on their eigenvalues.

Stage 3: Visualizations design and Questionnaire

The last stage is developed using the case study presented in subtitle 3.2 . Four Alternatives of a hypothetical redevelopment of a highway corridor are proposed. Each alternative is constructed as a visual embedding several of a conjoint of features related to the hierarchy of criteria obtained in stage 2 and is translated into different visualizations. Each visual constitutes a conjoint of features related to the hierarchy of criteria obtained in stage 2. The features for each visual were chosen based on engineering judgment and suggestions from academia members taking into account that they must reflect community and design values (Hughes, 2004) and should not severely alter the current configuration of the roadway.

Four alternatives and one Do-Nothing alternative were developed in the form of fly-through 3D visualizations along the corridor allowing the identification of their features. The process started with a 2-dimensional sketch of the highway and the surrounding features. Subsequently, elevations, surfaces textures, and colors were added. The final step was the generation of the 3D animations. This process is repeated for each design alternative. The modeling process was developed using the software Google SkecthUp version 8 (for more details read Chapter 5). At the end of this stage a questionnaire “B” is conducted. The community is asked about their preferences over the Visualizations and contained features. Then an analysis of their preferences is conducted.

3.2 Local Context

The case study used in this project was developed in a low-income community called “Dulces Labios”. It is a coastal community located on the west side of the urban area of the municipality of Mayagüez in Puerto Rico. According to “Puerto Rico Special Communities”, “Dulces Labios” comprises of approximately 500 households and has an unemployment rate of 34.9%. More than 33% of the residents are aged 60 or higher. As a comparison, according to the Institute of Statistics of Puerto Rico (Insituto de Estadísticas de Puerto Rico, 2003), the overall unemployment rate in Mayaguez is about 17%. The community lacks reliable public transportation services and the only public transportation provided to the community is a municipal bus that passes thru a nearby arterial highway that connects the community with the city square. “Carros Públicos”, essentially shared taxis, also provide limited transportation services to the community. Therefore, the community of “Dulces Labios” constitutes a typical low income urban community with usual transportation issues and concerns in Puerto Rico.

The community board of directors possesses a stable organizational structure whose members have been cooperatively working with the Institute for Community Development of the University of Puerto Rico at Mayaguez. As part of the collaborative effort, university students perform community labor addressing community needs as part of their formal education. The present work constitutes a continuation of this cooperation effort between the University and the communities.

In this work a hypothetical redevelopment of an 860 meter segment of the highway PR-102 is considered. This corridor is an arterial road that passes west of the community from north to south. FIGURE 9 presents the location of the Municipality of Mayaguez with respect to Puerto Rico, the location of "Dulces Labios" within Mayaguez, and the location of PR-102 within the community.

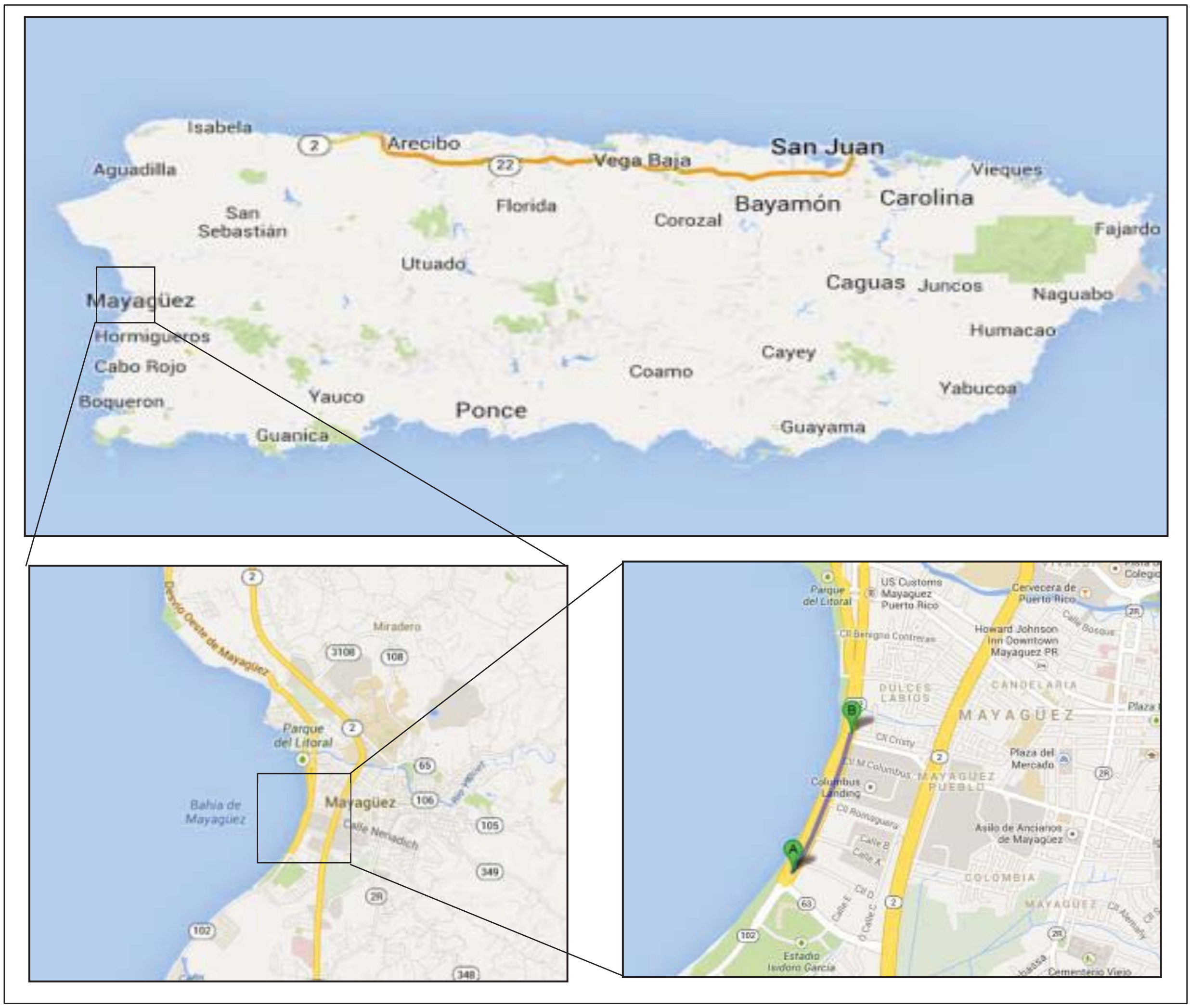

FIGURE 9 Geographical location of the case study area

The 3-lane 2-directional highway is also locally named the José González Clemente Avenue. It is located in a mixed land use zone. On the west side of the highway is the “Parque del Litoral” and the coastline of Mayaguez where mostly recreational activities take place. On the east side of the road is constituted by a mixture of residential, commercial, and educational facilities. Approximately a length of 230 meters of the corridor corresponds to the “Columbus Landing” residential complex. There are transversal streets that connect the PR-102 with the populated zones of the community of “Dulces Labios” as well as the main arterial highway PR-2. Additional information about the highway cross section can be reviewed in Chapter 5.

4 Criteria Identification and Hierarchyzation

Performances Measures were selected from literature and constitute the base to define our design criteria (see 2.1.2). The literature presents many efforts at different levels and locations for the development of sustainable transportation systems. These studies can be grouped based on their scope: transportation planning, project feasibility, and project design. Other studies are devoted to the identification of indicators, the development of rating systems, and the application of sustainable development (SD) criteria for decision making (see FIGURE 10). Most of the efforts are not aimed at the development of indicators, (e.g., the "Boston Indicators project" (The Boston Foundation, 2000), "Sustainability and the U.S. EPA" (EPA, 2011) and Developing Indicators for Comprehensive and Sustainable Transport Planning (Litman, 2009), and SD-rating at the planning and detailed design levels (e.g, INVEST, GreenLITES, and ENVISION), but very few at the feasibility level. Nevertheless, some similar efforts are the Public Participatory GIS (PPGIS) (Ball, 2002), the Analytic Minimum Impedance Surface (AMIS) (Grossardt et al., 2001) and Case wise Visual Evaluation (CAVE) (Bailey et al., 2007). The selected criteria were established based on indicators, performance measures and other criteria that were pulled out from the selected sources founded in the reviewed literature (FHWA, 2011; Litman, 2009, 2007; Sinha and Labi, 2007).

The criteria were selected based on their compatibility and scope regarding to public involvement. However, it is important to note that the literature shows a vast quantity and variety of criteria related to sustainability and projects' development. For that reason the criteria presented in this thesis intend to infer the most relevant aspects of community involvement in the development of transportation projects in the selected community, and they are not limited to what is listed. The author believes that the criteria must be adapted to each situation in order to reflect the real community needs and values. Moreover, local agencies should be encouraged to select, adapt or develop their own pull of criteria that are compatible with their context and specific goals. These indicators would not be limited to the planning and development of new projects the realm on transportation.

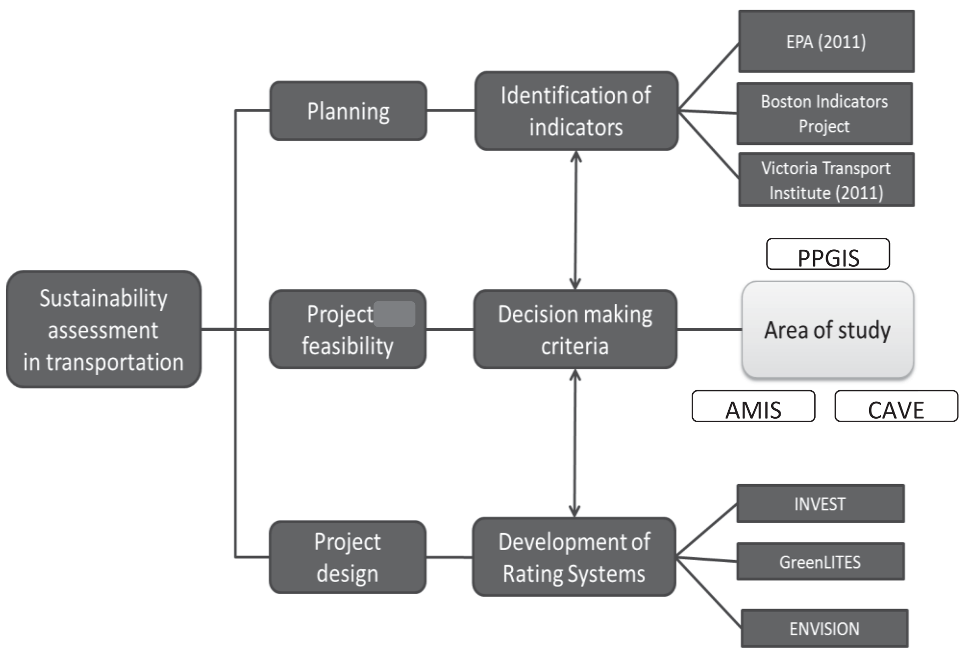

FIGURE 10 Sustainability assessment initiatives

The list of pre-selected criteria is shown on TABLE 6. They aim to cover most relevant aspects regarding a Sustainable Transportation Systems, including technical, environmental, economic development, economic efficiently, sociocultural, and project implementation aspects.

TABLE 6 List of Preselected Design Criteria

Criterion
a. Safety Improvements of transportation infrastructure and operations
b. Generation of employment and economic activity in the community
c. Transportation system can take me the places I need to go
d. Inclusion of greenery and landscaping
e. Ecologically friendly Infrastructure (Recycled materials, Solar energy, etc.
f. Includes infrastructure for bicycle pedestrian movement
g. Preservation of cultural, historic and archeological elements
h. Reduction of urban sprawl
i. Self-sustainable financial system
j. Aesthetics with the surroundings
k. Reliable and easy to access to public transportation system
l. Rapid construction of the infrastructure
m. Reduction of water and air pollution
n. Reduction of noise pollution
o. Reduction of vehicle operation cost
p. Reduction of travel time
q. Reduction of the area occupied by the facilities
r. Minimization of impacts on community and environment

4.1 Survey design and sampling

A written questionnaire "A" was prepared to obtain individual preferences with respect to the preselected criteria. The questionnaire was written in Spanish and a copy is included in the Appendix 7.1. A questionnaire was chosen because of the simplicity of the method and its compatibility with the socioeconomic characteristics of the community, e.g., many people could be reluctant or limited to attend group meetings. The survey was conducted during the months of June and August, 2012. The questions were elaborated using simple and clear language that was first tested with the community board members and peer graduate students. The survey was designed to be filled out without assistance; however, because the people were elderly and/or illiterate, the process required the assistance of an interviewer. Each questionnaire required approximately 20 minutes to be completed, and respondents had respondents the opportunity to ask questions and comments at any time. Participants were required to sign a "letter of informed consent" to participate in the study. Appendix 7.3 shows the letter of inform consent. Most of the questionnaires were completed at the respondent's house, and the others were completed at the community center, local businesses, or on streets. The number of surveyed people in the community was 114.

The questionnaire contains nineteen questions grouped into four parts. The first part collects demographic information of the participant. The second part asks information about the mobility of people, such as the principal mode of transportation and alternative mode, if any. Also, the main issues affecting respondent's quality of life are solicited. Respondents could choose among a preselected list of common issues or write their own. The third part is directed to consult the level of awareness and concerns from individuals with regard to Project Development Process and Sustainability. It also presents a list of nineteen pre-selected criteria and the respondent is asked to select the most important. The last part of the questionnaire brings the pairwise comparisons of a selected subset of criteria using a graphical scale (FIGURE 11). The scale includes a description at each level of importance and shows how many times a criterion is more important with regard to the other. It use a bidirectional scale from 1, meaning equally important, to 9 in one extreme to 1/9 in the other, meaning extremely relative importance form one criterion over the other. Additionally the scale showed circles in different sizes reflecting relative degree of importance graphically.

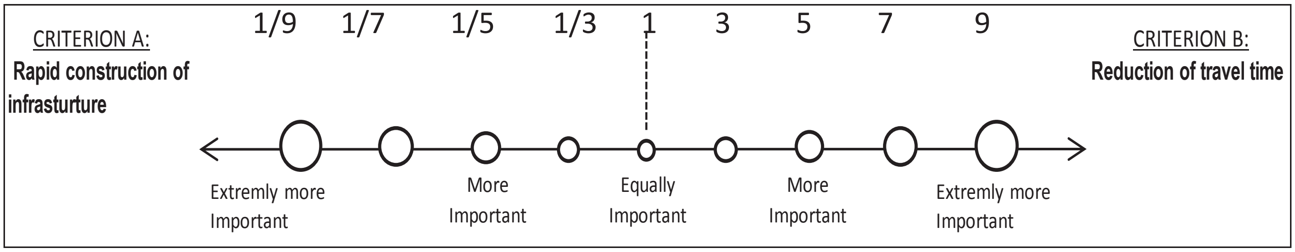

FIGURE 11 Graphic pairwise comparison of a given criteria A and Criteria B

The comparison scale shows how more important is one criterion regarding to the other. Each level of importance corresponds to a specific numeric value that is used to subsequent calculations. The levels and values are shown in TABLE 7. The scale labels shown in FIGURE 11 are literal translations from Spanish-written labels presented to the public. They correspond to, from right to left, “extreme importance,” “Strong Importance,” and “Equal importance.”

TABLE 7 Scale of level of importance for the criteria comparison (Saaty 2008)

Intensity of Importance	*Definition*	*Explanation*
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

Reciprocals of above	If activity “i" has one of the above non-zero numbers assigned to it when compared with activity “j”, then “j” has the reciprocal value when compared with “i”	A reasonable assumption
1.1–1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

The sample selection followed a non-probability method denominated “at convenience”, which means that the study relies on voluntary participation of community members and attendees to the community center. This method was chosen because it was more feasible to the study context. In that sense, the scope of this study does not attempt to infer conclusions about the entire population of the community of “Dulces Labios”.

4.2 Analytic Hierarchy Process

Multi-criteria decision making is defined as those decisions that must take into account more than one objective and more than one criterion. MCDM is used when multiple criteria cannot be integrated into a single objective, such as when they are in conflict or they cannot be combined because of difference in type. In the end, a group of better possible solutions is identified.

There are different techniques to deal with multi-criteria analysis, including the “Rating and Ranking” (Figueroa-Medina, 1999), the Matrix Method, the Step Matrix Method, and the Analytical Hierarchy Process (AHP) (Ohman, 2008). Some advantages from AHP to be considered in the present project are that it allows a trade off when making the pairwise comparisons and because of its intrinsic mathematical procedures that improves the credibility regarding to the consistency. The system developed by Saaty (1977) has been applied to a wide range of disciplines such as health sciences, allocation of recourses, land use planning, marketing, among others. Despite of this diversity they share common attributes such as the combination of qualitative and quantitative elements, the need of prioritization of alternatives based on ratings and the definition of a hierarchy in the evaluation criteria (Zahedi, as cited by Ohman 2008).

The AHP is typically carried out in four steps. The first one is the definition of the problem that then is broken down into its components: the goal, criteria, and the alternatives. The second step is the collection of input data through pairwise comparisons. The third step is the assembly of the "Matrix" and the Eigenvalue is calculated as a weight to estimate the relative weight of each criterion. The final step is the aggregation of the individual pairwise comparisons in order to obtain a hierarchy of the preferred alternatives (Saaty 1977). The present study is focused on the criteria stage in order to evaluate the transportation project alternatives. At the end of the process the consistency of the judgments is evaluated. The consistency is evaluated based on a "Consistency Ratio" (CR) that is defined as the ratio between the Consistency Index (CI) and the Random Index (RI). The maximum desired value of the CR is 0.10.

4.2.1 Aggregation method

In this study, the AHP is applied using the process of Group Decision Making (GDM) in which individual judgments should be aggregated. In AHP, two approaches are the most used:

the Aggregation of Individual Judgments (AIJ) and the Aggregation of Individual Priorities (AIP). According to (Wu et al., 2008) the type of aggregation used may influence the result of the priorities. Some researchers made comparisons between the three most common aggregation methods, using the Geometric mean for AIP, the Geometric mean for AIJ and the Arithmetic mean for AIJ. (Wu et al., 2008) shown that using the Arithmetic mean for AIP is inefficient. On the other hand, (Forman and Peniwati, 1998) state that both the Arithmetic and Geometric means are applicable. They also suggest that the Geometric mean is more appropriate for AIJ, which is also supported by (Ishizaka and Labib, 2011) . Wu et al. also state that the number of judgments influences the type of aggregation method that is used. However, they did not find any significant differences when the number of judgments was below 200. In addition, James and James (as cited by (Forman and Peniwati, 1998)1998) explained that when using ratio scales (Geometric progression) the Geometric mean is more applicable; likewise, the same can be said for the average when using Arithmetic scales (Arithmetic progression). For instance, the Arithmetic mean is 5 in an Arithmetic progression from 1 to 9, while in a Geometric progression from 1 to 9 the Geometric mean is 3. Based on the reciprocal property, (Ishizaka and Labib, 2011) also explained the compatibility between the mean and the progression scale by giving the following example: if a person "X" ranked a given criteria A as 9 times a given criteria B, and a person "Y" ranked the same criteria A as 1/9 times the criteria B, then the appropriate mean between "X" and "Y" would be $\frac{1}{9}*9 = 1$, rather than $\frac{\left(\frac{1}{9}+9\right)}{2} = 4.56$; however, they recommend to avoid early aggregation in order to visualize individuals preference and identify outliers.

Additionally, other aggregations methods have been explored, such as compromised methods, Linear Programming, and Bayesian approach, and the consideration of uncertainty (Ishizaka and Labib, 2011). In general terms, (Ravana and Moffat, 2009) state that when aggregating numerical scores the Geometric mean is more stable than the Arithmetic Mean in the sense that is less affected by outliers, being followed by the Harmonic mean and the median that is relatively unaffected by outliers. However, the Geometric and Harmonic mean are sensible to values close to zero.

The mathematical expressions are as follow:

Let the pair comparison for each criterion be: $C_{12}, C_{13}, C_{14}, C_{15} \ldots . C_{nxn}$. "C" accounts for "criteria" and the subscripts represent the two criteria under comparison. The subscript "12" represents the comparison between the criteria "one" and the criteria "two". All pairs comparisons can be represented in a comparison matrix called "A", denoted by $A^k = [C_{ij}^k]_{nxn}$, where k represents each person making the comparison and m the total number of people $(k = 1,2,3 \ldots m)$:

$$A^k = \begin{bmatrix} 1 & {C_{12}}^{k} & {C_{13}}^{k} & \ldots & {C_{1n}}^{k} \\ 1/{C_{21}}^{k} & 1 & {C_{23}}^{k} & \ldots & {C_{2n}}^{k} \\ \vdots & \vdots & \vdots & \ldots & \vdots \\ 1/{C_{n1}}^{k} & 1/{C_{n2}}^{k} & 1/{C_{n3}}^{k} & \ldots & 1 \end{bmatrix} \qquad (1)$$

then the Arithmetic mean is represented by:

$$AM(A) = \begin{bmatrix} 1 & \frac{\sum_{k=1}^{m} c_{12}^{k}}{m} & \cdots & \frac{\sum_{k=1}^{m} c_{1n}^{k}}{m} \\ \frac{m}{\sum_{k=1}^{m} c_{12}^{k}} & 1 & \cdots & \frac{\sum_{k=1}^{m} c_{2n}^{k}}{m} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{m}{\sum_{k=1}^{m} c_{1n}^{k}} & \cdots & \frac{m}{\sum_{k=1}^{m} c_{2n}^{k}} & 1 \end{bmatrix} \qquad (2)$$

The Geometric mean is represented by:

$$GM(A) \quad = \begin{bmatrix} 1 & \sqrt[m]{\prod_{k=1}^{m} c_{12}^{k}} & \cdots & \sqrt[m]{\prod_{k=1}^{m} c_{1n}^{k}} \\ \frac{1}{\sqrt[m]{\prod_{k=1}^{m} c_{12}^{k}}} & 1 & \cdots & \sqrt[m]{\prod_{k=1}^{m} c_{2n}^{k}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{\sqrt[m]{\prod_{k=1}^{m} c_{1n}^{k}}} & \cdots & \frac{1}{\sqrt[m]{\prod_{k=1}^{m} c_{2n}^{k}}} & 1 \end{bmatrix} \tag{3}$$

The Harmonic mean is represented by:

$$HM(A) \quad = \begin{bmatrix} 1 & \frac{\mathrm{m}}{\sum_{\mathrm{k}=1}^{\mathrm{m}} \frac{1}{\mathrm{c}_{12}^{\mathrm{k}}}} & \cdots & \frac{\mathrm{m}}{\sum_{\mathrm{k}=1}^{\mathrm{m}} \frac{1}{\mathrm{c}_{1\mathrm{n}}^{\mathrm{k}}}} \\ \frac{\sum_{\mathrm{k}=1}^{\mathrm{m}} \frac{1}{\mathrm{c}_{12}^{\mathrm{k}}}}{\mathrm{m}} & 1 & \cdots & \frac{\mathrm{m}}{\sum_{\mathrm{k}=1}^{\mathrm{m}} \frac{1}{\mathrm{c}_{2\mathrm{n}}^{\mathrm{k}}}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\sum_{\mathrm{k}=1}^{\mathrm{m}} \frac{1}{\mathrm{c}_{1\mathrm{n}}^{\mathrm{k}}}}{\mathrm{m}} & \cdots & \frac{\mathrm{m} \sum_{\mathrm{k}=1}^{\mathrm{m}} \frac{1}{\mathrm{c}_{2\mathrm{n}}^{\mathrm{k}}}}{\mathrm{m}} & 1 \end{bmatrix} \tag{4}$$

The Consistency Ratio (CR) for AHP is based on the Consistency Index (CI) and the Random (RI) Index as shown in the following expression:

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{5}$$

where n is the dimension of the matrix and λ_{max} is the maximum eigenvalue of comparison matrix. Then the Consistency Ratio (CR) is calculated as:

$$CR = \frac{CI}{RI} \tag{6}$$

RI values are derived from the average of Consistency Index from a sample of randomly generated reciprocal matrices using the scale from 1/9 to 9 (Saaty and Vargas, 2000). Random Indexes are shown in TABLE 8.

TABLE 8 Random Index (RI) values (Saaty 2008)

Matrix order	RI	Matrix order	RI	Matrix order	RI
1	0.00	6	1.24	11	1.51
2	0.00	7	1.32	12	1.48
3	0.58	8	1.41	13	1.56
4	0.90	9	1.45	14	1.57
5	1.12	10	1.49	15	1.59

4.2.2 Characterization of Respondents

The questionnaire allowed the identification of important socio-demographic and mobility characteristics of the respondents. Furthermore, it shows a preliminary baseline of the main transportation-related issues that affect the people's quality of life and their preferences over the evaluation criteria to be considered when solving these issues. The respondents whose place of residence was in the community were grouped under the name "Dulces Labios" , the rest of respondents were grouped under the label "Others". FIGURE 12 to 19 describe the main characteristics gathered through the performed survey. FIGURE 12 shows the sample description in terms of gender, which is similar to the percentage given by (OCE (2003), 44% of males and 58% of females. FIGURE 13, FIGURE 14, and FIGURE 15, show the level of education, and occupation for both groups in a combined "pie chart". The outer ring corresponds to the "Others" group with 72 respondents and the inner one correspond to the group of "Dulces Labios" with 114 respondents. More than 60 % of surveyed people are at least 45 years old. The OCE in 2003 showed in 2003 that this group constitutes approximately 41% of the people at that time. As comparison, the 2010 U.S. Census statistics shows 48% of males and 52% of females for Puerto Rico.

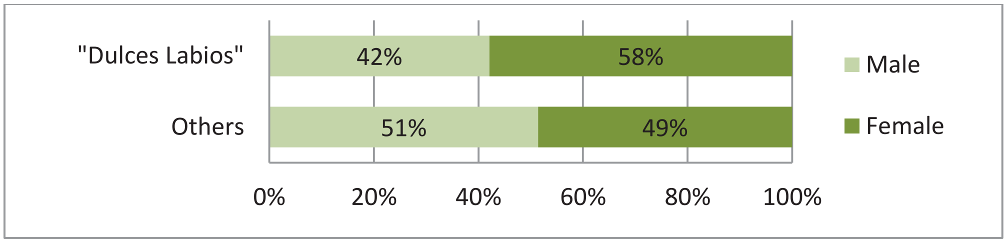

FIGURE 12 Distribution by gender and group of surveyed people

Most of surveyed people in the community were at least 45 years old and 51% were older than 60. On the other hand, most of the respondents in the “Others” group were between 18 and 30 years old. Also, 60 years or older people only represent around 7% (FIGURE 13).

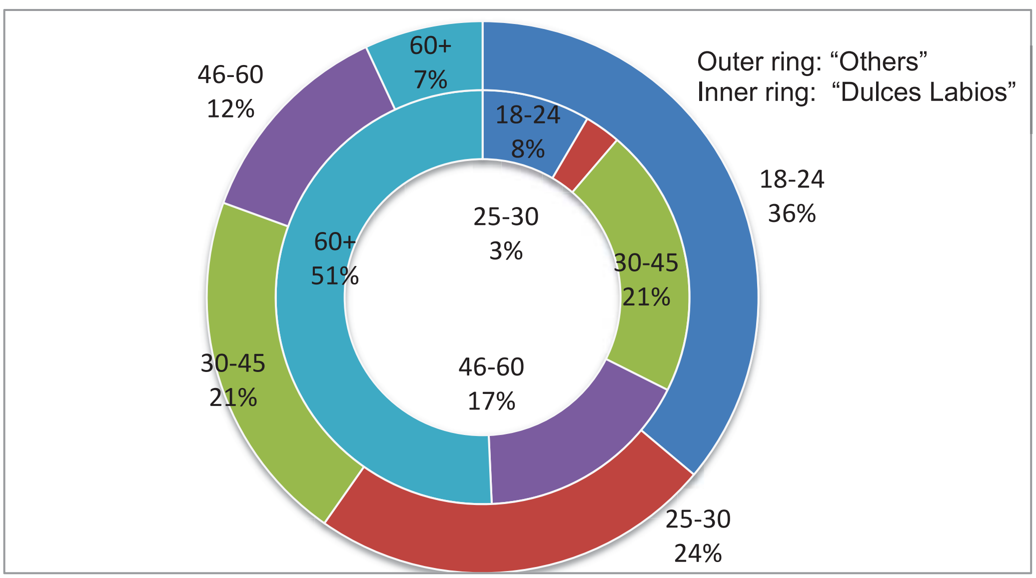

FIGURE 13 Distribution by age

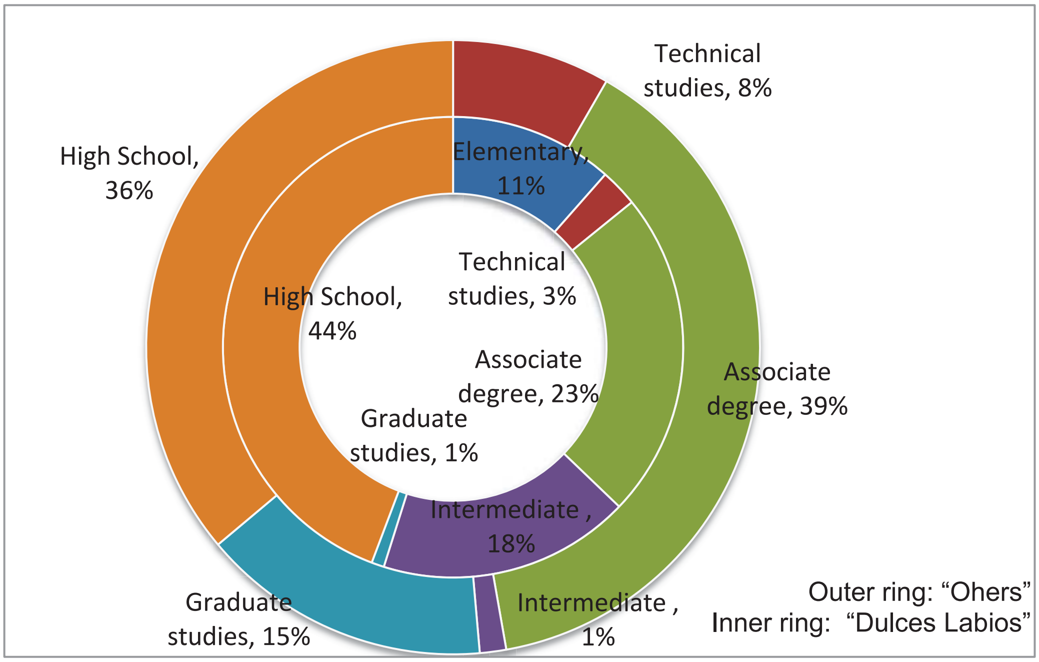

FIGURE 14 Distribution by level of education

The level of education of the surveyed people is shown in FIGURE 14. The greater level of education completed by most people in the group of "Dulces Labios" was high school (44%). FIGURE 15 shows that around 3% of surveyed people were unemployed and most of the employed people perform technical occupations.

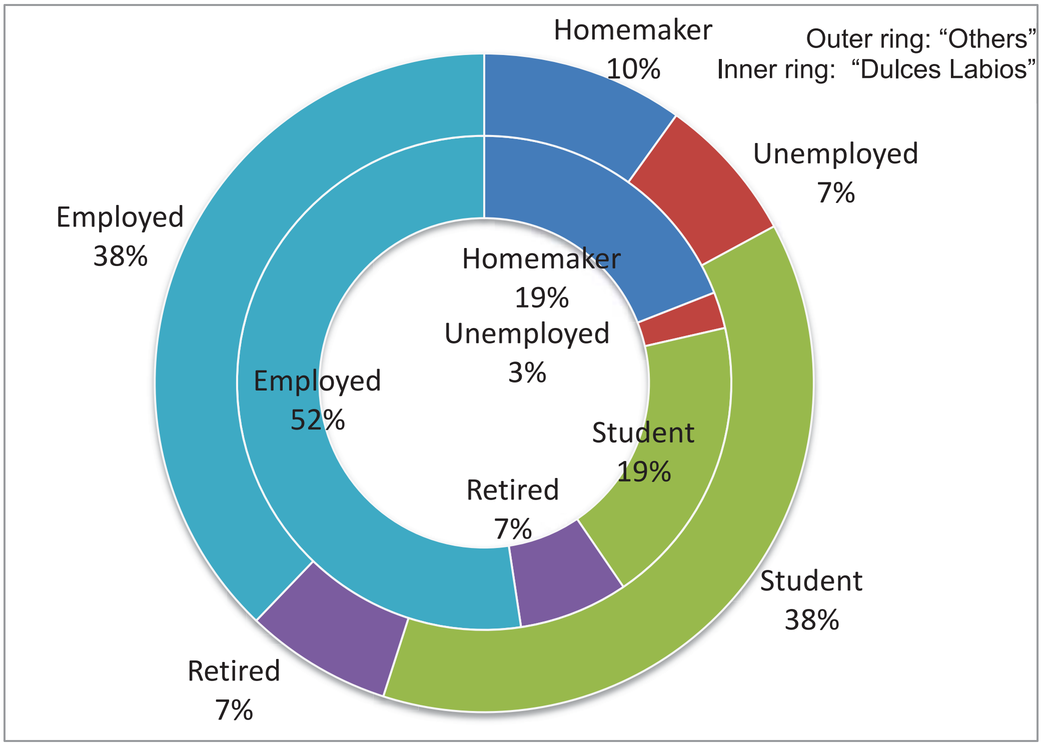

FIGURE 15 Distribution by occupation

The second part of the survey allowed characterizing aspects of mobility and outlining some transportation related issues that respondents considered important. FIGURE 16 shows the distribution by main mean of Transportation in the overall sample. The prevalent mode of transportation is the owned vehicle with 61% of the respondents, followed by public transportation in the “Dulces Labios” group and carpool in the “Others” group.

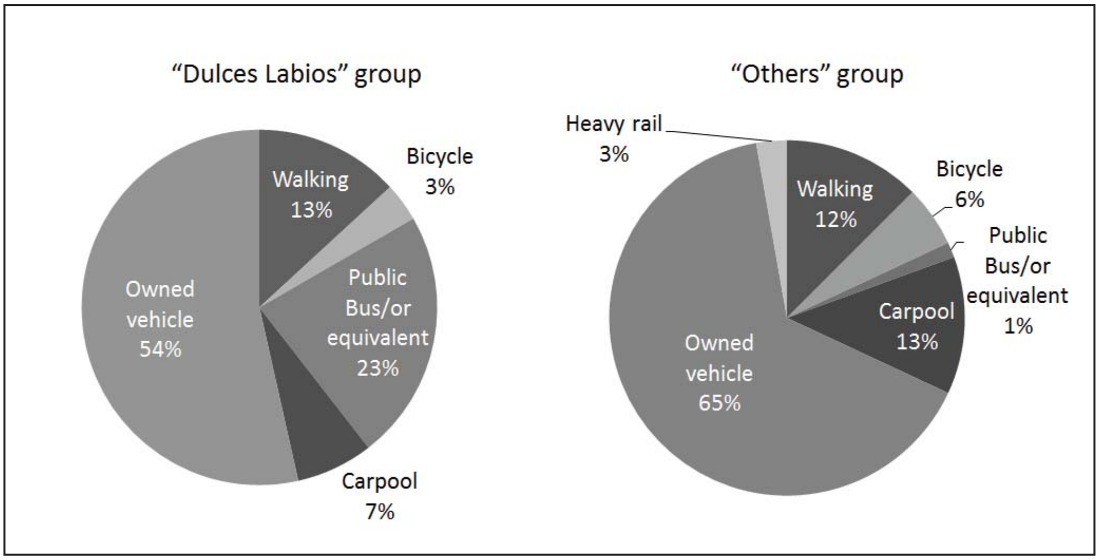

FIGURE 16 Preferred transportation mode

The use of private cars as a primarily mode for mobility is similar in other areas of Puerto Rico. For instance, in the San Juan metropolitan area the use of private vehicle represents 89% of the daily trips, while the others modes such as the heavy rail and public buses (AMA, Metrobus) accounts by 4% and the "Públicos" system (a type of paratransit service) accounts by 5% (Quiñones 2008).

FIGURE 17 summarizes the main issues that most affect the quality of life of the surveyed people. Traffic congestion, the cost of gasoline and the availability of public transportation and personal security constitute the three most important issues in the "Dulces Labios" group. A second category of moderate importance is constituted by safety, pavement quality, and bike facilities. Finally a third and fourth group present topics such as vehicle acquisition cost, pollution caused by vehicles, parking, and noise from traffic, among others.

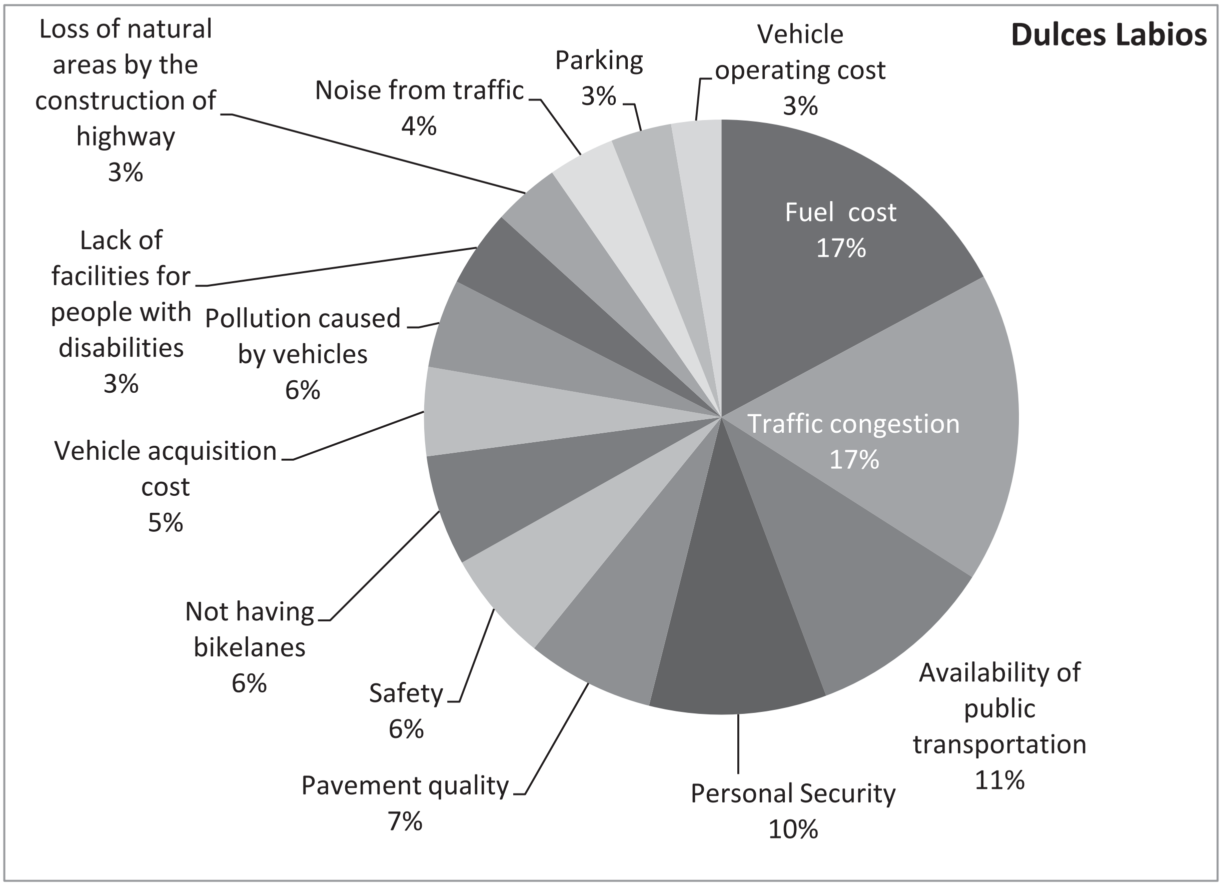

FIGURE 17 Main issues affecting the quality of life of surveyed people

FIGURE 18 and FIGURE 19 show the level of awareness of people with regard to the project development processes. An average of 50 % of sampled people known or have heard about Environmental Impact Assessment documents and a 73% know about public hearings; however, only 21% have participated in this process. Moreover, an average 85% mentioned that they were not or never felt consulted about their opinion during a project development in their community. These values tend to worsen when analyzing only the group of "Dulces Labios." Participation of people in public hearings rounds the 15 % and 93% of respondents never felt consulted about any project development.

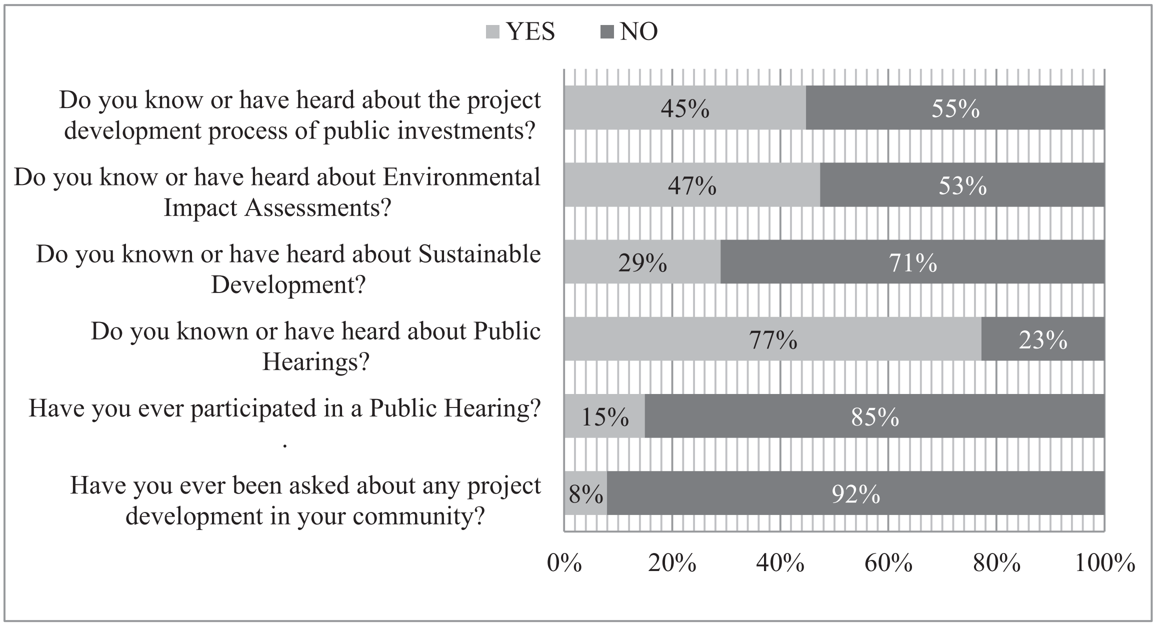

FIGURE 18 Level of awareness about the project development process for "Dulces Labios"

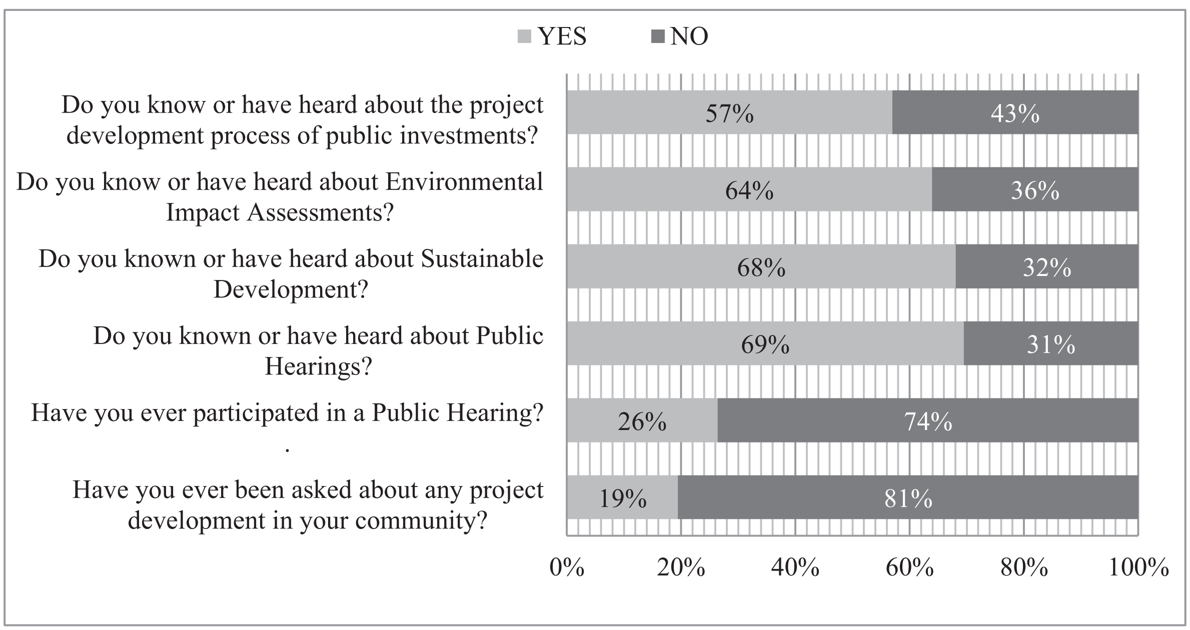

FIGURE 19 Level of awareness about the project development process for "Others" group

4.2.3 AHP Modeling

In the last part of the questionnaire people were solicited to assign values of relative importance to each project evaluation criterion with regard to another using consecutive pairwise comparisons. The number of pairwise comparison to be filled without exhausting the respondents limited the number of criteria to be used. Additionally, the literature states that in order to reach adequate levels of Consistency in the AHP procedure (see section 4.2) the recommended number of criteria to be considered should be around 7. In that sense, the criteria shown in TABLE 6 were reduced and paraphrased to a subset of eleven criteria shown in TABLE 9. Nevertheless, the intrinsic relationship among criteria made more difficult the establishment of the grouping criterion. The initial eight categories (technical, environmental, economic development, economic efficiently, sociocultural, and project implementation aspects) were kept as guideline for criteria selection. Each comparison was rated once for every five respondents. The comparisons were randomly arranged in five questionnaire templates

TABLE 9 Selected Criteria and Index ID

Criteria	Index ID
Reduction of travel time	1
Generation of employment and economic activity in the community	2
Rapid construction of the infrastructure	3
Reduction of air and water pollution	4
Including greenery and landscaping	5
Ecologically-friendly Infrastructure. (Recycled materials, Solar energy, etc.)	6
Infrastructure for bicycle/pedestrian movement	7
Reduction of vehicle operatiing cost	8
Self – Sustainable financial system	9
Preservation of cultural, historic and archeological elements	10
Safety Improvements of transportation infrastructure and operations	11

Subsequently, individual judgment values were aggregated using different measures of central tendency and three percentile values. The best aggregated measure was chosen based on the Consistency Index (CI). The matrices of aggregated values by each method are shown in the Appendix A and an example is shown in TABLE 10. The values in the cells represent the comparison between the criteria “A” and “B” given by the pair (i,j), where “i” and “j” correspond to the “Index ID” for the criteria “A” and “B” taken from TABLE 9.

TABLE 10 Comparison matrix of Aggregated Values using the Geometric mean for the “Dulces Labios” group

Project Evaluation Criteria											
	1	2	3	4	5	6	7	8	9	10	11
1	1.00	0.50	1.00	0.40	0.80	0.80	0.40	0.60	1.00	0.83	0.29
2	1.85	1.00	8.90	1.10	2.70	1.70	1.70	5.70	4.60	2.35	1.13
3	1.01	0.10	1.00	0.70	0.60	0.60	0.40	0.90	0.90	0.94	0.78
4	2.25	0.90	1.50	1.00	1.90	1.20	3.30	1.30	1.10	3.51	1.17
5	1.20	0.40	1.80	0.50	1.00	1.20	0.50	0.50	3.30	1.24	0.53
6	1.30	0.60	1.80	0.90	0.90	1.00	1.10	0.80	0.90	1.35	0.66
7	2.23	0.60	2.20	0.30	2.00	0.90	1.00	1.70	3.50	0.87	1.37
8	1.65	0.20	1.10	0.80	1.90	1.20	0.60	1.00	0.30	0.32	0.52
9	1.02	0.20	1.10	0.90	0.30	1.10	0.30	3.20	1.00	0.96	0.36
10	1.21	0.40	1.10	0.30	0.80	0.70	1.20	3.10	1.00	1.00	0.61
11	3.41	0.90	1.30	0.90	1.90	1.50	0.70	1.90	2.80	1.63	1.00

After calculating the aggregated values, the eigenvector and the maximum eigenvalue (λ max) were calculated. The Eigenvector on TABLE 16 provides the ranking among the criteria and the λ max is used to calculate the Consistency Index. A higher consistency is reached when the maximum eigenvalue is close to the value of “n”, which is the order of the square comparison matrix. Subsequently, the Consistency Index was compared with the Random Index (RI) shown in TABLE 8. Spreadsheets with detailed information for each aggregation method and corresponding group are shown in the appendices. TABLE 11 and TABLE 12 summarize the Maximum Eigenvalues, Consistency Index and Consistency Ratios for each type of aggregation for the group of "Dulces Labios" for the "Others" group.

TABLE 11 Maximum Eigenvalues, Consistency Index and Consistency Ratios by aggregation method for the community of "Dulces Labios"

Data aggregation type	*λ max*	*CI*	*RI*	*CR*
Average	12.935	0.194	1.510	0.128
Geometric mean	12.111	0.111	1.510	0.074
Harmonic mean	13.248	0.225	1.510	0.149
Mode	22.987	1.199	1.510	0.794
Percentile 50	14.656	0.366	1.510	0.242
Percentile 75	16.609	0.561	1.510	0.371
Percentile 80	18.275	0.728	1.510	0.482
Percentile 90	18.878	0.788	1.510	0.522

TABLE 12 Maximum Eigenvalues, Consistency Index and Consistency Ratios by aggregation method for the "others" group.

Data aggregation type	*λ max*	*CI*	*RI*	*CR*
Average	12.803	0.180	1.510	0.119
Geometric mean	11.937	0.094	1.510	0.062
Harmonic mean	12.823	0.182	1.510	0.121
Mode	18.277	0.728	1.510	0.482
Percentile 50	13.598	0.260	1.510	0.172
Percentile 75	16.851	0.585	1.510	0.387
Percentile 80	16.893	0.589	1.510	0.390
Percentile 90	17.233	0.623	1.510	0.413

TABLE 13 and TABLE 14 show the priorities for each type of aggregation method for each sample category. The number in each cell shows the alternative chosen for that level of the 1 to 11 hierarchy. The list of alternatives related to each number is shown in TABLE 9. The hierarchy for the criteria can be calculated by normalizing the Eigenvector.

TABLE 13 Priorities matrix for the group of "Dulces Labios"

Data aggregation type	*Ranking of Project Evaluation Criteria*										
	1st	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11th**
Average	2	4	1	3	7	6	5	11	8	9	10
Geometric mean	2	4	11	7	6	5	10	9	8	1	3
Harmonic mean	11	10	9	2	7	8	4	6	5	3	1
Mode	2	4	11	5	7	6	10	9	1	3	8
Percentile 50	2	4	11	7	5	9	6	8	10	3	1
Percentile 75	2	4	1	3	6	7	5	11	8	9	10
Percentile 80	2	4	1	3	6	7	5	11	10	8	9
Percentile 90	1	2	3	4	5	6	7	11	8	9	10

TABLE 14 Priorities matrix for group of "others"

Data aggregation type	*Ranking of Project Evaluation Criteria*										
	1st	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11th**
Average	2	4	1	6	3	7	5	8	9	11	10
Geometric mean	11	4	2	6	7	9	8	10	1	5	3
Harmonic mean	11	10	9	8	7	6	4	2	5	1	3
Mode	11	4	7	6	2	10	8	1	9	5	3
Percentile 50	11	4	6	7	2	8	10	9	1	5	3
Percentile 75	2	1	4	7	6	3	5	8	11	9	10
Percentile 80	2	1	4	6	7	3	5	9	8	10	11
Percentile 90	1	2	4	3	5	6	7	9	8	11	10

A comparison between the two methods with the lowest CR and the answers directly pulled from people was performed. The results are shown in Table 11.

TABLE 15 Hierarchy from AHP and Frequency of Responses in the Questionnaire

Ranking	Hierarchy from AHP: Arithmetic mean	Hierarchy from AHP: Geometric mean	Questionnaire respond frequency
1st	2	2	2
2nd	4	4	11
3rd	1	11	4
4th	3	7	7
5th	7	6	5
6th	6	5	10
7th	5	10	6
8th	11	9	8
9th	8	8	9
10th	9	1	3
11th	10	3	1
CR	**0.128**	**0.074**	

The final list of hierarchy is show on TABLE 16. This criteria list was used as criteria design for the elaboration of the redevelopment alternatives.

TABLE 16 Hierarchical List of Criteria (Geometric mean, CR=0.07)

Criteria	Eigenvalue	Hierarchy
Generation of employment and economic activity in the community	0.19312	**1st**
Reduction of air and water pollution	0.13361	**2nd**
Safety Improvements of transportation infrastructure and operations	0.11531	**3rd**
Infrastructure for bicycle pedestrian movement	0.10391	**4th**
Ecologically friendly Infrastructure. (Recycled materials, Solar energy, etc.)	0.07713	**5th**
Including greenery and landscaping	0.07532	**6th**
Preservation of cultural, historic and archeological elements	0.07256	**7th**
Self – Sustainable financial system	0.06485	**8th**
Reduction of vehicle operation cost	0.06151	**9th**
Reduction of travel time	0.05194	**10th**
Rapid construction of the infrastructure	0.05073	**11th**

4.3 Logistic regression

Logistic regression is a special case of the Generalized Linear Models (GLM). GLM are the integration of linear and non-linear models that present normal or non-normal response distributions. It also encompasses discrete and categorical variables. The response variable must follow an exponential family distribution (there are: normal, Poisson, binomial, exponential, Bernoulli, gamma among others distributions). Nevertheless, the objective of finding the best and most reasonable model to describe the relationship among an outcome and a set of independent variables remains the same (Hosmer and Lemeshow, 2000). Unlike ordinary regression models, the logistic regression model presents a nonlinear relationship between the response (outcome) and independent (predictor or covariate) variables. The response variable only has two possible outcomes: they are success or failure, sometimes represented as 0 and 1 (dichotomous variable). This does not necessarily mean that the response variable will take those values; they could be a translation of any dual qualitative outcome. For instance, whether or not a person chooses to travel by bus, or if a student passes or not fails an exam. Logistic regression is especially attractive when dealing with non-normal distributed responses and or non-constant variances (Agresti, 2002; Hosmer and Lemeshow, 2000; Montgomery and Runger, 2006). More details about the Logistic Regression can be found in Appendix 7.6

For a binary response variable "Y" and an explanatory variable "X", let $\pi(x) = P(Y = 1|X = x) = 1 - P(Y = 0|X = x)$. The logistic regression model is:

$$E(Y|x) = \pi(x) = \frac{e^{(\beta_0+\beta_1 x)}}{1 + e^{\beta_0+\beta_1 x}} = \frac{1}{1 + e^{[-(\beta_0+\beta_1 x)]}} \qquad (7)$$

The logit transformation corresponds to a linearization of the logistic regression model. The log odds, called the logit, has the following expression:

$$\text{logit}[\pi(\text{x})] = \log\left(\frac{\pi(\text{x})}{1 - \pi(\text{x})}\right) = \beta_0 + \beta_1 x \qquad (8)$$

The evaluation of the significance of the coefficients is performed by comparing the observed values to the predicted values with and without the variable in question. This comparison does not constitute a “goodness-of-fit” test, but rather is a relative comparison among the models that include different variables. The comparison is based on the log likelihood function $[l(\beta)]$ for both the fitted and saturated model.

Logistics regression can take into account different kind of independent variables, including interval, ordinal, and nominal variables. In the case variables are merely identifiers, a collection of design variables (dummy or indicator variables) must be used (Agresti, 2002). For instance, the model to be developed considers three level of education (EDU), two dummy variables will be needed (EDU1, EDU2). The values for each dummy variable representing the three education levels groups are given in TABLE 18.

TABLE 17 Dummy variables for a there level categorical variable

Education level	***Design variable***	
	EDU1	EDU2
Level 1	0	0
Level 2	0	1
Level 3	1	0

4.3.1 Logistic regression modeling

The part I and II of the questionnaire 1 gathered demographic and mobility information respondents. The gathered information included different types of variables, including nominal (place of residence), ordinal (education level) and intervals (number of vehicles per household) as predictors and a dichotomous output as the dependent variable. A binary logistic regression was chosen for the analysis. The gathered information was tabulated and grouped in a set of variables that constitute the predictor variables of the model. Discrete variables such as age were taken as continuous variables, and discrete variables such as number of people and vehicles per household were used as continuous by using a ratio. The dichotomous outcome variable is determined by the selection or non-selection of a criteria design obtained from the part III of the questionnaire. The selection and grouping of criteria were based on the levels of statistical significance. The models with reduced number of variables were compared with the full model containing all variables (Hosmer and Lemeshow, 2000). There are eleven output criteria and their selection was assumed to be independent from each other. The set of grouped predictor variables was the same when modeling each of logistic regression. The predictor variables are shown in TABLE 18. The variable corresponding to "primary mode of transportation" (PRIM) is a three-level category variable and two dummy variables (PRIM1, PRIM2) were generated to enter it in the model. If the criterion was selected in the survey, the dichotomous response variable took the value of 1, otherwise 0. The same binary values were assigned for sex (male, female), place of residence ("*Dulces labios*", other), level of education, participation in public hearings, level of awareness about Project Development Process and Public Involvement, and level of awareness about sustainable development and Environmental Impact Assessments. The binary logistic regression will show the probability of selecting each criterion based on these predictor variables.

For the modeling process the statistical software Minitab version 16 was used. Eleven binary regressions corresponding to each one of the selected criteria (TABLE 9) were modeled. TABLE 19 presents a summary of the β estimates ($\hat{\beta}$) and its corresponding significance based on a p-value of 0.10 for each logistic regression. The variables that resulted statistically significant at that alpha level are highlighted. Additionally, a forward stepwise, and variance inflation factor (VIF) analysis for each regression were also performed. The results are shown in appendix 7.6

TABLE 20 presents an example of the logistic regression output from the statistical software Minitab. This logistic regression corresponds to the criteria (11) "Safety Improvements of transportation infrastructure and operations" (see TABLE 9). The logistic output tables for criteria (1) to (10) can be found in appendix 7.7. The output includes the estimators ($\hat{\beta}$), the p-values, the ODDs ratios, log-likelihood of the model, and a chi-square test for the categorical variables.

TABLE 18 Predictors code table

Description	*Code / Values*	*Name*
Constant	numeric	Constant
Age	Years	AGE
Sex	1=Male 0=Female	GEN
Place of residence	1="Dulces labios" group 0 = "Others" group	CATV
Ratio vehicles/people per household	Numeric	RTVR
Level of awareness about the Project Development Process or/and Public hearings,	1=Knows or have heard about it 0= None	PDP1
Level of awareness about Sustainable Development or Environmental Impact Assessments	1=Knows or have heard about it 0= None	EISD
Participation in at least 1 public hearing	1=Participated 0 = None	PPUH
Primary mode of transportation	0=Private car or carpool, 1= Trolley, Bus, train, or "*carros públicos*" 2=Walking or biking	PRIM
Level of education	0=none or basic education (elementary, intermediate, superior) 1=Higher education (Associate degree, certificates, postgraduate)	EDU2

TABLE 19 Summary of the β estimates (β̂).

Highlighted cells correspond to significant variables at alpha level of 0.10.

Predictor	$\hat{\beta}$ *coefficients for criterion:* (2)	(4)	(11)	(7)	(6)	(5)	(10)	(9)	(8)	(1)	(3)
Constant	-0.56	0.44	-0.21	0.09	-1.15	-0.96	-2.26	-1.66	-2.39	-1.63	-2.25
AGE	0.00	-0.03	0.03	0.00	0.00	-0.01	0.00	0.00	0.00	-0.01	0.02
GEN	0.58	-0.25	-0.01	0.48	0.24	0.55	-0.09	0.54	0.57	0.21	-0.66
CATV	1.55	1.43	-0.09	-0.08	-0.22	0.20	0.03	-0.28	0.24	-0.50	-0.67
RTVR	0.36	-0.18	-0.39	-0.30	-0.09	0.27	-0.57	-0.66	0.18	-0.20	-1.29
PDP1	0.63	-0.60	-0.39	-0.56	0.56	0.27	1.27	-0.04	0.60	-0.28	-0.05
EISD	-1.36	0.46	-0.35	0.18	-0.35	-0.24	0.31	-0.02	-0.58	0.49	0.69
PPUH	0.01	0.72	0.42	-0.42	-0.11	0.35	-0.86	0.60	-0.18	-0.37	-1.41
EDU2	-0.02	0.04	-1.15	0.16	0.29	-0.08	-0.31	0.81	0.75	0.70	0.06
PRIM1											
1	-1.02	-0.58	-0.76	0.01	-0.15	-0.35	0.50	-0.31	-0.89	0.44	0.16
2	-0.10	-0.21	-0.43	0.05	-0.10	-0.11	0.69	-0.73	-0.09	0.05	-0.09

The p-value for the statistic G in TABLE 20 indicates that a least one of the coefficients is different from 0. This statistics can be found by comparing the log likelihood of the fitted model including all the independent variables and the constant only model. Then the null hypothesis (H_0) that all the coefficients are zero is rejected (G=34.92, p-value<0.001). As we rejected H_0, it is concluded that at least one explanatory variable can be used to predict the criteria (11) will be selected. The p-values for each variable show that the null hypothesis that the coefficient is 0 can only be rejected for the variables AGE and EDU2. The corresponding ODDS ratio is the change in the event odds [P(event=selection)/P(non-event=no selection)] for every unit increase in the variable while holding the other variables fixed. Then, the estimated coefficient of 0.030 for AGE is the change in the log of P(selection)/P(no selection) with one year increase in age, with the factor EDU2 held in constant. The estimated odds ratio for AGE is 1.03; meaning that for each additional increase of one year in the age, the odds of selecting the criteria (11) increase by 3%. However, this odd is very close one, indicating that the increase in one year in age minimally affects the preference of the person. However, a more meaningful difference would be found in greater periods of time. The confidence interval for AGE is positive, meaning that the interval doesn't include the number one. This fact means that the odds of choosing the criteria (preference, value =1) increase along with the predictor AGE.

TABLE 20 Logistic regression output for criteria (11): Safety Improvements of transportation infrastructure and operations

Predictor	Coef	SE Coef	Z	P	*Odds* Ratio	*90% CI* Lower	Upper
Constant	-0.210	0.617	-0.340	0.733			
AGE	0.030	0.009	3.200	0.001	1.030	1.010	1.050
GEN	-0.008	0.337	-0.020	0.981	0.990	0.570	1.730
CATV	-0.088	0.409	-0.220	0.830	0.920	0.470	1.790
RTVR	-0.389	0.496	-0.780	0.433	0.680	0.300	1.530
PDP1	-0.390	0.472	-0.830	0.409	0.680	0.310	1.470
EISD	-0.347	0.389	-0.890	0.371	0.710	0.370	1.340
PPUH	0.418	0.446	0.940	0.349	1.520	0.730	3.160
EDU2	-1.147	0.365	-3.150	0.002	0.320	0.170	0.580
PRIM1							
1	-0.764	0.518	-1.480	0.140	0.470	0.200	1.090
2	-0.429	0.474	-0.900	0.366	0.650	0.300	1.420

Tests for terms with more than 1 degree of freedom :

Term	Chi-Square	DF	P
PRIM1	2.450	2	0.294

Log-Likelihood =-110.938

Test that all slopes are zero: G = 34.920, DF = 10, P-Value = 0.000

Goodness-of-Fit Tests

Method	X^2	DF	P
Pearson	186.125	174	0.251
Deviance	221.876	174	0.008
Hosmer-Lemeshow	6.528	8	0.588

The estimated coefficient of -1.147 for Education (2) represents the change in the log of P(selection)/P(no selection) compared when the subject has completed the predefined level 1 of education compared with the subject completed level 2 of education, with the covariate AGE held in constant. The goodness-of-fit part indicates whether or not there is sufficient evidence to claim that the model does not fit the data adequately. For criteria (11), the Person and Hosmer-Lemeshow do not reject the null hypothesis (H_0= adequate fit) at an alpha level of 0.10. On the other hand, the deviance test suggests there is evidence that the model does not fit the data well. However, as seen in TABLE 21, the observed and predicted data values are very similar.

TABLE 21 Table of Observed and Expected Frequencies for criteria (11)

	Group 1	2	3	4	5	6	7	8	9	10	Total
Value											
Observed =1	2	6	2	7	9	9	10	13	15	13	86
Expexted = 1	2.9	4.3	4.9	6.2	7.4	8.6	11.1	11.9	13.8	15	
Observed = 0	16	13	16	12	10	9	9	5	4	6	100
Expexted = 0	15.1	14.7	13.1	12.8	11.6	9.4	7.9	6.1	5.2	4	
Total	18	19	18	19	19	18	19	18	19	19	186

The variables were introduced in the model as a block in a single step. This process was performed using the software SPSS version 21. The variables considered to be significant were selected based on their p-values values. Additionally the significance of the categorical variable (factor variables with two or more degrees of freedom) was tested. In TABLE 20, the categorical variable PRIM1 possessed 3 levels and thus, 2 degrees of freedom. It has a chi-square value of 2.45, resulting in a not significant effect (p-value > 0.10) The resulting fitted model included as significant variables age (AGE) and level of education (EDU2). Additionally, a forward variable selection can be performed to construct the model with only significant variables (TABLE A 11). The resulting logistic regression model (with entry probability for stepwise of 0.05 and removal of 0.10) for the selection of the criteria [11] is:

$$\hat{\pi}_{11}(\mathrm{AGE}, \mathrm{EDU2}) = \frac{e^{-0.980+0.027AGE-1.090EDU2}}{1+e^{-0.980+0.027AGE-1.090EDU2}} \tag{16}$$

And the logit is:

$$\ln\left(\frac{\pi_i}{1-\pi_i}\right) = g(x) = -0.980 + 0.027AGE - 1.090EDU2 \tag{17}$$

The estimated logit for an average of age of 46 years old and a level of education equal or lower than high school is:

$$g(x) = -0.980 + 0.027(46) - 1.090(0) = 0.262 \tag{18}$$

Then, the estimated proportion of preference among 46 year old people with Superior education is 0.565.

$$\hat{\pi}(AGE = 46, EDU2 = 0) = \frac{e^{0.262}}{1+e^{0.262}} = 0.565 \tag{19}$$

In the same vain, for people with higher level of education (EDU2=1), the estimated logit for an average age of 46 years old is:

$$g(x) = -0.980 + 0.027(46) - 1.090(1) = -0.828 \tag{20}$$

Then, the estimated proportion of preference among 46 year old people is 0.304:

$$\hat{\pi}(AGE = 46, EDU2 = 1) = \frac{e^{-0.828}}{1+e^{-0.828}} = 0.304 \tag{21}$$

TABLE 22 indicates that the model classified adequately 52 respondents who selected the criteria (11) and 73 who did not select it. However it misclassified 27 answers as selected and 34 as not selected. The overall accuracy of the model expressed as percentage of correct classification is 67.2%.

TABLE 22 Classification Table

Observed		*Predicted*		
		CRITa		Percentage Correct
		0	1	
CRIT [11]	0	73	27	73%
	1	34	52	60.5%
Overall Percentage				67.2%

TABLE 20 also show the values of the odds ratio which give the change in odds resulting from a unit change in the predictor variable, and the corresponding 90% confidence intervals (CI). The odds are defined as the ratio of the probability of an event occurring and the probability of that event not occurring (Hosmer and Lemeshow, 2000). Both intervals (for variable AGE, and EDU2) do not cross the number 1, meaning that as the predictor increase (AGE) the odds of selecting the design criterion [11] also increase (CI ranges from 1.01 to 1.05). Contrariwise, with the increase of the predictor variable EDU2 the odds of selecting the criterion [11] decrease, presenting a CI from 0.17 to 0.58, or 17/100 to 58/100.

Summarizing from TABLE 19, the variables that most influenced the selection of the criteria are the age, gender, level of education and participation in public hearings. For criteria [2], gender presents an odd ratio of 1.78 (TABLE A 2) which means that the odds of a respondent being male are 1.78 times higher to select the criteria [2] than female respondents (when all the rest of variables are held in constant). This trend is confirmed because the confidence interval (90% of confidence level) does not include the number 1. For the same variable, the odds of respondents whose place of residence is the Community of "Dulces Labios" to select criterion [2] (Generation of employment and economic activity in the community) are 4.71 times higher than those whose place of residence is not the community of “Dulces Labios”. The corresponding confidence interval (CI) ranges from 2.07 to 10.72. The “EISD" variable (TABLE 18) has an odd ratio of 0.26 (CI from 0.11 to 0.6) (TABLE A 2), meaning that as people get aware about the concept sustainable development and environmental impact assessments the selection of the criteria [2] decrease. Finally, the variable related to primary mode of transportation has some evidence of significant influence, however the chi-square test to this variable gave a p-value>0.10, and the variable was discarded as significant.

The selection of criteria [4] (Reduction of air and water pollution) was influenced by place of residence of respondents and if they had participated in a Public Hearing (PPUH). The results indicated that the odds of selecting this criterion are 4.19 times higher if the respondent is a resident of the community of “Dulces Labios” when compared to the “others” group. Regarding to the variable PPUH, the confidence interval varies from 0.42 to 2.47 meaning that there is a chance that the relationship between the outcome and this predictor variable might change of direction in the population. However, the apparent relationship states that the odds of selecting these criteria are two times higher if the respondent had attended to a Public Hearing.

Criteria [7] (Infrastructure for bicycle/pedestrian movement) didn’t seem to be influenced by any of the selected predictor variables; nevertheless, there is some statistical evidence that gender influenced in this variable selection. The same was for criterion [2] (Generation of employment and economic activity in the community) with the variable level of education and criterion [6] (Ecologically-friendly Infrastructure) with the variable “level of awareness about Public Hearings and Project development process”

The selection of criteria [8] and [9] (Reduction of vehicle operating cost, and Self – Sustainable financial system) were influenced by the level of education. As the level of education increase the odds of selecting this variable also increase. However, in both cases the confidence interval includes the number 1, which means that the direction of the influence may vary in the population.

The odds of selecting of the criterion [3] (Rapid construction of the infrastructure) and criterion [10] (Preservation of cultural, historic and archeological elements) decrease as the respondents had attended to a Public Hearing.

TABLE 23 shows the Variance Inflation Factor (VIF) and tolerance for each of the predictor variables used in the logistic regression for criteria [11]. These values are used to test the multi-collinearity in the variables. The tolerance values are well higher than 0.1 (Field, 2009) and the VIF are lower than 10 (Field, 2009), which imply there are not issues of collinearity among predictor variables .

TABLE 23 Variance Inflation Factors (VIF) and tolerance for predictor variables for Criteria [11] selection.

	Tolerance	*VIF*
AGE	.753	1.328
GEN	.942	1.062
CATV	.665	1.505
RTVR	.751	1.332
PRIM1	.845	1.184
PDP1	.801	1.248
EISD	.749	1.335
PPUH	.835	1.198
EDU2	.828	1.208

5 VISUALIZATIONS DESIGN AND EVALUATION

Each feature was visually represented using computer-aided graphics software. The generated features were placed on a map along with the others in order to constitute a given scenario. Two main processes were carried on for the elaboration of the visuals. The first one was the construction of a "Base Scenario" that is directed to reflect the current state of the area of study. The second process aimed to generate four design scenarios for the re-development of the chosen highway. Both processes were intrinsically related because one occurs iteratively within the other. The steps followed for the development of the "Base Scenario" are summarized in the shadowed boxes of FIGURE 20. The final output of this first process constitutes the alternative denominated "Do-Nothing".

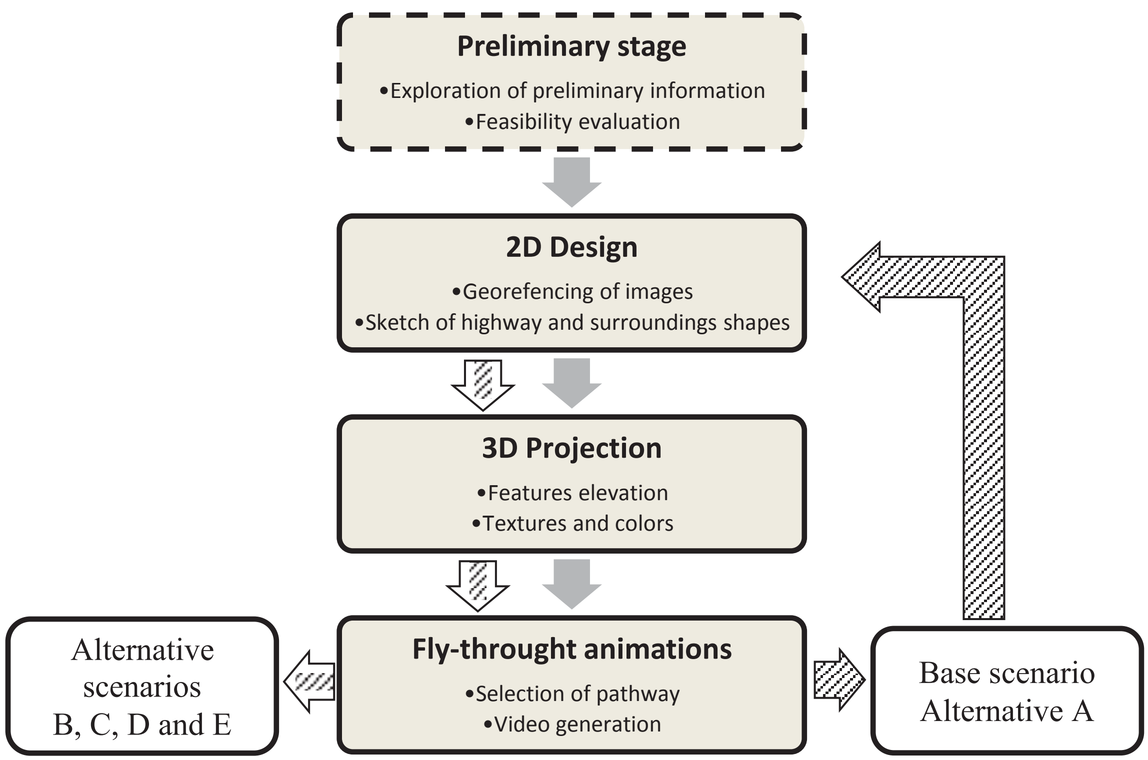

FIGURE 20 Visualizations construction process

In the preliminary stage, a group of corridors that cross the community were analyzed, and some general geometric information was gathered. More importantly, the community board was consulted about the suitability of the highway as a case study. Among all available options, highway PR-102 possesses unique attributes: it runs across the community from north to south, the cross section width is approximately 100 feet, including 3 lanes in each direction; there are sidewalks on both sides, and a 12 feet median. In addition, the surroundings of PR-102 present a mixed land use zone where business, educational and recreational activities take place. These characteristics permitted the exploration of a wide range of options to match each of criterion design. Despite some variation in dimensions, e.g., sidewalk width, the typical cross section is shown in FIGURE 21.

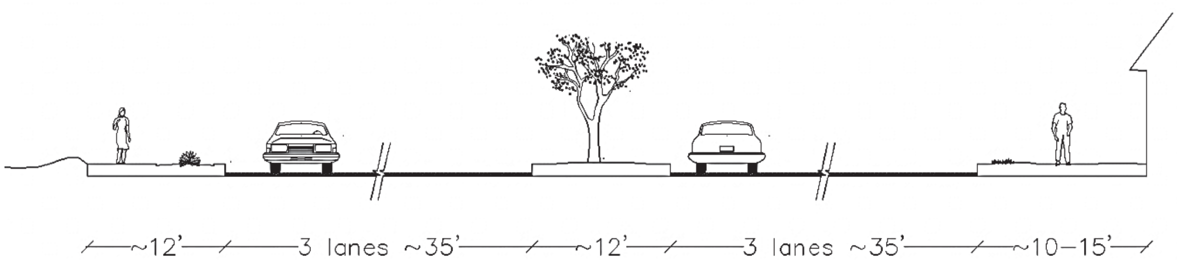

FIGURE 21 Cross section of highway PR-102

Other characteristics of the highway segment, include: the length is 2,830 feet (~860 meters), the pavement surface is made of asphalt concrete, the posted speed limit is 35 mph, and the average daily traffic was 22,400 vehicles in the year 2004 (DTOP, 2010b). The preliminary stage culminated with an exploratory visit to the selected area.

The second stage of the visualizations design was to sketch the highway and surrounding features in a two dimensional plan. During this stage, 2D satellite images were imported using The “geo-location” tool from Google SketchUp ® version 8. These images are geo-referenced to a UTM using a cylindrical WGS84 projection. Using the same software, the horizontal geometry of the highway, feeder streets, surrounding properties and open areas such as parking areas, were located and drawn. Most of the highway segment was located in tangent; however, two horizontal curves were aligned with the tangent in order to simplify the design. Vertical curves or high longitudinal grades were not present. The width and composition of sidewalks and median were standardized in a attempt to reflect their most visible attributes. Around 60 facilities were represented including 02 schools, 01 temple, 15 business places, and 45 residential places. All of them were located within a 300 feet left offset of the highway edge. The right side of the highway present an open area followed by the coastline of Mayaguez. FIGURE 22 shows the 2D sketching process for the shape of the facilities.

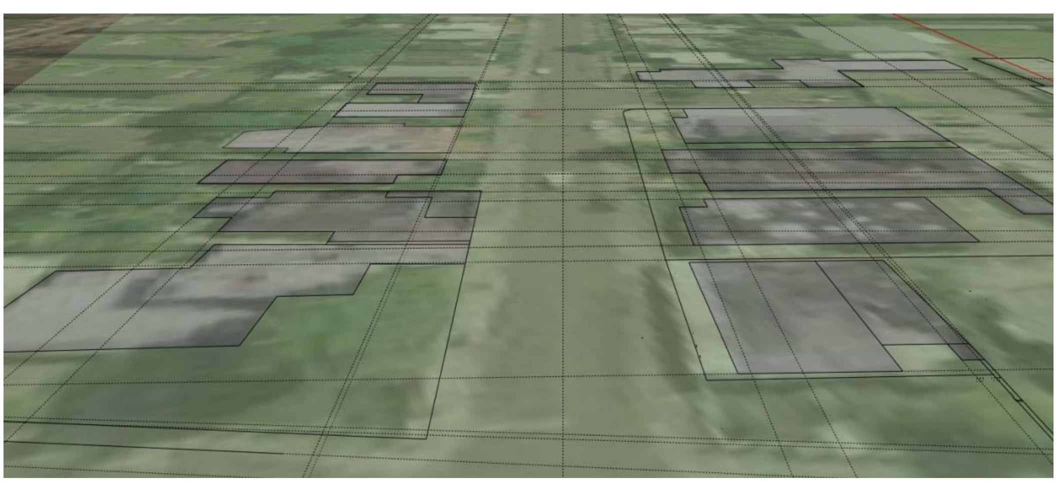

FIGURE 22 Sample of 2D sketching of facilities shape

The third stage consisted of adding elevation and components such as doors, windows, and fences, to each of the generated features. Textures and colors were added to the new faces in elevation. Also at this stage, particular elements such as signs, trees and electric posts were located and drawn. This third stage was, in turn, divided in two stages. The first stage included visiting the area of study and generating a photographic record of the features to be modeled in 3 dimensions. The field work demanded the participation of members from the community board due to the need for pictures of private residences along the highway. Ate the second stage, the pictures were scaled and the height of features was taken. The height was used for dimensioning the elevation of 2-dimensional shapes generated during stage two. The pictures were also used to generate textures and perspectives in order to add realism to the 3-D features. Photo simulations techniques were also applied. Two dimensional pictures with perspective were transformed in 3D features using the "*Match Photo*" tool, in which Cartesian axis for both the picture and drawing were aligned and scaled.

FIGURE 23 Example of three-dimensional model

The desired level of realism to be reached was such that people would recognize and feel related to the elements presented in the visualizations. Moreover, special emphasis was put on showing how the infrastructure will work. For that reason different kind of users (e.g., pedestrians and vehicles) were added. FIGURE 23 shows the 3-dimensional model of a commercial facility. FIGURE 24 shows the base scenario of the highway.

FIGURE 24 Base scenario, "Do-Nothing" alternative

The final stage of the visualization design was to generate a fly-though animation. This included creating a pathway showing the main characteristics and attributes of each given alternative. The animation time was around 1 minute. The chosen video format was the Audio Video Interleave (AVI) at a rate of 15 frames per second. The output of this stage represents the "base scenario", that in this study will be also denominated "Do Nothing" alternative and will be labeled as the Alternative "A" in subsequent paragraphs.

The second process of the visualizations design consisted in the construction of 4 different scenarios for a hypothetical re-development of highway PR-102. This process performed iteratively the stage two, three and four of the first process (explained above). This corresponds to the white boxes and hatched arrows in FIGURE 20.

Each scenario was constructed based on a combination of specific features aligned to certain set of the criteria previously selected in chapter 4. The eleven criteria were grouped taking into account the level of preference. On one side, the first scenario represented the set of most preferred criteria, and on the other, the fourth scenario reflected the set of less preferred criteria. The other two alternatives aim to reflect the middle –preferred criteria as shown in FIGURE 25.

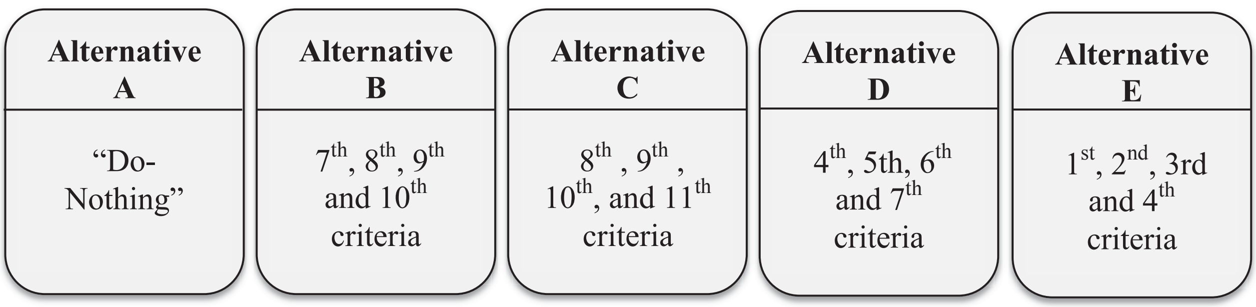

FIGURE 25 Grouping of selected criteria per alternative.

Features addressing each criterion were selected and loaded into the base scenario, thereafter referred as Alternative "A". New features were selected using the author's engineering judgment, and suggestions from experts. They included: wider sidewalks, bike lanes, bus lanes, reversible lanes, traffic calming elements, urban art, parking, pedestrian bridges, solar panels, horizontal marking and kiosks. Alternative "A" ("Do-Nothing" alternative) was modified adding these features according to the corresponding set of criteria (FIGURE 25). As a result, alternatives "B" to "D" were generated. Additionally, in order to reflect the functionality of the system, people, trolleys and cars were added into each scenario.

Alternative “B” included the following: exclusive bus lane, greenery in sidewalks and median, electric poles with solar panels, and ornamental sidewalks surface and urban art.

FIGURE 26 Scenario for alternative B

Alternative “C” included: exclusive bus lane, reversible lane instead of median, additional parking areas, and pedestrians bridges. Alternative “D” included: wider left sidewalk in place of the left-most highway lane, greenery in sidewalks and medians, speed bumps, a bike lane on the right side in the place of one highway lane, electric poles with solar panels, and ornamental sidewalks surface and urban art. Alternative “E” included a wider left sidewalk instead of one highway lane, kiosk along the left sidewalk, speed bumps, improved horizontal marking, storm water treatment, a bike lane on the right side in the place of one highway lane. The visualizations were intended to encourage not only discussion of characteristics or dimensions, but also the discussion of whether or not to include specific features. Visualizations allowed the exploration of alternative solutions alternatives to specific issues, taking into account the community values. These visualizations may be able to reflect different features that can be isolated in order to explore other specific design characteristics. FIGURE 24 through FIGURE 29 show alternatives "A" through "E" respectively.

FIGURE 27 Scenario for alternative C

FIGURE 28 Scenario for alternative D

FIGURE 29 Scenario for alternative E

Three of criteria shown in FIGURE 25 were difficult to represent in the visualizations due to its abstract concept or difficult understanding for lay people. They were self-sustainability of infrastructure, rapid construction of infrastructure, ecologically friendly infrastructure. For that reason, a brief description of the contained features was given to respondents when shown the multimedia presentation. A special care was took it in to account to ensure the neutrality in the description of features in order to minimize a possible a bias in respondents' preference. Nevertheless the description was added, respondents were still found difficult to identify the design criteria in the visualizations. The development of the visualizations required approximately 14 weeks, divided as follows: 2 weeks in preparatory training in Google SketchUp v8, 4 weeks to build the current corridor and surroundings, which constitute the "Do-Nothing" alternative, and 2 weeks per each alternative.

5.1 Visual preference questionnaire

The third part of the methodology process (see FIGURE 8) included the evaluation of preferences over the designed alternatives. In order to achieve this objective a dual instrument was developed: a written questionnaire and a multimedia presentation. The questionnaire was chosen because, as explained in subtitle 4.1, the simplicity and accessibility of this method is suitable for the local context. The questionnaire contains seven questions divided in two parts. The first part asks about the elements, characteristics or attributes that the respondent likes or dislikes of alternatives “A” through “E”. The second part of the questionnaire is composed of two questions. The first question asks respondents to establish a hierarchy of preference with regard to the 5 presented scenarios. The second question evaluate whether or not the desired characteristics and/or attributes of each visual were perceived by respondents. This question was presented in the form a matrix where rows containing specific questions and columns list all the alternatives plus a “none” option. The matrix possesses eleven rows corresponding to each design criterion (see TABLE 24). The questionnaire was presented on two separated sheets in order to be divisible. The latter allows respondents to see their answers from part 1 while answering part 2.

The questionnaire was complemented by an oral and multimedia presentation. The presentation includes a brief overview of the study and gave the location of the study area. Afterwards, a slide describing the main visual features of alternative “A” is shown, followed by a slide with the fly-through animation. At the end of the animation respondents are requested to fill out part 1 of the written questionnaire as explained above. This part of the questionnaire was executed by showing to respondents the slide outlining the features presented, and the 3-D fly-through animations of each alternative. The process is repeated until the 5 alternatives are presented. The presentation then introduces a slide showing the five alternatives simultaneously and respondents are requested to fill out part 2 of the questionnaire.

TABLE 24 Matrix of Questions, Questionnaire B (part II)

According to your opinion:	Alt A	Alt B	Alt C	Alt D	Alt E	None
Which alternative would generate employment and economic activity in the community?						
Which alternative would reduce air and water pollution?						
Which alternative would reduce the number of traffic accidents?						
Which alternative would improve biking and walking?						
Which alternative does possess ecological friendly Infrastructure?						
Which alternative does favor greenery and landscaping?						
Which alternative does preserve cultural, historic and archeological elements?						
Which alternative would be a self – Sustainable financial system?						
Which alternative would reduce of vehicle operation cost?						
Which alternative would reduce travel time?						
Which alternative would be constructed quickly?						

The questionnaire was developed so as to be filled out by the respondent without assistance. Nevertheless, an interviewer was available to assist respondents because of the interaction between the multimedia presentation and questionnaire. The questionnaire took approximately 30 minutes to be completed.

The targeted people were community leaders and community residents. The sample chosen sample attempted to reach the people surveyed in the 2nd stage of this study (see chapter 4). However, the number of people sampled was smaller due to the process requirements.

In the initial approach consecutive meeting in the community center were planned. Oral and written invitations distributed to residents and posted in local business. The first meeting was set up on Thursday May 23rd. However, the attendance was very poor and only members of the community board were present. Additionally, the participation in local community leaders meeting was planned. The meeting is periodically organized by a non-profit organization denominated "*Fundación 2010*". Nevertheless, the meeting was not scheduled by the time of the research field work. For that reason, a different approach was taken. The sampling technique adopted is denominated "at convenience" and consisted in interviews held at respondent's house and public open areas. Respondents were informed about their rights, such as confidentiality. The multimedia presentation was shown to respondents using a personal computer (PC). A total of 28 questionnaires were filled out in both the meetings and personal interviews. This process took place during the months of July, August and September on 2013. During this process a member of the community board collaborate. Besides the respondents of the community of "Dulces Labios", a comparison group was selected. This group was composed of six peer graduate students, and seventeen high school students attending a transportation summer camp held at the University of Puerto Rico. The sampling was also selected at author's convenience. The process took place during in July for the high school students and September for the peer graduate students. A copy of the questionnaire template can be located in the Appendix 7.2.

5.2 Analysis of Preferences

The data was summarized in tables and analyzed based on the frequencies of the responses. Each categorical level in the hierarchy corresponds to a number from 1 to 5. The resulting set of numbers was assumed to be continuous in order to be analyzed quantitatively. Then basic statistics can be calculated and compared among the groups. The distributions of the preference values were summarized using boxplots in order to analyze the differences in the values assigned to each alternative. Boxplots give a simple graphical idea of the central tendency and variability of each subset of data. Each boxplot reflects the interquartile values of 75% with upper box line, median with middle line, and 25% with the bottom line. It also shows the upper and lower whisker lines. Each line extends to the relative maximum value and relative minimum value within 1.5 times the height of the box (Interquartile range). The outliers are also show in the form of asterisks (*). They represent the values that are beyond the upper or lower whisker line. Finally, the mean is also represented by a combined cross-circular symbol.

FIGURE 30 shows the distribution of the assigned values for each level of the alternatives hierarchy for the "Dulces Labios" group. The number of responses per each alternative is 28. The most preferred scenario was the Alternative "E" with a mean value of 1.5. A total of 75% of respondents assigned a value of 1 in the hierarchy, 10% of them assigned the value of 2, and less that 15% assigned a value of 3,4, or 5. The less preferred scenario corresponds to the Alternative "A" with a mean value of 4.35. More than 85% of respondents assigned the last two places in the hierarchy, only a 14% assigned the values of 2 or 3. None of the respondents assigned the number 1.

Alternatives B and C have a similar mean value; however the quartiles indicate that the alt B as most preferred by a least 50% of the respondents. With regard to the Alternative D, the preference values were consistently located between 2 and 3, with a mean of 2.2.

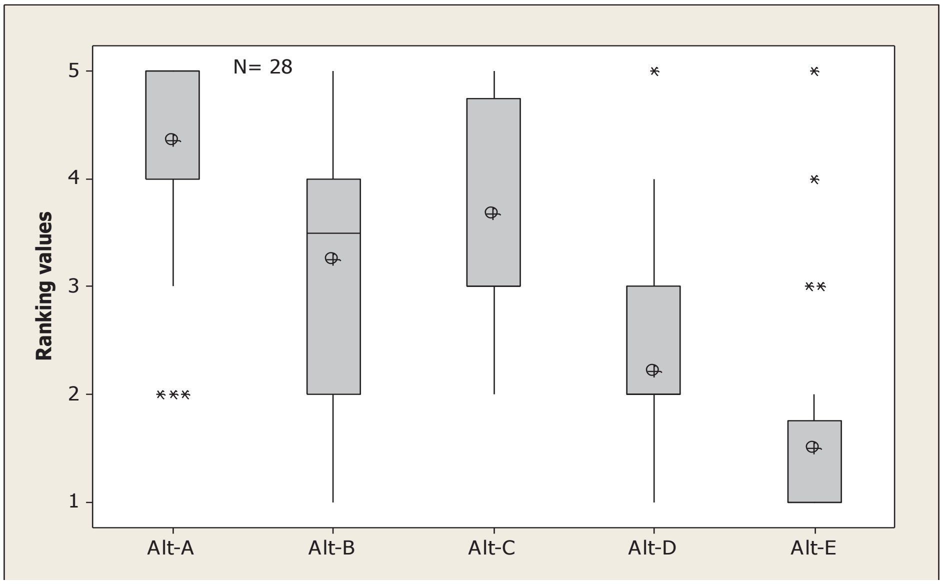

FIGURE 30 Boxplot of preference values for Alternatives A to E for "Dulces Labios" group (N=28).

Some outliers are present in the Alternative A and E. This could be consequence of miss interpretations of the directions given in the question. Some people tended to assign the values in the inverse order that was indicated. The frequency of values for each alternative is shown in the Appendix:. A sample for the Alternative E is shown in FIGURE 31.

The same graphical data analysis was performed for the comparison group (FIGURE 32). The less preferred scenario was also the Alternative A. More than 80% of respondents placed it in the last level of the hierarchy (value of 5); however, a most preferred alternative was not completely defined. Moreover, the dispersion among the assigned values was broader than the “Dulces Labios” group. Although the alternative D was considered the most preferred scenario by at least 50% of respondents, its mean value is similar to the alternative B. The latter possesses consistency in the values of 2 and 3 (69%). The alternative E was, in turn, almost equally distributed among the values of 2, 3, and 4.

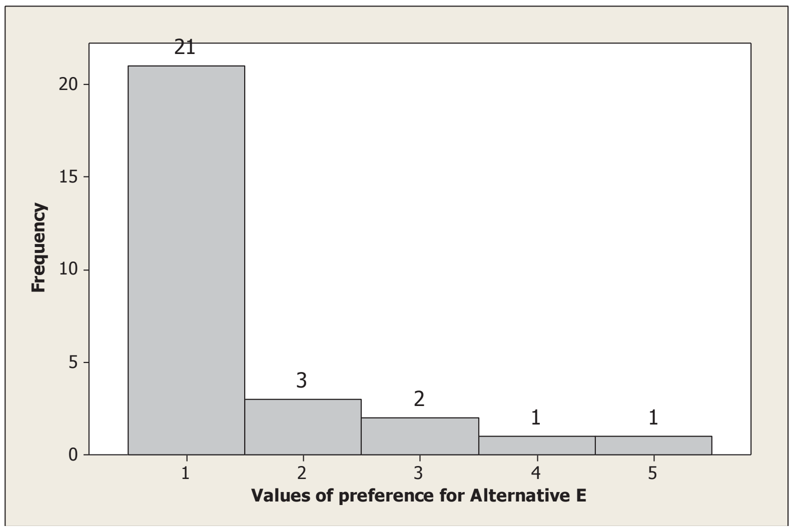

FIGURE 31 Histogram of values of preference for Alternative E in the “Dulces Labios” group.

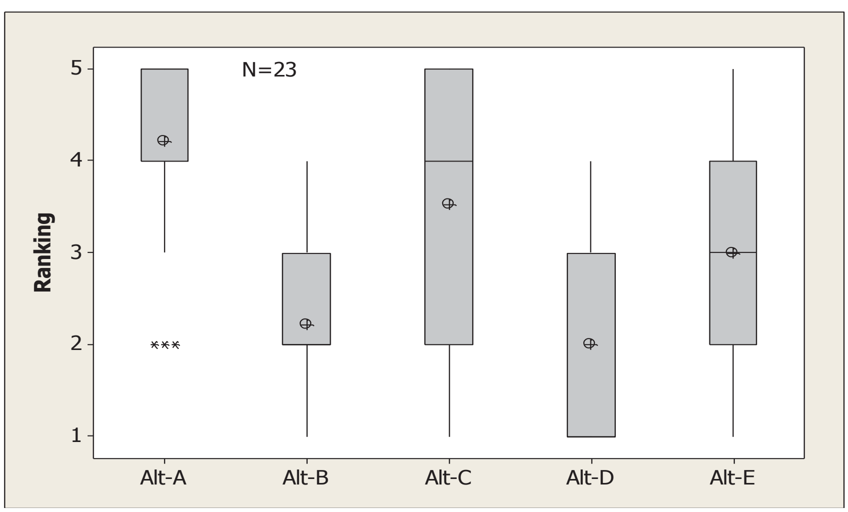

FIGURE 32 Boxplot of preference values for Alternatives A to E for the comparison group (N=23).

Alternative C shows a wide variability among the assigned values. 39% of respondents assigned the value of 5, 21% assigned the value of 4, 17% of them assigned the value of 1, and 21% assigned 21% assigned the value of 2 or 3.

Despite the explicit graphical difference in the values assigned to each alternative for each group (FIGURE 30 and FIGURE 32) a statistical test of differences on the medians was performed. When response variables follow a normal distribution and there exits equal variances, the common method of “Analysis of Variance” (ANOVA) is used. Nevertheless, as shown in FIGURE 31 the responses are left-skewed, and the Anderson-Darling normality test gave a p-Value < 0.005 which means that data is very non-normal. Additionally, FIGURE 33 shows that the variance varies with the fitted value. For that reason, a simple ANOVA cannot be applied and non-parametric comparison method was chosen.

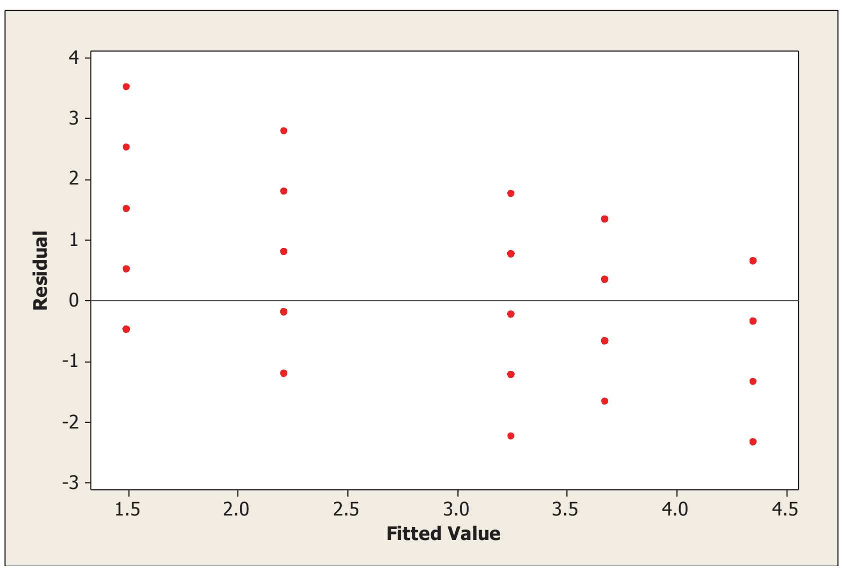

FIGURE 33 Residuals for alternatives A, B, C, D, and E

The method chosen to evaluate the differences in medians among the different alternatives is called the "Friedman" test. It is equivalent to the one-way ANOVA with repeated measures, and it is applied for correlated observations (the assigned value to one alternative is dependent of the values assigned to the others). The dependent variable can be ordinal or interval. The null hypothesis (H_0) is that the treatments effects are zero. The results are shown in TABLE 25.

TABLE 25 Friedman Test on Preferences for the "Dulces Labios" group

Alternative	*N*	*Estimated medians*	*Sum of Ranks*
Alt-A	28	4.4	122
Alt-B	28	3.0	91
Alt-C	28	3.4	103
Alt-D	28	2.2	62
Alt-E	28	1.0	42

S = 58.60 DF = 4 P = 0.000
Grand median = 2.800

The analysis was performed using the statistics package Minitab ® version 16.1. TABLE 25 shows the estimated medians for the 5 alternatives. The lower values in the estimated medians correspond to the most preferred alternatives. Then, alternative E (Alt E), with the smallest median value, was the most preferred alternative for respondents in the community of "Dulces Labios". In the same vein, the median for alternative A correspond to the less preferred alternative. The gran median is 2.8, and the median for each alternative adds a effect on this values. Finally, the test statistic (S) had a p-value of 0.001 indicates that the null hypothesis can be rejected at a levels higher than 0.001.

TABLE 26 Kruskal-Wallis Test on Preferences, comparison group

Alternative	*N*	*Estimated medians*	*Sum of Ranks*
Alt-A	23	4.6	97.5
Alt-B	23	2.6	51.0
Alt-C	23	4.0	81.5
Alt-D	23	1.8	46.0
Alt-E	23	3.0	69.0

S = 31.68 DF = 4 P = 0.000
Grand median = 3.200

Similar to the "Dulces Labios" group there is statistical evidence that at least one alternative is different from the others (p-value<0.001). Alternative A possesses the furthest media in one extreme and alternative D in the other.

The "Mann-Whitney U Test" test was used to test the difference in the median of preference for each alternative in between the respondents in the community of "Dulces Labios", and the respondents in the comparison group. The null hypothesis is that there is no difference in the median for a given alternative "i" (i= A,B,C,D,E) between the two groups group. This test was used to evaluate whether or not the obtained preferences in the visualizations for a given alternative are dependent on the respondents group. The assumptions for this test are similar to the "Kruskal-Wallis Test". It releases the need for normality and equally of variances; however, it is still assumed that the response values similar continuous distributions and they are independent.

TABLE 27 shows the comparison of the medians of preferences for Alternative E between respondents in the community of "Dulces Labios" and the comparison group. The null hypothesis is that both medians are equal. The two-tailed test gave a p-values<0.001, meaning that the null hypothesis Ho: $M_{\text{Dulces-Labios}} = M_{\text{Comparison-group}}$ can be rejected.

Consequently the medians of preference for alternative E in both groups are statistically different. The same test was performed for alternatives A, B, C and D. The results are shown in appendix 7.8.

TABLE 27 Mann-Whitney Test for preferences in Alternative E between the "Dulces Labios" and comparison group

Test Statistics	
	Alternative E
Mann-Whitney U	181.500
Wilcoxon W	587.500
Z	-3.312
Asymp. Sig. (2-tailed)	.001

TABLE 28 Kruskal-Wallis Test for preferences in Alternative E between the "Dulces Labios" and comparison group

SOURCE	*N*	*Median*	*Ave Rank*	*Z*
Dulces Labios	28	1	18	-4.25
Comparion	23	3	35.8	4.25
Overall	51	26		

H = 18.06 DF = 1 P = 0.000
H = 20.22 DF = 1 P = 0.000 (adjusted for ties)

The test statistic (H) (TABLE 28) had a p-value of 0.001, both adjusted and unadjusted for ties indicates that the null hypothesis can be rejected at a levels higher than 0.001. Then, there enough evidence that both median are statistically different.

5.3 Criteria design validation

The second part of the questionnaire aimed to validate the interpretation of the initial respondents' preferences with regard to the design criteria (see FIGURE 24) used in the visualizations (as embodied in Alternatives A-E). The data collected in the criteria selection matrix (TABLE 24) was disaggregated per each alternative. A histogram of the frequencies of criterion selection was selected was generated for each alternative and compared with the set of criteria shown in FIGURE 25. These graphical representations are shown from FIGURE 34 through FIGURE 38. In each graphic, the vertical axis gives the complete list of 11 criteria, whereas the rectangle group the specific set of criteria used in the design of the corresponding alternative. Each bar represents the number of people who that criterion is benefited by the corresponding alternative. Each respondent was asked 11 questions related to the design criteria and six answer alternatives are shown, five corresponding to each alternative and one "none" option. A total of 15 people completed this part of the questionnaire.

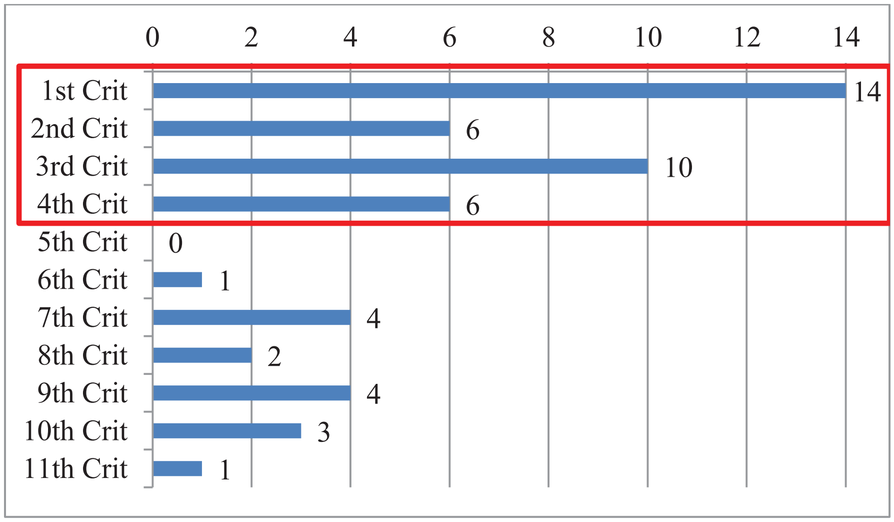

FIGURE 34 Histogram of identified criteria versus selected criteria for Alternative E, “Dulces Labios” group

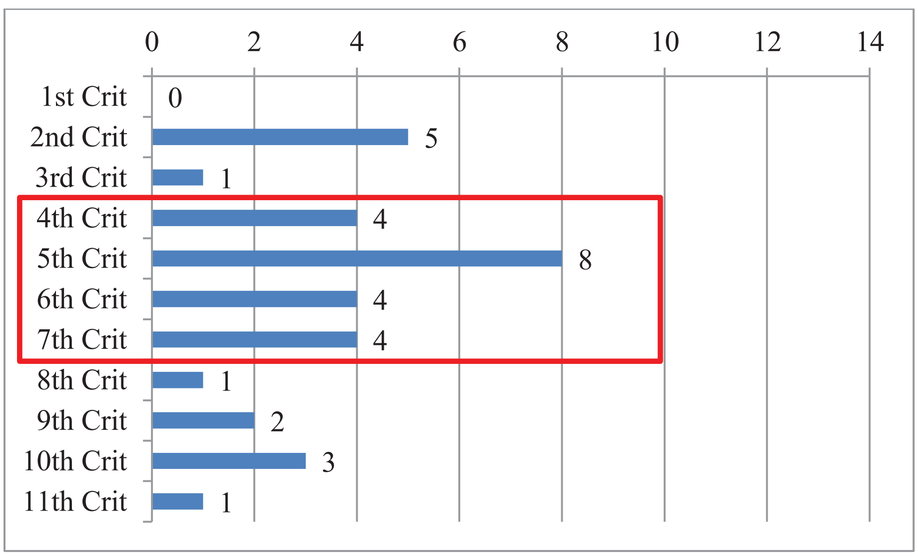

FIGURE 35 Histogram of identified criteria versus selected criteria for Alternative D, “Dulces Labios” group

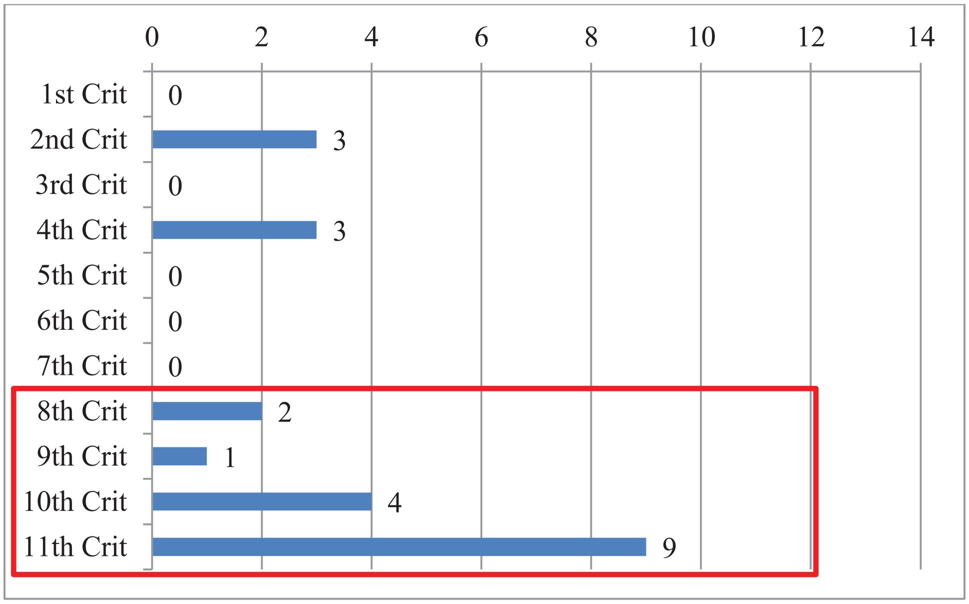

FIGURE 36 Histogram of identified criteria versus selected criteria for Alternative C, "Dulces Labios" group

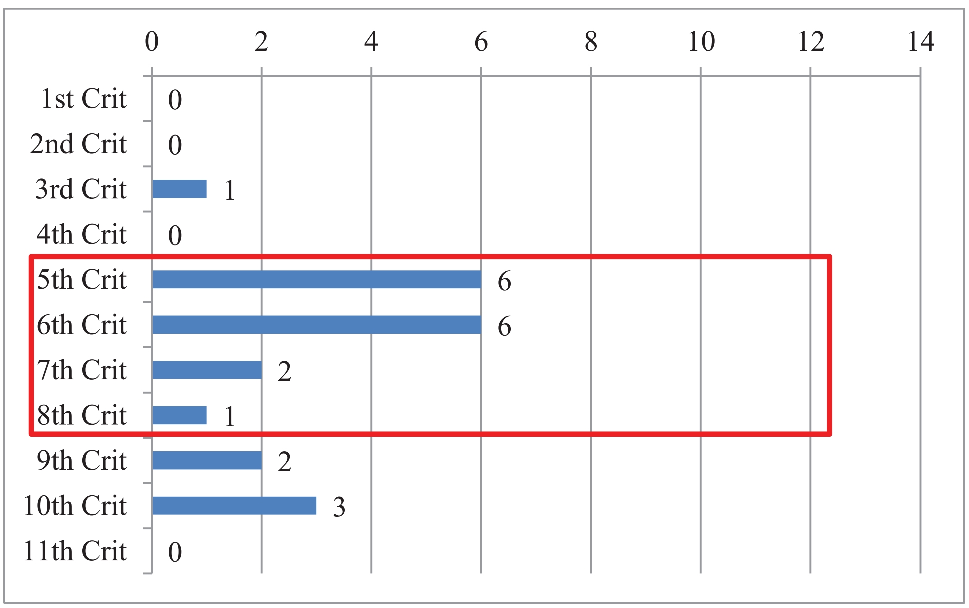

FIGURE 37 Histogram of identified criteria versus selected criteria for Alternative B, "Dulces Labios" group

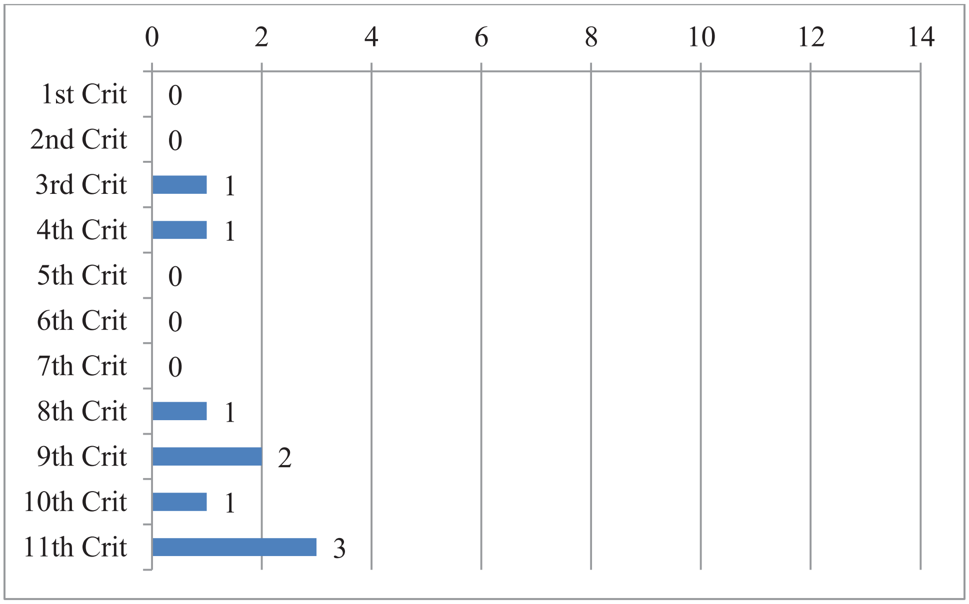

FIGURE 38 Histogram of identified criteria versus selected criteria for Alternative A. "Dulces Labios" group

For each set of design criteria, an ideal frequency value of 15 was expected in each alternative. In FIGURE 34, all of the addressed criteria were adequately identified; however, others criteria such as preservation of cultural elements, Operation cost, and rapid construction were also present Moreover, less that 50% of respondents identified the 2nd and 3rd criteria. This could be caused by different reasons in the design, e.g., inclusion or omission of specific features, questionnaire design and spelling, as well as individual characteristics of respondents, e.g., personal experience. However, because the fuzziness of responses and many factors that influence people behavior, further research must be implemented in this area. The same pattern is seen for alternatives D and C (FIGURE 35 FIGURE 36). Although, alternative D was designed considering the 4th to 7th criteria, the inclusion of greenery and landscaping influenced in the identification of the 2nd criterion

("Reduction air and water pollution") as a criteria design. In the case of alternative C, the four criteria (8th to 11th) were also identified by respondents. Nevertheless, an average of 6 responses was received. Additionally, the 2nd and 4th criteria were also identified. This might be caused by the inclusion of pedestrian bridges and bus lanes. The alternative B, in turn, reflects the criteria 5th and 6th with 6 responses out of 15, and criteria 7th and 8th with only 2 and 1 responses out of 15. Both alternatives C and B included the criterion 8th ("Self – Sustainable financial system") that was expected to have a very low level of identification due to the difficulty of represented it graphically. It was identified only by 3 respondents out of 15. The same phenomenon occurred with criterion 9th ("Reduction of operation cost"). It was only identified by 1 respondent out of 15.

6 CONCLUSIONS, RECOMMENDATIONS AND PERSONAL REFLECTION

6.1 Conclusions

Traditional means of public involvement such as Public Hearings might not reach important groups of people in the community (e.g. minorities, aging people), and they are often conducted at a point in time after important decisions by developers have been made. For that reason a change in the paradigm of public involvement should be promoted.

In this study, early involvement allowed the participation of specific groups such as community leaders and minorities (e.g. aging people, handicapped) that otherwise would not have had the chance to express their opinions in traditional Public Hearings. Early involvement allowed the definition of what is important for interviewed people in the transportation PDP and tailored the design of alternatives around these preferences. Additionally, the use of visualizations promoted a different kind of communication in two ways: first, people easily understood the proposed designs and second, potential designers can get important public feedback. Thus, the combination of early involvement and visualizations has great potential to benefit the process of Public Involvement.

Nevertheless, there are some aspects to be considered. First, early involvement requires logistical resources and trained people to survey people preferences and opinions. Second, there is no standard in the process of transforming preferences and design criteria into visual features. Third, the design of the visualizations required expertise in design software and its elaboration is very time-consuming. Fourth, the quality of the visualizations design of the alternative might influences the results in people preferences.

Approaches such as Sustainable Development, Appropriate Technology and Context Sensitive Designs, different in detail but similar in goals, aim to generate human well-being without disturbing the social, economic or environmental systems. The principles that lay down these approaches have also influenced the transportation sector. Currently the mission and vision of various Department of Transportations and available literature mention mobility, accessibility, environmental stewardship, Public Involvement, among others. However, there exists a gap between what is required in those principles and what it is being done by current practitioners. This study is an effort to close that gap.

In the literature there are many aspects to be considered in the project development process for transportation projects. The selection of criteria to be considered in the study obeys to three main aspects. The first was to cover most of the significant aspect of what is defined in the reviewed literature for Sustainable Transportation. Second, the number of pairwise comparisons is limited to the available time when performing the questionnaires. Questionnaire A brought 11 pairwise comparisons which sometimes tired the respondents, resulting in loss of attention. Third, the criteria selected should be able to be translated to visuals. These aspects should be considered when doing similar works.

The results show a gap between the community's perception of the transportation issues that affect them and their preferences toward transportation evaluation criteria selected by respondents. The pairwise comparison resulted in a similar set of preferred criteria. Public preference might be influenced by media and current socio-economic and political contexts. The aggregation method that best fits the mathematical requirements and the surveyed public preferences is the Geometric mean. However, with the exception of the Mode, the other methods also reflected approximately the same upper level of hierarchy of project evaluation criteria.

The approach of early involvement not only fostered the discussion about design aspect, but rather it generates a discussion about the objectives and goals of the project development process, in which each community member expressed his/her particular or opinion. In this process it is very important that the visualizations reflect the surroundings of the area where the project is going to be developed at an adequate degree. People have to identify with the visualization in a way that internalizes the possible benefits and possible negative consequences of each alternative being communicated. This aspect was addressed by showing current scenario ("Do-Nothing" alternative) first and subsequently the alternative designs. As people already know the current configuration, they could understand how the proposed alternatives will work.

Visualizations were designed aiming to reflect a given set of criteria. Some criteria (e.g. rapid construction, water and air pollution, vehicle operation cost) were difficult to represent graphically. An implemented mechanism to verify if the respondents in the community identified the desired criteria in each alternative showed that most of the desired criteria were identified. Nevertheless, as shown in FIGURE 34 to FIGURE 38, some sets of criteria were not fully identified by every respondent.

Sometimes, designers take only one alternative and ask community to choose specific characteristic (e.g., size, form); by not evaluating the adequacy of this feature against the community values, the designer limits the universe of solutions. In this study, Questionnaire A allowed the identification of important values to consider when addressing transportation issues and proposing alternative of solutions. Additionally, the designer has the freedom to evaluate more than one feature or set of features, and combine them differently in each alternative that the "sketch" constitutes. New ideas may arise from the discussion around these sketches. The visualizations allow the assessment of features' appropriateness in terms of the community and design values. This may allow designers to grasp a final design that not only achieve technical goals, but also lead to consensus and social legitimacy within the community.

For respondents in the community of "Dulces Labios", the most preferred alternatives were those that embodied the most preferred criteria (i.e., the highest ranked). In the same sense, the alternatives designed with the less preferred alternatives were less preferred. However, the least preferred alternative in both groups of respondents corresponds to the alternative "Do-Nothing" (Alt A). Interestingly, this scenario corresponds to a recently constructed 3-lane corridor, with apparently good levels of service. However, this alternative was scored with the least preference values when compared to the other alternatives in both the "Dulces Labios" and Comparison group. Additionally, the preferred alternative is built with criteria that according to the Logistic regression is influenced by socio-economic characteristics of the community.

Values of consistency ratios (CR) lower than 0.10 were reached by using the Arithmetic and Geometric mean as shown in Tables 7 and 8. The lowest consistency ratio value corresponds to the Geometric mean which is consistent with the reviewed literature. On the other hand, the Harmonic mean gives a CR value equivalent to twice the value of CR for the Arithmetic mean in both cases. Similarly, the results show that neither the Percentiles nor the

Mode are an adequate approach for aggregating the judgment values. Furthermore, the worst indices were produced by the Mode. The results show a relationship between the number of judgments and the CR. The higher the number of judgments is, the lower the consistency ratio.

When analyzing the preferences, both the group of the Community of "Dulces Labios" and the overall sample do not show variance among the top three preferred criteria. This is shown in TABLE 13 and TABLE 14. When comparing between the Arithmetic mean and the Geometric mean, the first and second preferred criteria are interchangeable while the third remains the same. The subsequent levels of the hierarchy indicate a disparity among the ranking values. Among the different aggregation methods, there is an inversion of the hierarchy for some criteria (e.g. criterion [11]). This could be a consequence of one or the combination of important characteristics; the sensitivity to the values near to zero for the Geometric mean and the presence of outliers result in such different values when the individual values are aggregated. Despite the CR values, about 80% of aggregation methods considered the criteria numbers 4 and 2 to be preferred in the top 3 levels. 50% of the methods considered the criteria number 11 to be in the top 3 levels. However, the resulting hierarchy is primarily based on the methods with CR values under 0.10. Based on the evidence, the best approach would be the Geometric mean.

Regarding transportation issues affecting the quality of life, the people surveyed in the community of "Dulces Labios" showed concern with traffic congestion (17% of total responses), fuel cost (17%), and availability of public transportation (11%). The pavement quality, the pollution caused by vehicles, safety, security, and the provision of bicycle lanes were around 6% of the total number of responses. As a third group, lacking of facilities for people with disabilities, vehicle operating and acquisition cost, and parking were around 3%. These results show that the surveyed people are more concerned with aspects of mobility and economy rather than social, environmental, or economic development aspects. This is strongly related to the fact that 63% of people use a private motor vehicle as their primarily mode of transportation. However, when people were asked about the criteria to be used for the evaluation of transportation infrastructure, the top criteria was related to the provision of transportation alternatives. These alternatives include bicycle lanes and sidewalks (11% of the responses), accessibility (10%), pollution (9%), constructability (8%), and economic development (8%). Moreover, the top three criteria resulting from the AHP hierarchy were generation of employment and economic activity in the community, reduction of air and water pollution, and safety improvements of transportation infrastructure and operations.

6.2 Recommendations

Regarding the criteria used, additional criteria, such as the evaluation of construction cost, should be incorporated in order to cover other important aspects related to Sustainable Transportation and the community's development. Moreover, the designer or researcher should be aware that the values may vary both between communities and within the same community over the time. These criteria should then be translated into a language that people in the community can understand.

Investing time in becoming familiar with the community values and activities is important. Community members need to recognize the developer, planner or researcher as partner rather than only a public server. This requires implementing different strategies such as successive visits, informal meetings, and talks. An example would be to get involved in additional community activities held or organized in the community.

Higher levels of public participation remains to be challenging and different strategies to incorporate more people in the participatory process should be evaluated. Especially under especial socioeconomic conditions such as those that exhibit “Dulces Labios”.

There are local and supra-local organizations that represent important links to communities (e.g. the program of especial communities in Puerto Rico). Further research should take into account the means of communication that these programs/agencies represent. Additionally, their experiences and strategies can be used.

Regarding to the design of the visualizations, it would be very useful to work on the elaboration of add-ons, libraries, or complementary software that allows the quick generation of alternatives is recommended. Furthermore, this could establish the standards for alternative development, and streamline the elaboration of the visualizations.

6.3 Future work

As an outgrowth of this work, several additional efforts can be pursued to further substantiate the methodology and to increase its impact in the planning process. These include the following:

- It is very common that initiatives state the importance of community well-being as a component of sustainability. However, very few take it into account in the proposed methodology or case study. The conflicting positions of the stakeholders are usually undertaken or considered a minor issue in the process as compared to the benefits of the chosen alternatives. In that sense, the analysis of the tradeoffs among the different design criteria should be further investigated, especially when dynamic techniques such as public meeting, task forces or similar methodologies are used.
- The use of the technique presented in this thesis could be extended to generate more scenarios with different features combinations that could be shown iteratively to the community and, ultimately, be combined into one final preferred alternative using different techniques such as Conjoint Analysis. This final conjoint of features could be used to evaluate more specific characteristics of the design, engineering standards, specifications, among others.
- It was found that people had problems in the assignment of values during the pairwise comparison because of the relativeness of human judgments. In that sense, an important aspect to explore for future studies is the fuzziness in the values assigned during the

pairwise comparison. Additionally, the aggregation methods that would work best with fuzziness could be evaluated.

- This study was not meant to establish a list of criteria to be used in alternatives generation. It was intended to explore a methodology to use visualizations made of conjoint features to reflect community preferences. For that reason, a methodology in the definition and judgment of the design criteria reflecting the literature and public preferences can be implemented.

6.4 Personal reflection

During the development of this work the most important lesson learned was that professionals, and especially engineers, should be aware of the role they develop within society. They might be aware that the actions they perform directly or indirectly impact social wellbeing. During the development of this study I had the chance to feel that by working in a community in Puerto Rico, and applying the principles of Appropriate Technology, I had a chance to contribute directly to the wellbeing of a community. I believe that this is the essence of what it means to practice engineering in the best sense. Engineering is not only a discipline of technical expertise, but it is also about using interdisciplinary knowledge and sensibility of the broader societal impacts.

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7 APPENDIXES

7.1 Questionnaire A

Encuesta de preferencias sobre la toma de decisiones en proyectos de transporte

Le agradecemos su participación. Le recordamos que su participación es voluntaria y que la información que usted ofrezca es anónima y confidencial. NO ESCRIBA SU NOMBRE EN ESTE CUESTIONARIO.

Parte I: Preguntas Socio-demográficas

Por favor llene o seleccione la alternativa según corresponda :

1. **Edad**:
   _______ años

2. **Género:**
   __Femenino
   __Masculino

3. **Último nivel de educación completado:**

___ Elemental (1-6) \`
___ intermedia (7-9)
___ Superior (10-12)
___ Grado Asociado / Bachillerato
___ Estudios Técnicos / Vocacionales
___ Maestría / Doctorado

4. **Ocupación:**

____
(Por favor escriba en letra imprenta)

5. **¿En qué comunidad o barrio reside?**

____
(Por favor escriba en letra imprenta)

6. **¿Cuánto tiempo lleva viviendo allí?:**

___Años
___Meses

Parte II: Preguntas sobre Movilidad

7. **¿Con cuántos vehículos de motor dispone usted en su residencia?**

___Ninguno ___ 1 ___ 2 ___3 o más

8. **¿Cuántas personas viven en su residencia (incluyendo a usted)?**

___ 1 ___ 2 ___ 3 ___4 ___5 o más

9. **Identifique cual es el principal medio de transporte que usted utiliza para sus gestiones diarias (trabajo, escuela, compras, etc.).**
   (MARQUE SÓLO UNA)

☐ Carros Públicos
☐ Trolley / Guagua Municipal
☐ Bicicleta
☐ A pie
☐ Automóvil propio
☐ Automóvil compartido ("En pon")
☐Otro: ______________________

10. **Identifique cuales de estos medios de transporte ha usado de forma alternativa para sus gestiones diarias en los últimos 6 meses :**
    (MARQUE LAS QUE APLICAN)

☐ Carros Públicos.
☐ Trolley / Guagua Municipal.
☐ Bicicleta
☐ A pie
☐ Automóvil propio
☐ Automóvil compartido ("En pon")
☐Otro: ______________________

11. **Seleccione de la siguiente lista hasta un máximo de <u>TRES</u> aspectos que más afectan su calidad de vida sobre el sistema de transportación en su comunidad:**

___ Congestión del tráfico
___ Choques / Seguridad en las carreteras
___ Calidad del pavimento
___ Ruido por el tráfico de vehículos
___ Costo de adquirir un vehículo de motor
___ Costo de la gasolina
___ Falta de carriles para bicicletas
___ Costo del mantenimiento de su vehículo de motor
___ Emisión de gases por el tráfico de vehículos
___ Disponibilidad de Carros Públicos/Guaguas/ Trolleys
___ Pérdida de áreas verdes para la construcción o ampliación de carreteras.
___ Costo o disponibilidad del "parking"
___ Seguridad personal (Crimen)
___ Falta de facilidades para personas físicamente impedidas
___Otros. Por favor indique:
____

Parte III: Conocimiento sobre el proceso de toma de decisiones	
Para cada una de las siguientes preguntas, marque con una equis (X) la alternativa que más se acerque a su conocimiento personal.	
12. ¿Ha escuchado o conoce sobre los procedimientos para la elaboración de proyectos de infraestructura? __Sí __No	**13. ¿Ha escuchado o conoce qué es una <u>Declaración de Impacto Ambiental</u>?** __Sí __No
14. ¿Le han preguntado alguna vez acerca de su opinión sobre un proyecto de infraestructura en su comunidad? __Sí __No	**15. ¿Ha escuchado o conoce sobre lo que es <u>desarrollo sostenible o sustentable?</u>** __Sí __No
16. ¿Sabe lo que es una Vista Pública? __Sí __No (pase a la pregunta 18)	**17. ¿Ha participado en alguna Vista Pública sobre algún proyecto de infraestructura?** __Sí __No

18. A continuación se muestra una lista de criterios para la evaluación de proyectos de infraestructura vial. Por favor marque con una equis ("X") los <u>CINCO</u> criterios que usted considera son los más importantes:

	Criterio	Marque en esta columna
a	Que se mejore la seguridad contra accidentes de tránsito	
b	Que ayude a generar empleos y actividad económica en la comunidad	
c	Que el sistema de transporte me permita llegar a todos los lugares que necesite	
d	Que incluya áreas verdes y elementos paisajistas	
f	Que la infraestructura sea construida con materiales ecológicos (Reciclados/ Reusados)	
g	Que permita un flujo cómodo y seguro de peatones y ciclistas	
h	Que preserve elementos culturales, históricos o arqueológicos	
i	Que reduzca el "desparramamiento" urbano	
j	Que sea auto-sostenible económicamente	
k	Que sea estético	
l	Que sea un sistema confiable y accesible en todo momento	
m	Que su construcción sea rápida	
n	Que se reduzca la contaminación del agua y del aire	
o	Que se reduzca la contaminación por ruido del transito de vehículos	
p	Que se reduzcan los costos de operación del vehículo (reparaciones, llantas, gasolina)	
q	Que se reduzca el tiempo de viaje	
r	Que se reduzca el espacio necesario para la localización de la infraestructura	
s	Que su construcción minimice el impacto al ambiente y a la comunidad.	

Parte IV: Preferencias

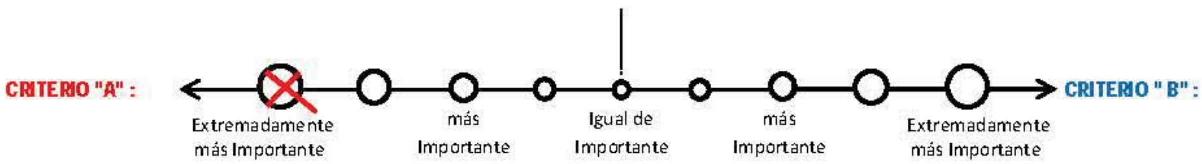
19.- Las gráficas mostradas a continuación sirven para evaluar el nivel de importancia relativa que usted asignaría a un criterio de evaluación de proyectos de transporte con respecto a otro criterio.

Según su opinión, compare cuáles de los siguientes criterios deben tener mayor importancia cuando se evalúa un proyecto de transportación (como carreteras, puentes, estacionamientos, etc.) para su construcción en/o cerca de su comunidad.

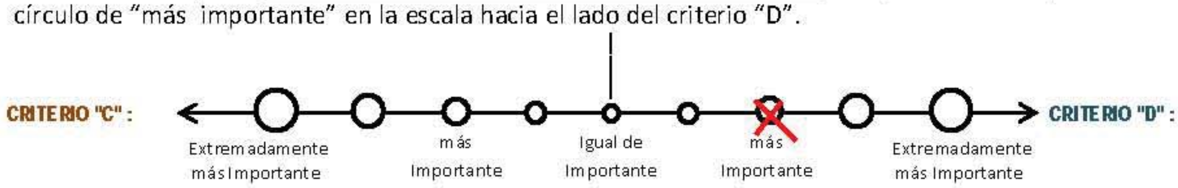
Por favor marque con una equis ("X") sobre un círculo en la línea indicando cuán importante para usted es un criterio con respecto al otro.

A continuación se muestran dos EJEMPLOS:

Si considera que el criterio "A" es extremadamente más importante que el Criterio "B", marque con una equis "X" sobre el círculo de "extremadamente más importante" en la línea hacia el lado del criterio "A". Los círculos intermedios también son VÁLIDOS.



Si se considera que el criterio "D" es más importante que el Criterio "C", marque con una equis "X" sobre el círculo de "más importante" en la escala hacia el lado del criterio "D".



Por favor indique su opinión sobre cuál criterio es más importante para usted en las siguientes comparaciones:

Par :1

CRITERIO A: **Que mejore la seguridad contra accidentes de tránsito**

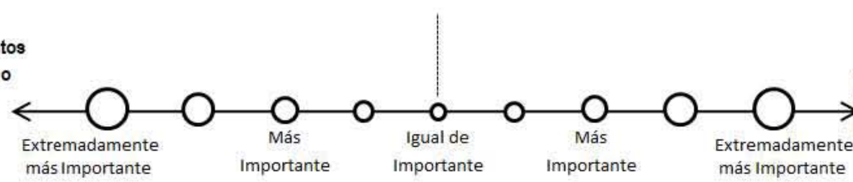
CRITERIO B: **Que incluya carriles y veredas que permitan un adecuado flujo de bicicletas y peatones**

c117

Par :2

CRITERIO A: **Que preserve elementos culturales, históricos o arqueológicos y estéticos**

CRITERIO B: **Que incluya carriles y veredas que permitan un adecuado flujo de bicicletas y peatones**



c107

Par :3

CRITERIO A: **Que reduzca la contaminación del agua y del aire**

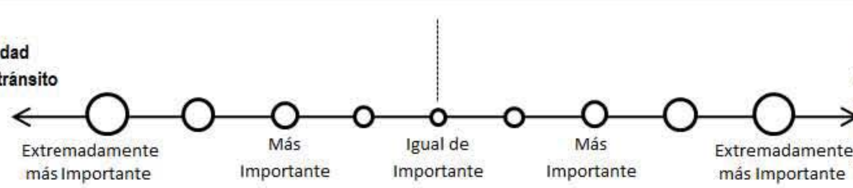
CRITERIO B: **Que ayude a generar empleos y actividad económica en la comunidad**

c42

Par :4

CRITERIO A: **Que mejore la seguridad contra accidentes de tránsito**

CRITERIO B: **Que reduzca los costos de operación del vehículo (repuestos, llantas, combustible, etc.)**



c118

Continua de la pregunta 19:

Par :5 CRITERIO A: **Que preserve elementos culturales, históricos o arqueológicos y estéticos**

CRITERIO B: **Que reduzca el tiempo de viaje**

Extremadamente más Importante — Más Importante — Igual de Importante — Más Importante — Extremadamente más Importante

c101

Par :6 CRITERIO A: **Que reduzca los costos de operación del vehículo (repuestos, llantas, combustible, etc.)**

CRITERIO B: **Que reduzca el tiempo de viaje**

Extremadamente más Importante — Más Importante — Igual de Importante — Más Importante — Extremadamente más Importante

c81

Par :7 CRITERIO A: **Que la infraestructura sea ecológicamente amigable (Materiales reciclados, semáforos con energía solar, etc.)**

CRITERIO B: **Que incluya áreas verdes y elementos paisajistas**

Extremadamente más Importante — Más Importante — Igual de Importante — Más Importante — Extremadamente más Importante

c65

Par :8 CRITERIO A: **Que ayude a generar empleos y actividad económica en la comunidad**

CRITERIO B: **Que reduzca el tiempo de viaje**

Extremadamente más Importante — Más Importante — Igual de Importante — Más Importante — Extremadamente más Importante

c21

Par :9 CRITERIO A: **Que incluya áreas verdes y elementos paisajistas**

CRITERIO B: **Que reduzca la contaminación del agua y del aire**

Extremadamente más Importante — Más Importante — Igual de Importante — Más Importante — Extremadamente más Importante

c54

Par :10 CRITERIO A: **Que incluya carriles y veredas que permitan un adecuado flujo de bicicletas y peatones**

CRITERIO B: **Que incluya áreas verdes y elementos paisajistas**

Extremadamente más Importante — Más Importante — Igual de Importante — Más Importante — Extremadamente más Importante

c75

Par :11 CRITERIO A: **Que mejore la seguridad contra accidentes de tránsito**

CRITERIO B: **Que reduzca los costos de operación del vehículo (repuestos, llantas, combustible, etc.)**

Extremadamente más Importante — más Importante — Igual de Importante — más Importante — Extremadamente más Importante

c118

Muchas gracias por su amabilidad y por el tiempo dedicado a contestar esta encuesta.

Atentamente. **Davis Chacón Hurtado.**

7.2 Questionnaire B

Cuestionario de opinión sobre alternativas de diseño de la vía del litoral de Mayagüez, sector "Dulces Labios"

Le agradecemos su participación. Le recordamos que su participación es voluntaria y que la información que usted ofrezca es anónima y confidencial. NO ESCRIBA SU NOMBRE EN ESTE CUESTIONARIO.

Parte I
Por favor responda las siguientes preguntas según corresponda :

1. Con respecto a la ALTERNATIVA "A" :

a. Identifique 2 (DOS) elementos o características que MÁS le gustan y diga porqué (Por favor escriba con letra de molde):

____

____

____

b. Identifique 2 (DOS) elementos o características que MENOS le gustan y diga porqué (Por favor escriba con letra de molde):

____

____

____

2. Con respecto a la ALTERNATIVA "B" :

a. Identifique 2 (DOS) elementos o características que MÁS le gustan y diga porqué (Por favor escriba con letra de molde):

____

____

____

b. Identifique 2 (DOS) elementos o características que MENOS le gustan y diga porqué (Por favor escriba con letra de molde):

____

____

____

3. Con respecto a la ALTERNATIVA "C" :

a. Identifique 2 (DOS) elementos o características que MÁS le gustan y diga porqué (Por favor escriba con letra de molde):

____

____

____

b. Identifique 2 (DOS) elementos o características que MENOS le gustan y diga porqué (Por favor escriba con letra de molde):

____

____

____

4. Con respecto a la ALTERNATIVA "D" :

a. Identifique 2 (DOS) elementos o características que MÁS le gustan y diga porqué (Por favor escriba con letra de molde):

____

____

____

b. Identifique 2 (DOS) elementos o características que MENOS le gustan y diga porqué (Por favor escriba con letra de molde):

____

____

____

5. Con respecto a la ALTERNATIVA "E"

c. Identifique 2 (DOS) elementos o características que MÁS le gustan y diga porqué (Por favor escriba con letra de molde):

____

____

____

d. Identifique 2 (DOS) elementos o características que MENOS le gustan y diga porqué (Por favor escriba con letra de molde):

____

____

____

Parte II

1.- A continuación se muestra la lista de las alternativas vistas en la Parte I. Por favor coloque los números DEL UNO AL CINCO según SU PREFERENCIA, siendo :

UNO (1) para la "MÁS PREFERIDA" y
CINCO (5) para la "MENOS PREFERIDA".

Opción :	"Ranking" de preferencia
Alternativa A	
Alternativa B	
Alternativa C	
Alternativa D	
Alternativa E	

2.- Responda a las siguientes preguntas según su opinión y marcando con una equis ("X") en la columna correspondiente:

Según su opinión:	Alternativa A	Alternativa B	Alternativa C	Alternativa D	Alternativa E	Ninguna
¿Cuál alternativa generaría empleos y actividad económica en la comunidad?						
¿Cuál alternativa mejoraría la seguridad contra accidentes de tránsito?						
¿Cuál alternativa reduciría la contaminación del agua o del aire?						
¿Cuál alternativa permitiría un flujo cómodo y seguro de peatones y ciclistas?						
¿Cuál alternativa favorece las áreas verdes y elementos paisajistas?						
¿Cuál alternativa preserva los elementos culturales, históricos o arqueológicos?						
¿Cuál alternativa usa materiales o elementos ecológicos ?						
¿Cuál alternativa reduciría más los costos de operación del vehículo (reparaciones, gomas, gasolina, etc.)?						
¿Cuál alternativa sería más auto-sostenible económicamente?						
¿Cuál alternativa se construiría más rápido?						
¿Cuál alternativa reduciría más el tiempo de viaje en vehículo?						

Muchas gracias por su amabilidad y por el tiempo dedicado a contestar este cuestionario.

Davis Chacón Hurtado.

7.3 Letter of Inform Consent

UNIVERSIDAD DE PUERTO RICO
RECINTO UNIVERSITARIO DE MAYAGÜEZ
Colegio de Ingeniería
Departamento de Ingeniería Civil Y Agrimensura

Davis Chacón Hurtado,
P.O. Box 2116, Mayagüez, PR 00681.
Teléfono: (787) 516-2871
E-mail: davis.chacon@upr.edu

Consentimiento Informado

Estimado(a) participante:

Soy Estudiante del Colegio de Ingeniería del Recinto Universitario de Mayagüez y como parte de los requisitos para completar mis estudios de maestría en Ingeniería Civil, vengo conduciendo una investigación con el fin de desarrollar una metodología para la evaluación de la viabilidad de proyectos de infraestructura de transporte tomando en cuenta las preferencias de la comunidad.

Con ese objetivo en mente, lo(a) invito cordialmente a completar el presente cuestionario. Su participación es totalmente voluntaria y tiene la opción de contestar sólo las preguntas que considere pertinentes o de abandonar su participación en cualquier momento sin perjuicio alguno. Completar el cuestionario le tomará aproximadamente 20 minutos y su colaboración ayudará a que en un futuro se tomen mejores decisiones para la construcción de infraestructura vial en Puerto Rico.

La información recolectada será manejada de forma confidencial y su identidad se mantendrá en el anonimato. Sólo se publicará el resultado del análisis de datos de forma agregada. Asimismo, los cuestionarios individuales sólo serán vistos por mi persona y el presidente de mi comité graduado. Dichos cuestionarios serán destruidos al cabo de un año.

De participar en el estudio y si a así lo solicita, se le enviará los resultados del análisis de datos.

Agradezco su tiempo. De tener alguna duda o pregunta, se puede comunicar conmigo al contacto arriba indicado y/o con el presidente de mi comité, el Dr. Alberto Figueroa Medina al teléfono (787)832-4040 extensión 3395 o al correo electrónico alberto.figueroa3@upr.edu.

Si está de acuerdo en participar en el presente estudio por favor firme y escriba su nombre en los espacios abajo suministrados. De lo contrario sírvase devolver el presente material. Gracias.

Atentamente,

Davis Chacón Hurtado

____

Firma del Participante

Nombre: ___________________________________

7.4 Letter of authorization from the Institutional Review Board committee (IRB) (CPSHI by its acronym in Spanish)

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

28 de abril de 2012

Sr. Davis Chacón Hurtado
P.O. Box 2116
Mayagüez, PR 00681

Estimado Sr. Chacón Hurtado:

El Comité para la Protección de los Seres Humanos en la Investigación (CPSHI) ha considerado la Solicitud de Revisión y demás documentos sometidos para el proyecto titulado *Incorporating public preferences into transportation decisión making* y le otorga una aprobación expedita. Esta aprobación tiene una vigencia de un año, es decir, a partir de hoy, 28 de abril de 2012 hasta el 27 de abril de 2013.

Cualquier modificación al protocolo o a la metodología deberá someterse al CPSHI para su consideración y aprobación antes de su implantación. Asimismo deberá informarle al CPSHI sin dilación cualquier efecto adverso inesperado que surgiera en el transcurso de su investigación. También se le deberá informar inmediatamente al CPSHI cualquier queja con relación a la investigación con seres humanos y cualquier violación a la confidencialidad.

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 – RUM

Teléfono: (787) 832 - 4040 x 3196, 3807, 3808 – **Fax**: (787) 831-2085 – **Página Web**: www.uprm.edu/cpshi
Email: cpshi@uprm.edu

7.5 Appendix: Histograms of preference values

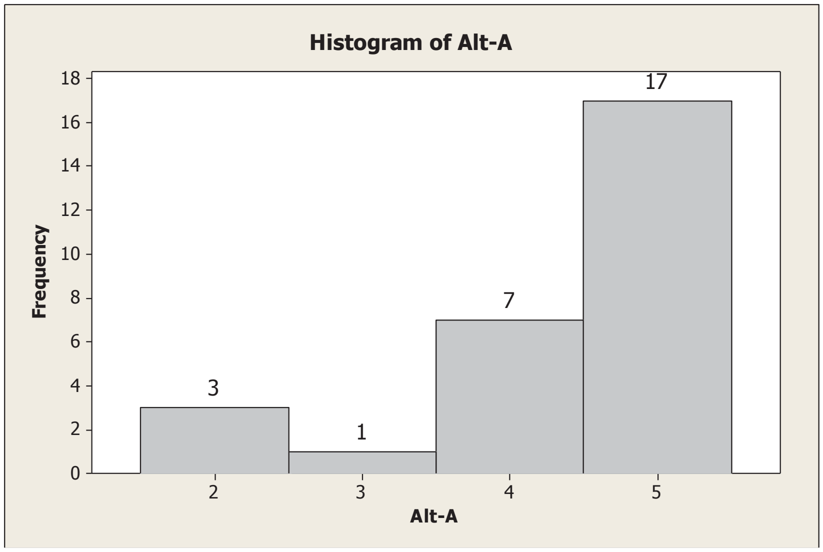


Figure 39 Histogram of preference values for Alternative A in the "Dulces Labios" group

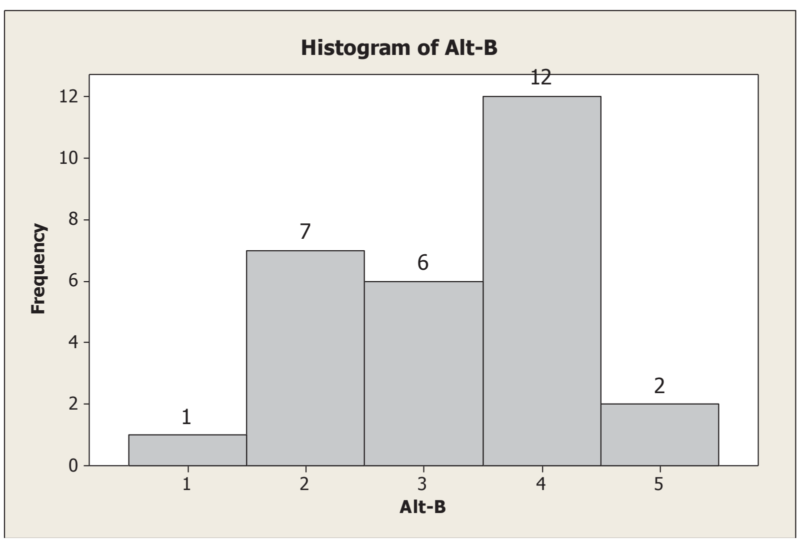


Figure 40 Histogram of preference values for Alternative B in the "Dulces Labios" group

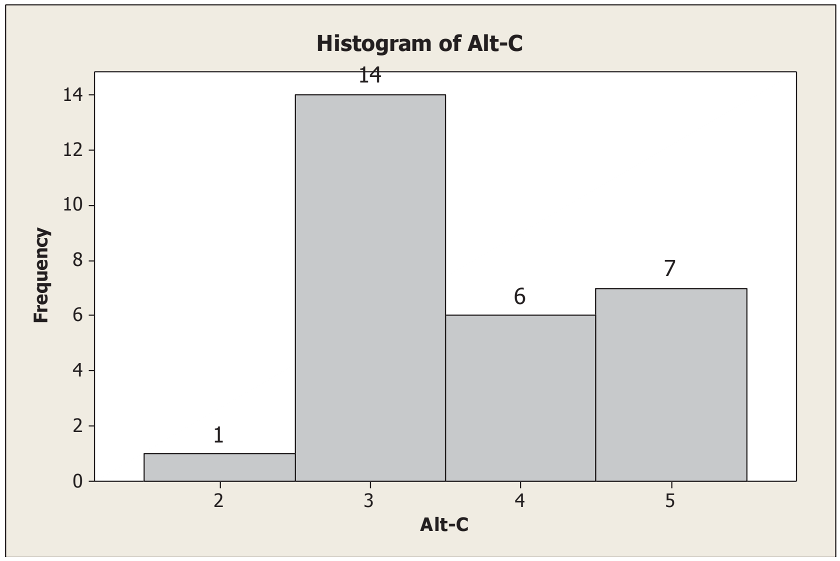


Figure 41 Histogram of preference values for Alternative C in the "Dulces Labios" group

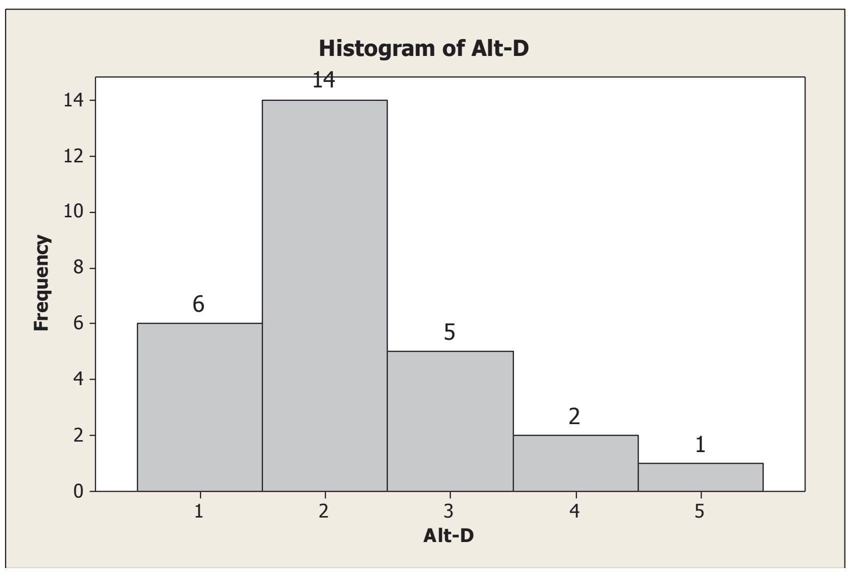


Figure 42 Histogram of preference values for Alternative D in the "Dulces Labios" group

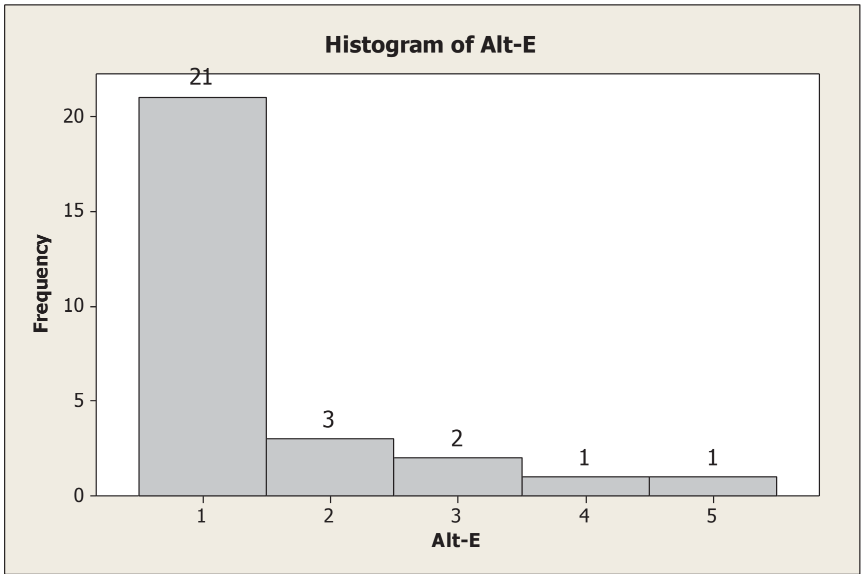


Figure 43 Histogram of preference values for Alternative E in the "Dulces Labios" group

7.6 Logistic Regression (cont.)

The logistic model was originally used for epidemiologic research (Hosmer and Lemeshow, 2000). Currently, it is widely used in many fields such as finance, engineering, health policy and linguistics, among others. For instance, some credit-scoring applications use logistic regression to model the probability that a subject is credit worthy (Agresti, 2002). In this thesis, the logistic regression is applied to evaluate the relationship among socio-demographic characteristics of the people surveyed and the odds of selecting or not a given design criteria as important for the design of a transportation project in the Community of "Dulces Labios".

The distinction between linear models and logistic models is reflected in the choice of the parametric model and the assumptions. However, once this difference is accounted for, they follow the same general principles for their analysis (Hosmer and Lemeshow, 2000). The probability of selecting or not a criterion is assumed that follows the discrete Bernoulli distribution. It follows then that it can only take the exclusive values of 0 or 1. The probability distribution is shown in TABLE 29; the probability that the outcome will be 1 is represented by π_i, and the probability that outcome will be 0 is represented by $1 - \pi_i$.

TABLE 29 Probability of the outcome that follows a Bernoulli distribution

Outcome(Y_i)	***Probability***
1	$P(Y_i = 1) = \pi_i$
0	$P(Y_i = 0) = 1 - \pi_i$

The expected value of the response variable $E(Y_i|x_i)$ is defined as:

$$\boldsymbol{E[Y_i|x_i] = 1 * \pi_i + 0 * (1 - \pi_i) = \pi_i} \qquad (8)$$

The expected value for the response variable and the probability that the response takes the value of 1 are the same. Empirical evidence shows that when the outcome variable is dichotomous, the shape of the response will follow a S-shaped curve that gradually approaches 0 and 1 (Hosmer and Lemeshow, 2000; Montgomery and Runger, 2006). FIGURE 44 shows an example of the probability of failure versus temperature of a given process.

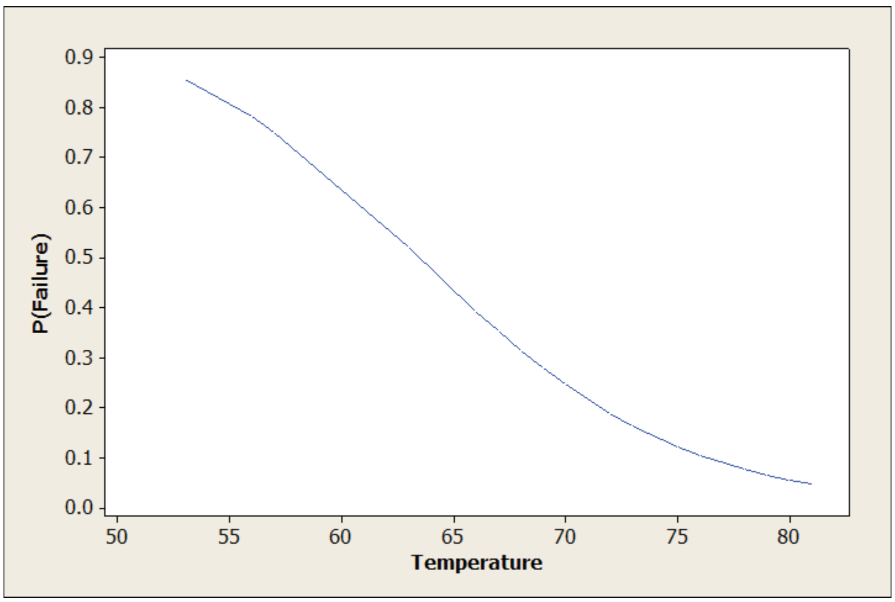


FIGURE 44 Probability of failure versus temperature of a given process (Data taken from Montgomery & Runger (2006)).

The S-shape function is called the logistic response function. For binary response variable Y and an explanatory variable "x", let $\pi(x) = P(Y = 1|x = x) = 1 - P(Y = 0|x = x)$. The specific form of the logistic regression model is:

$$E(Y|x) = \pi(x) = \frac{e^{(\beta_0+\beta_1 x)}}{1 + e^{\beta_0+\beta_1 x}} = \frac{1}{1 + e^{[-(\beta_0+\beta_1 x)]}} \qquad (9)$$

The logit transformation corresponds to a linearization of the logistic regression model and is expressed in equation 10. This will be called simply the logit or the log odds.

$$g(x) = \ln\left(\frac{\pi(x)}{1-\pi(x)}\right) = \beta_0 + \beta_1 x \qquad (10)$$

The estimation of the parameter is performed using the maximum likelihood method. To apply the method, a likelihood function is first constructed. It reflects the probability of the observed data as a function of the unknown parameter. Estimates ($\widehat{\beta}$) are chosen in such a way that the function is maximized. If the dichotomous outcome is coded as 0 and 1, the pairs (x_i,y_i) whose "y_i" is equal to 1 will contribute $\pi(x_i)$ to the likelihood function. In the same vein, the pairs whose "y_i" is equal to 0 will contribute $(1-\pi(x_i))$ to the likelihood function. Because each pair is assumed independent, the total contribution of all pairs could be interpreted as shown in (11):

$$l(\beta) = \prod_{i=1}^{n} [\pi(x_i)]^{y_i} [1 - \pi(x_i)]^{1-y_i} \qquad (11)$$

$$\text{If } y_i = 1,\ then\ [1-\pi(x_i)]^{1-y_i} = 1$$
$$\text{If } y_i = 0,\ then\ [\pi(x_i)]^{y_i} = 1$$

$L(\beta)$ corresponds to the natural logarithm of $l(\beta)$. $L(\beta)$ is also denominated as "Log likelihood" in statistical software packages. The estimate of β that maximizes this equation will be used.

$$L(\beta) = \sum_{i=1}^{n} \{y_i \ln[\pi(x_i)] + (1-y_i)\ln[1-\pi(x_i)]\} \qquad (12)$$

This expression is partially differentiated with respect to β_0 and β_1 and equaled to zero in order to find the β that maximizes the expression. The results are the "maximum likelihood estimates of β and $\pi(x_i)$ denoted as $\widehat{\beta}$ and $\hat{\pi}(x_i)$ respectively. This is easily estimated with statistic software (e.g. Minitab ®)

The evaluation of the significance of the coefficients is performed by comparing the observed values to the predicted values with and without the variable in question. This comparison does not constitute a "goodness-of-fit" test, but rather is a relative comparison among the models that include different variables. The comparison is based on the log likelihood function $[L(\beta)]$ for both the fitted and saturated model. The latter relationship is called the likelihood ratio. The same expression is used to calculate the deviance [D] (equivalent to the residual sum of squares in linear regression, SSE)

$$D = -2\mathrm{Ln}\left[\frac{\text{likelihood of the fitted model}}{\text{likelihood of the saturated model}}\right]$$

When the outcome has only two possible values (0, 1), the likelihood of the saturated model is 1. In order to assess the significance of an independent variable, the value of D for both the model with and without the variable are compared

$$G = -2\mathrm{Ln}\left[\frac{\text{Likelihood without variable}}{\text{likelihood with the variable}}\right] \tag{13}$$

For the case of multiple logistic regressions, the procedure to fit the model is the same as the univariate model. The logit is shown in (14).

$$g(x) = \beta_0 + \beta_1\,x_1 + \beta_2\,x_2 + \beta_3\,x_3 \ldots \beta_p x_p \tag{14}$$

The logistic regression model is:

$$E(Y|x) = \pi(x) = \frac{e^{(\beta_0+\beta_1 x_1+\beta_2 x_2+\beta_3 x_1 \ldots \beta_p x_p)}}{1+e^{(\beta_0+\beta_1 x_1+\beta_2 x_2+\beta_3 x_1 \ldots \beta_p x_p)}} = \frac{e^{g(x)}}{1+e^{g(x)}}$$

Given "n" independent observations (x_i, y_i), where i = 1,2,3… n. Each sample observation follows the Bernoulli distribution, thus the likelihood function is:

$$\mathrm{L}(y_1, \mathrm{y}_2 \ldots \mathrm{y}_n) = \sum_{i=1}^{n}\left[y_i \ln\left(\frac{\pi}{1-\pi}\right)\right] + \sum_{i=1}^{n} \ln(1-\pi) \qquad (15)$$

The method requires obtaining the vector of coefficients β'= (β_0, β_1, β_2, β_3 … β_p). These coefficients are also estimated using the likelihood function. There are "p+1" likelihood equations obtained by differentiating the log likelihood function with respect to the "p+1" coefficients. The univariate case has only one independent variable, then p+1 = 1+1= 2. Let $\hat{\beta}$ be the solutions to these equations, and then the fitted values are denoted by $\hat{\pi}(x_i)$. According to the theory of maximum likelihood, the estimators are obtained from the second partial derivatives of the likelihood function (with respect to β_j, j=1,2,…p). The results of these derivatives are presented in the form of a matrix that allows the calculation of the variance and covariance of the estimated coefficients. The jth diagonal element of the matrix corresponds to the variance of $\hat{\beta}_j$. In the same sense, $cov(\hat{\beta}_j, \hat{\beta}_l)$ correspond to the covariance between $\hat{\beta}_j$ and $\hat{\beta}_l$. Once a particular model is fit, its significance can be assessed. The first step is to check the significance of the variables in the model. The test is based on the G statistic given in equation (13).

Finally, different kind of independent variables can be included at the same time, including intervals, ordinals, and nominal variables. There are cases where numbers are wrongly included in the model as intervals. In the case variables are merely identifiers, a collection of design variables (dummy or indicator variables) must be used (Agresti, 2002). If there are “c” classes the number of dummy variables will be “c-1”. For instance, the model to be developed considers three level of education (EDU), two dummy variables will be needed (EDU1, EDU2). Intervals variables can be treated as ordinals if the data number is small. In the same vain, ordinals variables could be assigned with a numeric value and be used as intervals variables. Each category has a difference in magnitude than the other and a underlying continuous variable is assumed (Agresti, 2002).

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7.7 Logistic regression output tables

TABLE A 1 Logistic regression output for criteria [1]: Reduction of travel time

					Odds	*90%*	*CI*
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Constant	-1.63304	0.833306	-1.96	0.05			
AGE	-0.007561	0.012813	-0.59	0.555	0.99	0.97	1.01
GEN	0.208385	0.436661	0.48	0.633	1.23	0.6	2.53
CATV	-0.497858	0.514738	-0.97	0.333	0.61	0.26	1.42
RTVR	-0.20165	0.652308	-0.31	0.757	0.82	0.28	2.39
PDP1	-0.277697	0.601607	-0.46	0.644	0.76	0.28	2.04
EISD	0.486139	0.552407	0.88	0.379	1.63	0.66	4.03
PPUH	-0.366338	0.61791	-0.59	0.553	0.69	0.25	1.92
EDU2	0.703226	0.462369	1.52	0.128	2.02	0.94	4.32
PRIM1							
1	0.439711	0.711322	0.62	0.536	1.55	0.48	5
2	0.0485756	0.607855	0.08	0.936	1.05	0.39	2.85
	Tests for terms with more than 1 degree of freedom						
	Term Chi-Square DF P						
	PRIM1 0.388300 2 0.824						
	Log-Likelihood = -72.704						
	Test that all slopes are zero: G = 8.683, DF = 10, P-Value = 0.562						
	Goodness-of-Fit Tests						
	Method	X^2	DF	P			
	Pearson	185.512	174	0.261			
	Deviance	145.408	174	0.944			
	Hosmer-Lemeshow	8.117	8	0.422			

TABLE A 2 Logistic regression output for criteria [2]: Generation of employment and economic activity in the community

					Odds	*90%*	*CI*
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Constant	-0.55649	0.638878	-0.87	0.384			
AGE	0.001495	0.009831	0.15	0.879	1	0.99	1.02
GEN	0.5784	0.348252	1.66	0.097	1.78	1.01	3.16
CATV	1.54866	0.419948	3.69	0	4.71	2.36	9.39
RTVR	0.359816	0.49686	0.72	0.469	1.43	0.63	3.24
PDP1	0.629951	0.488553	1.29	0.197	1.88	0.84	4.19

EISD	-1.36025	0.432547	-3.14	0.002	0.26	0.13	0.52
PPUH	0.013792	0.453725	0.03	0.976	1.01	0.48	2.14
EDU2	-0.01912	0.367448	-0.05	0.958	0.98	0.54	1.8
PRIM1							
1	-1.01531	0.518587	-1.96	0.05	0.36	0.15	0.85
2	-0.09904	0.47742	-0.21	0.836	0.91	0.41	1.99

Tests for terms with more than 1 degree of freedom

Term	Chi-Square	DF	P
PRIM1	3.94023	2	0.139

Log-Likelihood = -106.774

Test that all slopes are zero: G = 40.656, DF = 10, P-Value = 0.000

Goodness-of-Fit Tests

Method	X^2	DF	P
Pearson	187.752	174	0.225
Deviance	210.776	174	0.030
Hosmer-Lemeshow	5.710	8	0.680

Coefficients[a]

Model		Collinearity Statistics Tolerance	VIF
1	AGE	0.753	1.328
	GEN	0.942	1.062
	CATV	0.665	1.505
	RTVR	0.751	1.332
	PRIM1	0.845	1.184
	PDP1	0.801	1.248
	EISD	0.749	1.335
	PPUH	0.835	1.198
	EDU2	0.828	1.208

a. Dependent Variable: Criteria [2]

TABLE A 3 Logistic regression output for criteria [3]: Rapid construction of the infrastructure

					Odds	*90%*	*CI*
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Constant	-2.25333	0.943702	-2.39	0.017			
AGE	0.024866	0.013175	1.89	0.059	1.03	1	1.05
GEN	-0.65842	0.509478	-1.29	0.196	0.52	0.22	1.2
CATV	-0.66632	0.620079	-1.07	0.283	0.51	0.19	1.42
RTVR	-1.29024	0.85016	-1.52	0.129	0.28	0.07	1.11
PDP1	-0.04626	0.642782	-0.07	0.943	0.95	0.33	2.75
EISD	0.690035	0.573032	1.2	0.229	1.99	0.78	5.12
PPUH	-1.41484	0.866489	-1.63	0.103	0.24	0.06	1.01
EDU2	0.055369	0.570197	0.1	0.923	1.06	0.41	2.7
PRIM1							
1	0.16263	0.698103	0.23	0.816	1.18	0.37	3.71
2	-0.09337	0.700892	-0.13	0.894	0.91	0.29	2.88
	Tests for terms with more than 1 degree of freedom						
	Term Chi-Square DF P						
	PRIM1 0.102302 2 0.950						
	Log-Likelihood = -61.676						
	Test that all slopes are zero: G = 11.864, DF = 10, P-Value = 0.294						
	Goodness-of-Fit Tests						
	Method	X^2	DF	P			
	Pearson	178.685	174	0.388			
	Deviance	123.352	174	0.999			
	Hosmer-Lemeshow	5.112	8	0.746			

TABLE A 4 Logistic regression output for criteria [4]: Reduction of air and water pollution

					Odds	*90%*	*CI*
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Constant	0.438113	0.631441	0.69	0.488			
AGE	-0.02823	0.009685	-2.91	0.004	0.97	0.96	0.99
GEN	-0.25003	0.325534	-0.77	0.442	0.78	0.46	1.33
CATV	1.43249	0.414691	3.45	0.001	4.19	2.12	8.29
RTVR	-0.17981	0.489494	-0.37	0.713	0.84	0.37	1.87
PDP1	-0.59886	0.468445	-1.28	0.201	0.55	0.25	1.19

EISD	0.460224	0.384877	1.2	0.232	1.58	0.84	2.98
PPUH	0.717806	0.436613	1.64	0.1	2.05	1	4.2
EDU2	0.037534	0.349909	0.11	0.915	1.04	0.58	1.85
PRIM1							
1	-0.5752	0.516728	-1.11	0.266	0.56	0.24	1.32
2	-0.21289	0.457366	-0.47	0.642	0.81	0.38	1.72
	Tests for terms with more than 1 degree of freedom						
	Term Chi-Square DF P						
	PRIM1 1.26578 2 0.531						
	Log-Likelihood = -115.754						
	Test that all slopes are zero: G = 21.483, DF = 10, P-Value = 0.018						
	Goodness-of-Fit Tests						
	Method	X^2	DF	P			
	Pearson	185.262	174	0.265			
	Deviance	231.508	174	0.002			
	Hosmer-Lemeshow	10.37	8	0.24			

TABLE A 5 Logistic regression output for criteria [5]: Including greenery and landscaping

					Odds	*90%*	*CI*
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Constant	-0.95805	0.656461	-1.46	0.144			
AGE	-0.01106	0.009733	-1.14	0.256	0.99	0.97	1
GEN	0.546387	0.340007	1.61	0.108	1.73	0.99	3.02
CATV	0.198424	0.413928	0.48	0.632	1.22	0.62	2.41
RTVR	0.274355	0.498447	0.55	0.582	1.32	0.58	2.99
PDP1	0.272089	0.498858	0.55	0.585	1.31	0.58	2.98
EISD	-0.23979	0.398368	-0.6	0.547	0.79	0.41	1.52
PPUH	0.35415	0.444582	0.8	0.426	1.42	0.69	2.96
EDU2	-0.07886	0.360993	-0.22	0.827	0.92	0.51	1.67
PRIM1							
1	-0.34567	0.559703	-0.62	0.537	0.71	0.28	1.78
2	-0.1079	0.468905	-0.23	0.818	0.9	0.42	1.94
	Tests for terms with more than 1 degree of freedom						
	Term	Chi-Square	DF	P			
	PRIM1	0.389183	2	0.823			

	Log-Likelihood = -108.760 Test that all slopes are zero: G = 6.588, DF = 10, P-Value = 0.764

	Goodness-of-Fit Tests			
	Method	X^2	DF	P
	Pearson	185.256	174	0.266
	Deviance	214.748	174	0.019
	Hosmer-Lemeshow	10.908	8	0.207

TABLE A 6 Logistic regression output for criteria[6]: Ecologically-friendly Infrastructure. (Recycled materials, Solar energy, etc.)

					Odds	*90%*	*CI*
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Constant	-1.14543	0.679821	-1.68	0.092			
AGE	-0.003532	0.009916	-0.36	0.722	1	0.98	1.01
GEN	0.239803	0.349689	0.69	0.493	1.27	0.72	2.26
CATV	-0.215636	0.424711	-0.51	0.612	0.81	0.4	1.62
RTVR	-0.089026	0.518234	-0.17	0.864	0.91	0.39	2.15
PDP1	0.564502	0.519084	1.09	0.277	1.76	0.75	4.13
EISD	-0.348032	0.408713	-0.85	0.394	0.71	0.36	1.38
PPUH	-0.11249	0.473389	-0.24	0.812	0.89	0.41	1.95
EDU2	0.287055	0.372513	0.77	0.441	1.33	0.72	2.46
PRIM1							
1	-0.151842	0.568182	-0.27	0.789	0.86	0.34	2.19
2	-0.103596	0.485883	-0.21	0.831	0.9	0.41	2

	Tests for terms with more than 1 degree of freedom Term Chi-Square DF P PRIM1 0.0950762 2 0.954
	Log-Likelihood = -104.504 Test that all slopes are zero: G = 3.413, DF = 10, P-Value = 0.970

	Goodness-of-Fit Tests			
	Method	X^2	DF	P
	Pearson	184.236	174	0.283
	Deviance	206.234	174	0.048
	Hosmer-Lemeshow	5.317	8	0.723

TABLE A 7 Logistic regression output for criteria [7]: Infrastructure for bicycle/pedestrian movement

					Odds	*90%*	*CI*
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Constant	0.0922252	0.593563	0.16	0.877			
AGE	0.0026631	0.008584	0.31	0.756	1	0.99	1.02
GEN	0.475732	0.309764	1.54	0.125	1.61	0.97	2.68
CATV	-0.075889	0.376813	-0.2	0.84	0.93	0.5	1.72
RTVR	-0.302766	0.461431	-0.66	0.512	0.74	0.35	1.58
PDP1	-0.559048	0.436841	-1.28	0.201	0.57	0.28	1.17
EISD	0.178724	0.360105	0.5	0.62	1.2	0.66	2.16
PPUH	-0.418196	0.421466	-0.99	0.321	0.66	0.33	1.32
EDU2	0.155952	0.334503	0.47	0.641	1.17	0.67	2.03
PRIM1							
1	0.008905	0.47801	0.02	0.985	1.01	0.46	2.21
2	0.0479864	0.430525	0.11	0.911	1.05	0.52	2.13
	Tests for terms with more than 1 degree of freedom						
	Term Chi-Square DF P						
	PRIM1 0.0125439 2 0.994						
	Log-Likelihood = -125.402						
	Test that all slopes are zero: G = 6.510, DF = 10, P-Value = 0.771						
	Goodness-of-Fit Tests						
	Method	X^2	DF	P			
	Pearson	183.892	174	0.289			
	Deviance	248.031	174	0			
	Hosmer-Lemeshow	13.545	8	0.094			

TABLE A 8 Logistic regression output for criteria [8]: Reduction of vehicle operatiing cost

					Odds	*90%*	*CI*
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Constant	-2.39125	0.854728	-2.8	0.005			
AGE	-0.002484	0.012132	-0.2	0.838	1	0.98	1.02
GEN	0.57369	0.426648	1.34	0.179	1.77	0.88	3.58
CATV	0.237695	0.511044	0.47	0.642	1.27	0.55	2.94
RTVR	0.183663	0.631196	0.29	0.771	1.2	0.43	3.39
PDP1	0.597517	0.644128	0.93	0.354	1.82	0.63	5.24

EISD	-0.578405	0.486383	-1.19	0.234	0.56	0.25	1.25
PPUH	-0.176224	0.589482	-0.3	0.765	0.84	0.32	2.21
EDU2	0.745219	0.445692	1.67	0.095	2.11	1.01	4.39
PRIM1							
1	-0.892158	0.84413	-1.06	0.291	0.41	0.1	1.64
2	-0.089882	0.584023	-0.15	0.878	0.91	0.35	2.39
	Tests for terms with more than 1 degree of freedom						
	Term Chi-Square DF P						
	PRIM1 1.12057 2 0.571						
	Log-Likelihood = -77.754						
	Test that all slopes are zero: G = 8.842, DF = 10, P-Value = 0.547						
	Goodness-of-Fit Tests						
	Method	X^2	DF	P			
	Pearson	179.984	174	0.362			
	Deviance	152.736	174	0.876			
	Hosmer-Lemeshow	10.651	8	0.222			

TABLE A 9 Logistic regression output for criteria [9]: Self – Sustainable financial system

					Odds	*90%*	*CI*
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Constant	-1.65847	0.766803	-2.16	0.031			
AGE	0.0011201	0.011449	0.1	0.922	1	0.98	1.02
GEN	0.535272	0.405836	1.32	0.187	1.71	0.88	3.33
CATV	-0.282544	0.476159	-0.59	0.553	0.75	0.34	1.65
RTVR	-0.664171	0.614993	-1.08	0.28	0.51	0.19	1.42
PDP1	-0.037296	0.582982	-0.06	0.949	0.96	0.37	2.51
EISD	-0.017811	0.497932	-0.04	0.971	0.98	0.43	2.23
PPUH	0.600619	0.512861	1.17	0.242	1.82	0.78	4.24
EDU2	0.80644	0.427758	1.89	0.059	2.24	1.11	4.53
PRIM1							
1	-0.313013	0.668928	-0.47	0.64	0.73	0.24	2.2
2	-0.725559	0.626687	-1.16	0.247	0.48	0.17	1.36
	Tests for terms with more than 1 degree of freedom						
	Term Chi-Square DF P						
	PRIM1 1.37609 2 0.503						
	Log-Likelihood = -82.921						
	Test that all slopes are zero: G = 11.084, DF = 10, P-Value = 0.351						

	Goodness-of-Fit Tests			
	Method	X^2	DF	P
	Pearson	176.239	174	0.438
	Deviance	163.069	174	0.713
	Hosmer-Lemeshow	7.955	8	0.438

TABLE A 10 Logistic regression output for criteria [10]: Preservation of cultural, historic and archeological elements

					Odds	*90%*	*CI*
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Constant	-2.2611	0.814549	-2.78	0.006			
AGE	0.0032208	0.010359	0.31	0.756	1	0.99	1.02
GEN	-0.09119	0.369045	-0.25	0.805	0.91	0.5	1.68
CATV	0.0328575	0.464364	0.07	0.944	1.03	0.48	2.22
RTVR	-0.56511	0.582377	-0.97	0.332	0.57	0.22	1.48
PDP1	1.26606	0.617394	2.05	0.04	3.55	1.28	9.79
EISD	0.30952	0.426531	0.73	0.468	1.36	0.68	2.75
PPUH	-0.857375	0.530672	-1.62	0.106	0.42	0.18	1.02
EDU2	-0.306897	0.40983	-0.75	0.454	0.74	0.37	1.44
PRIM1							
1	0.498214	0.535096	0.93	0.352	1.65	0.68	3.97
2	0.692179	0.481851	1.44	0.151	2	0.9	4.41
	Tests for terms with more than 1 degree of freedom						
	Term Chi-Square DF P						
	PRIM1 2.34863 2 0.309						
	Log-Likelihood = -95.883						
	Test that all slopes are zero: G = 14.062, DF = 10, P-Value = 0.170						
	Goodness-of-Fit Tests						
	Method	X^2	DF	P			
	Pearson	188.53	174	0.214			
	Deviance	188.993	174	0.207			
	Hosmer-Lemeshow	6.766	8	0.562			

TABLE A 11 Logistic regression output for criteria [11] using Forward Stepwise (Likelihood Ratio) method

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	AGE	.032	.008	16.838	1	.000	1.033
	Constant	-1.639	.395	17.202	1	.000	.194
Step 2[b]	AGE	.027	.008	11.670	1	.001	1.027
	EDU2	-1.090	.334	10.643	1	.001	.336
	Constant	-.980	.431	5.168	1	.023	.375

a. Variable(s) entered on step 1: AGE.

b. Variable(s) entered on step 2: EDU2.

7.8 Mann-Whitney U Test output for Alternatives B,C,D and E

TABLE A 12 Mann-Whitney Test for preferences in Alternative A between the "Dulces Labios" and comparison group

Test Statistics

	Alternative A
Mann-Whitney U	294.5
Wilcoxon W	570.5
Z	-0.584
Asymp. Sig. (2-tailed)	0.559

TABLE A 13 Mann-Whitney Test for preferences in Alternative B between the "Dulces Labios" and comparison group

Test Statistics

	Alternative B
Mann-Whitney U	153.5
Wilcoxon W	429.5
Z	-3.311
Asymp. Sig. (2-tailed)	0.001

TABLE A 14 Mann-Whitney Test for preferences in Alternative C between the "Dulces Labios" and comparison group

Test Statistics

	Alternative C
Mann-Whitney U	316
Wilcoxon W	722
Z	-0.118
Asymp. Sig. (2-tailed)	0.906

TABLE A 15 Mann-Whitney Test for preferences in Alternative D between the "Dulces Labios" and comparison group

Test Statistics

	Alternative D
Mann-Whitney U	275
Wilcoxon W	551
Z	-0.93
Asymp. Sig. (2-tailed)	0.352