Improving Pedestrian and Traffic Flows to Accommodate Existing Environmental Requirements at Vero Beach General Aviation Airport

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2010 FAA Design Competition for Universities

EXECUTIVE SUMMARY

The 2010 FAA Design Competition for Universities challenge that is addressed by this research is Airport Environmental Interactions. For many airports, current geometrical design of ground access areas does not provide safe and efficient flow for vehicles and pedestrians. The purpose of the research is to evaluate current and proposed "land-side" airport site plans in order to improve pedestrian safety and vehicular flow while minimizing environmental construction impacts within the airport's perimeter. In general, field observations are partnered with mathematical programming to mimic decision based route choice made by pedestrians. The outcome of which is a realistic representation of traffic and pedestrian movements on proposed site plan solutions. These solutions are then evaluated with regard to environmental impact, cost, safety and efficiency as their importance is perceived by airport stakeholders via survey.

Vero Beach General Aviation Airport's current site plan layout does not provide optimum efficiency. This site plan is subject to specific regulations: removal of large specimen trees are prohibited, maintain storm water detention requirements to accommodate impervious areas, and green space/landscaping requirements are to be in accordance with local ordinance. These issues have led to pedestrian safety concerns which continue to increase airport liability. The proposed solution site plan 2 provides for a 75% decrease in vehicular delay time providing for increased vehicular flow. These improvements also reduce the vehicle to pedestrian conflicts by 84%, allowing for safe movements to and from the airport terminal buildings. Based on current local construction project bids, these improvements will cost the airport a onetime fee of approximately 70,000$. Furthermore, the design and layout of this new site plan does not violate the environmental constraints.

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PROBLEM STATEMENT/BACKGROUND

The 2010 FAA Design Competition Project Team at Florida Atlantic University will address the Airport Environmental Interactions design challenge, with a focus on construction impacts. The project team consists of 6 graduate students from Florida Atlantic University (FAU) and Dr. Aleksandar Stevanovic serving as faculty advisor. Airports are multimodal centers where safety for all transportation modes is vital. Transportation challenges faced by many airports include balancing between pedestrian, car, and airplane flows. Airports play a major role in many passengers' transportation plans and have to be safe and equipped to handle pedestrian traffic appropriately. Persons driving a car have the obligation to yield to pedestrians which can become a difficult task in an airport setting considering the parking lot and drop off location characteristics. Pedestrian traffic in airports can sometimes be difficult to plan and design considering the sheer volume of passengers being dropped off, picked up, and travelling through the airport to and from air traffic flights. For this reason it is imperative for the construction impacts to focus on the environment and public safety.

Vero Beach General Aviation Airport is a facility that needs to reevaluate its current site plan in order to improve the site by increasing pedestrian safety and minimizing environmental construction impacts within the airport's perimeter. Recently completed (October 2008) Terminal Building at Vero Beach General Aviation Airport has a site plan designed to accommodate existing environmental requirements:

1. Large specimen trees that were not to be removed.
2. Storm water management requirements to accommodate additional non-pervious pavement.
3. Green space and landscaping requirements in accordance with local ordinances.

To meet these requirements, the resulting automobile and pedestrian traffic flow does not allow for optimum efficiency. In other words, because certain environmental requirements did not allow complete freedom of design, maximum safe and efficient design of the automobile and pedestrian traffic plan could not be achieved. These issues are addressed in this study, while complying with regulatory agencies such as the building department and The Department of Environmental Protection (F.D.E.P.). The goal of this study is to find a cost-effective and reasonable solution for the existing problems.

LITERATURE REVIEW

In constructing a methodology to improve an existing site plan with respect to environmental impacts, costs, safety, and efficiency a thorough literature review was performed. Emphases for the literature review was placed on crosswalk and walkway planning, design of crosswalks and walkways, cost function development, and calibration algorithms. In the proceeding section, the literature reviewed is discussed.

Crosswalk and Walkway Planning. New technologies have started being implemented by transportation planners to ensure better safety and mobility conditions for pedestrians. In a study conducted in Clearwater, Florida by the Federal Highway Administration in 2001, evaluated was the effect of illuminated overhead pedestrian signage and high-visibility ladder style crosswalks. An example of an illuminated overhead pedestrian sign used in the study can be seen in figure 1 located in Appendix G. The authors used three different categories to evaluate the pedestrian crosswalks. First, they looked to see if there was an increase in the amount of pedestrians using the crosswalk. Second, the authors looked to see if drivers would yield more due to the new signage. Third, the authors evaluated if the pedestrians used more, less, or the same amount of caution when using the crosswalk. This study found that daytime drivers showed a 30 to 40 percent increase in pedestrian awareness and yielding. The study only evaluated pedestrian crosswalks that are located at major intersections and does not take into consideration the specific characteristics found in an airport setting.

Another type of signage that improves safety for pedestrians in crosswalks is the in-street yield pedestrian street sign placed in the middle of the roadway. There are two types of these signs: the portable sign attached to a large drum and a fixed sign made of durable plastic. The portable sign is often seen as dangerous because of its potential to move when struck by a vehicle (Kannel and Souleyrette, 2003).

Besides adding additional signage to crosswalks transportation planners have been exploring the effectiveness of using rapid flashing LED beacons at crosswalks. In a study conducted by Van Houten and Malenfant (2008) rectangular-shaped rapid-flash LED beacons were evaluated on their effectiveness in St. Petersburg, Florida. The study found that the beacons increased yielding levels by 20-30% in some crosswalks and up to 80-90% in a majority of the crosswalks. The authors recommend that this new technology be applied at other crosswalk in the case study area considering it's relatively low cost and effectiveness.

A way to reduce the amount of traffic that flows through parking garages or lots that can be harmful to pedestrians already located in these facilities in the implementation of Parking Guidance Information (PGI) systems. The PGI systems inform drivers when a parking lot is full therefore eliminating through traffic in the garage that would normally circle around trying to find a parking spot. In the specific case study of PGI systems in Sligo City Centre the physical displays are connected to the software using GPRS modems. Furthermore, the sockets are secure prevent 'hackers' to gain access to the system.

Other than safety concerns transportation planners must also consider the level of service of pedestrian crosswalks, especially in an airport setting where crosswalks are utilized by large volumes of pedestrians at certain time intervals. If a large commercial flight is schedule to leave at a particular time the crosswalk located at airport terminals can become overcrowded prior to the flight. By keeping the level of service at a tolerable, passengers can be sure to arrive at their departing flights on time. Muraleetharan and Hagiwara (2002) completed a study that evaluated the level of service of crosswalks and sidewalks by using a geographical information system network to collect data. Using the collected data the authors were than able to calculate shortest-path routes and optimized level of service path routes between origin and destination pairs. In the case of an airport terminal the crosswalks are more defined than in an urban setting and need to be optimized in design.

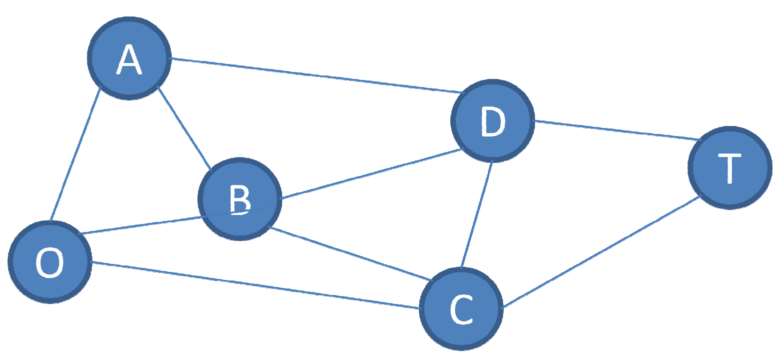
Modeling human behavior in transportation software is a natural phenomenon that transportation planners have been trying to mimic. Usually human behavior refers to driver user behavior and/or route choice behavior but in certain cases the human behavior of pedestrians is needed to be model and analyzed. In a study completed by Turner and Penn in 2002 the Gibson's ecological theory of perception is used to develop and calibrate a model of pedestrians to represent actual pedestrian behavior in a building setting. The authors used exosomatic visual architecture to pre-store relative distances of pedestrians and their surroundings in a table and use these values to determine the pedestrian's path in an agent-based software.

Airport terminals introduce a new type of pedestrian walkway that is not typically found in the urban setting. These congested walkways are sometimes equipped with automated pedestrian movement systems. Literature on airport walkways and airport pedestrian flow is rare but one study was found by Seth Young in the Transportation Research Record (1999). The study used empirical data collected from observations within an airport terminal corridor to evaluate the travel time and walking speed of pedestrians. Certain observations were made of each passenger including but not limited to age, gender, and travel type (personal, business or leisure). Human behavior such as bypassing the moving walkway to self select a faster pace, or immediately stopping walking speeds once reaching the moving walkway was observed complicating the calculation of pedestrian average walking speed.

Design of Crosswalks and Walkways. The design of pedestrian crossways and walkways are usually based off of two principles: shortest-path and routes choice. In the case of pedestrian route choice the shortest distance between the origin and destination has great influence considering that human nature is to walk the smallest distance. In a paper written by Dijkstra (1959) a method in finding the shortest path was presented. It consisted of two parts or two problems being solved through a process of steps. First, a tree was constructed for all minimum lengths between all the *n* points or nodes. Second, the minimum total length was found for a path between 2 given nodes. This process aids designers when having multiple points of interest and needing to find the shortest path between 2 exact points.

Furthermore, the shortest path algorithm can be used not only to find minimum travel distance but it can be used to find the lowest cost or time between activities (Hillier and Lieberman, 2005). In this case the branches, arcs or links between nodes no longer represent the distance between nodes but instead represent the cost or time between activities. If there are *n* nodes in the network the amount of needed connected arcs or links is *n*-1 to make a complete spanning tree. This spanning tree can then be used to analyze the network. An example of a network built with nodes and links can be seen in figure 2. .

Figure 1: Example of a node link network



In a study conducted by MTI pedestrian route choice and preferences for routes was analyzed in 2006. The authors wanted to explore how far pedestrian were willing to walk to transit stations and what environmental impacts influenced the route they choose to walk. The data collected in the study was responses from a survey that was conducted among local pedestrians in the case study area. The study found that the distance traveled by pedestrian was larger than the average length used by planners of one third or a quarter of a mile. The average distance found was 0.47 mile or almost a half of a mile. When asking pedestrian what factors most influenced their route choice the first answer usually given was the quickest or most direct (shortest) route. Other factors that respondents said influenced their route choice were safety, sidewalk conditions, and length of traffic lights when crossing intersections. The authors of this MTI paper categorized the different walking environmental factors into five different classifications:

1. functional (physical attributes of the street)
2. safety (characteristics of a safe environment)
3. aesthetic (elements such as trees or gardens)
4. destination (relationship of neighborhood services to residences)
5. subjective (attractiveness and difficulty)

The survey conducted by MTI found that 92% of people continually and consistently take the same walking route every day. The major influences and factors in their route choice can be seen and ranked in table 1. The shortest route was the priority of most pedestrians closely followed by safety.

Factor Type	Anywhere in List	First	Second	Third
Shortest/fastest	64	52	10	3
Safety	28	8	14	6
Convenience	9	6	2	1
Attractive	8	2	3	2
Habit	6	3	1	2
Stopped at a business	3	2	2	0
Other	27	13	9	5
Meaning of response unclear	16	9	5	3
Left blank	N/A	3	50	77

Table 1 - Route Choice Influences (MTI, 2006)

Another study that collected route choice preferences from pedestrians through the use of surveys was conducted by Verlander et al. in 2007 for a UK urban area. The study found that 75% of pedestrians choose the shortest route to their destination. The remaining one forth of pedestrians did not choose the shortest route and found the path length was weakly connected.

A type of model available to analyze traffic facility designs is the SURROGATE SAFETY ASSESSMENT MODEL (SSAM). It can be used to output meaningful measures of safety based on the occurrence of conflicts during the simulation and can also provide the comparisons the relative performance of one design between another. It operates by processing data describing the trajectories of vehicles driving through a traffic facility (e.g., a signalized intersection) and identifying conflicts. The vehicle trajectory input data for SSAM are generated by traffic simulation software in a trajectory file format, specially designed for SSAM. SSAM calculates surrogate measures of safety corresponding to each vehicle-to-vehicle interaction and determines whether or not each interaction satisfies the criteria to be deemed an official conflict.

The conflict classification is generally based on the conflict angle (SSAM Software User Manual 2008 FHWA-HRT-08-050). According to the manual they are four different types of conflicts:

- Unclassified: conflict angle unknown;
- Crossing: ||**ConflictAngle||** > 85 °
- Rear-end: ||**ConflictAngle||** < 30 °
- Lane-change: 30 °<||**ConflictAngle||**< 85 °

Transportation planners are aware of the increasing need for pedestrian safety and mobility in crosswalks. In order to optimize the safety and level of service for pedestrian new technologies such as illuminated overhead signage, human behavior modeling and evaluation current data using GIS systems. Walkways and crosswalks located in airports become more difficult when designing considering the demand and flow of the walkway and/or crosswalk.

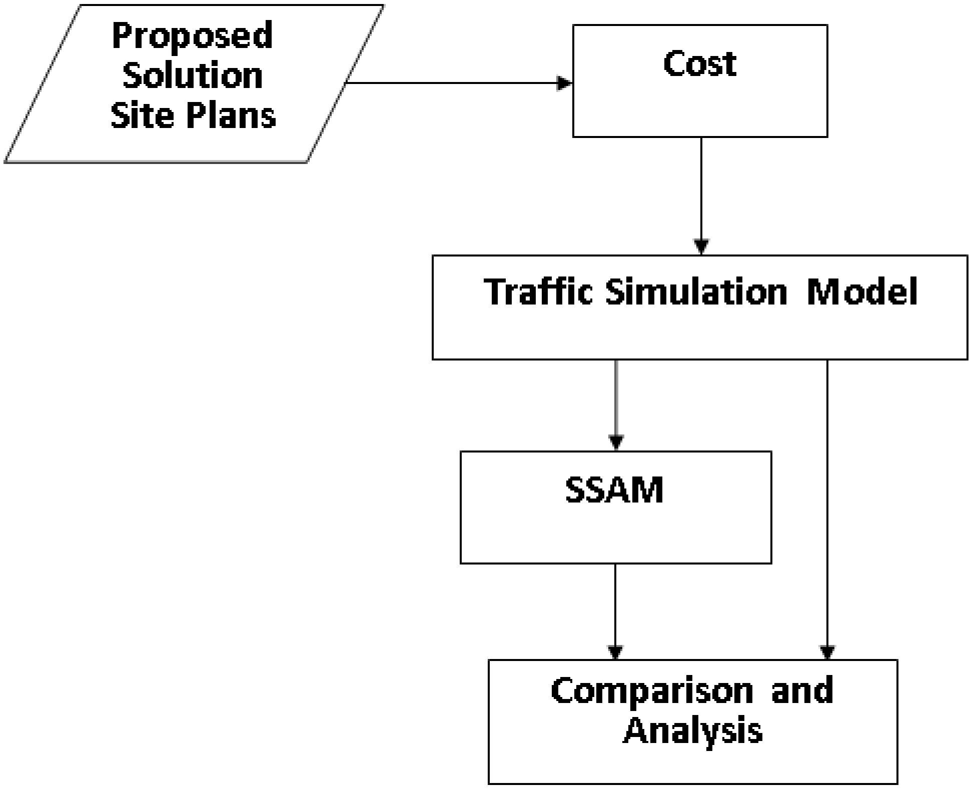
PROBLEM SOLVING APPROACH

Methodology. This research proposes a method for the comparison of airport site plans, both current and proposed with regard to environmental impact, cost, safety and efficiency. In general, field observations are partnered with mathematical programming to mimic decision based route choice made by pedestrians. The development and calibration of a cost function capable of evaluating current and proposed links is presented here. Proposed solutions site plan networks are evaluated using the cost function. These solutions are obtained for stakeholder interviews and field observations. The result of the cost function yields pedestrian flow and turnings resulting from the proposed site plan solutions. This is possible by replicating the route choice decision observed in the field and applying them to the proposed site plan improvements. These pedestrian flows, along with observed traffic flow are placed into a traffic simulation environment. The simulation platform then yields traffic operations statistics such as travel and delay time as well as vehicle and pedestrian trajectory files. These trajectory files are analyzed using Surrogate Safety Assessment Model (SSAM) developed by the Federal Highway Administration (FHWA). SSAM outputs measures of safety based on the occurrence of conflicts during the simulation. This software also provides comparisons of the relative performance of multiple site plan designs. It operates by processing the vehicle trajectories and identifying conflicts. SSAM calculates surrogate measures of safety corresponding to each vehicle-to-vehicle interactions (for the purpose of this study, pedestrians are considered a vehicle type) and determines whether or not each interaction satisfies the criteria to be deemed an official conflict.

Figure 2: SSAM Data Input Flowchart illustrates this process.

Finally, the results for effective movement of vehicles, the safety of pedestrian, environmental impact the proposed site plan solutions and projected cost of implementation are compared according to the stakeholder survey. The goal of this comparison is to establish which site plan presents the best solution for the airport. This objective is achieved by performing an alternative analysis of the different options including the current and proposed site plans. First, a rating system is developed to rate each option according to the decision criteria. A rating system of 1-3 points is proposed where a score of three is awarded to the option that best satisfies the corresponding criterion. Each alternative is analyzed separately to obtain an un-weighted solution. Ultimately, the final solution must meet the need of the stakeholders; thus, a survey is created to acquire specific weights for each of the decision criteria. These weights are then applied in order to develop a matrix that compares the alternatives for both the weighted and un-weighted analyses. This process is outlined in Figure 3: Methodology Flowchart. The remainder of the methodology explains the development and calibration of the pedestrian cost function model.

Figure 3: Methodology Flowchart



Cost Function Development and Calibration Algorithm. A cost function is the way by which the links within a network are assigned values. The general form of the cost function model in this research is similar to a modified linear regression equation seen in equation (2). The lower case variables (a, b, c) represent calibration values, case specific quantities which are determined from the Cost Function Calibration Algorithm. The upper case values (X_n, Y_n, Z_n) are assigned values based on field observations. X_n is the link length factor. This quantity represents the relative length of the section compared to all other link lengths. This value may be in feet or meters if obtained from a map or unit-less if captured from a scaled drawing of unknown dimensions. Y_n represents the pavement type factor. A value of 1 is associated with the most desirable payment types such as sidewalks and crosswalks. Streets, as a pedestrian path are valued at 2 and non-paved surfaces are valued at 3. Z_n accounts for vehicular crossings within the link. The value is summed for all street crossings. Crossings which take place on crosswalks are valued at 0.5. Those of which that do not directly cross a street but travel along it are quantified at 1 and those direct crossings that do not take place over a marked cross walk are assigned a value of 2 per traffic direction. Because these values are modified by the calibration values (a, b, c) which are derived from Cost Function Calibration Algorithm, that is heavily depend up field observations, any error associated with these assumptions are corrected.

The Cost Function Calibration Algorithm is designed to find lowest possible values for the calibration variables (a, b, c) which accurately represent the interaction observed in the field. Using the general form of the algorithm presented here, additional field observation constraints are applied to calculate the values of (a, b, c) which best represent reality. These constraints represent pedestrian route choice selections observed in the field.

Minimize:

$$\sum_{n=1}^{N} K_n \qquad \forall\, n \tag{1}$$

Subject to:

$$K_n = aX_n + bY_n + c\sum_{m=0}^{M} Z_{n,m} \qquad \forall\, n, m \tag{2}$$

$$0 < X_n < 0 \tag{3}$$

$$Y_n = 1, 2, 3 \tag{4}$$

$$Z_n = 0.5, 1, 3 \tag{5}$$

$$0 \leq m < \infty \tag{6}$$

$$a > 0 \tag{7}$$

$$b > 0 \tag{8}$$

$$c > 0 \tag{9}$$

Where,

K_n: Cost of link n

X_n: Link length factor

a: Link Length coefficient

Y_n: Pavement type factor

b: Pavement type coefficient

Z_n: Traffic conflict factor

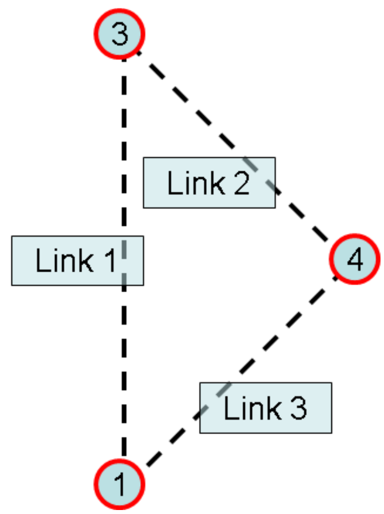
c: Traffic conflict coefficient

m: Traffic conflict within link n

The objective function attempts to minimize the cost of all links within the network. The cost function quantifies the relative value of each link individually. This function scores the links with X_n, Y_n, Z_n and then modifies these values to match observation seen in the field with a, b, c. $Z_{n,m}$ accounts for multiple traffic conflicts within a single link. For example, link 1 within a network has 2 crossings. If $Z_{1,1}$ is 0.5 and $Z_{1,2}$ is 2, than the total traffic conflict represented within link 1 is 2.5 (before being modified by the traffic conflict coefficient). Further constraints apply to variables a, b, c however these constraints are observed in the field as route choice observations and cannot be generalized.

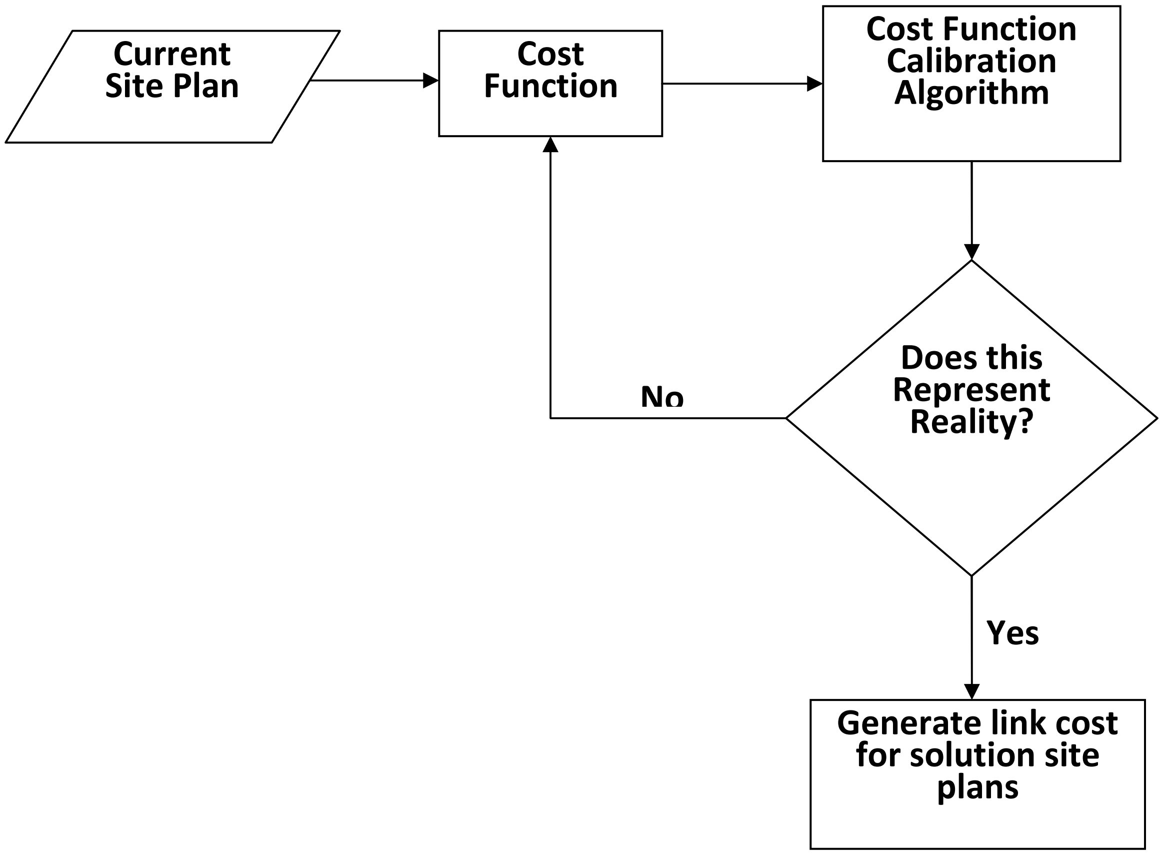
Figure 4 represents a small network with one origin (node 1), one destination (node 2) and two paths that connect them. If pedestrians are observe to chose to use link 3 and link 2 over traveling on link 1, a constraint is added to the Cost Function Calibration Algorithm that represents this ($K_2 + K_3 \leq K_1$). When diversity within the population is observed (some pedstrians choose link 1 while others chose the link 2/3 combination) multiple models can be developed if ample observgations are provided. One model representing risk neutral pedestrians, which are populations that tend toward the shortest-path regarudless pavement type, traffic interferrance, crosswalks, etc. The other model representing risk averse pedestrian, people whom value these factors at a higher benifit. This population distinction can be made only through rigouse field observations. Once the sample size reaches that comparable to the peak demand conditions conclusion are drawn and population divided into subcatagories by percent (risk nuetral and risk adverse) for the purpose of pedestrian route choice modeling within the simulation environment.

Figure 4: Example Node Network



After values of the calibration variables are know the cost function is applied to the links of the current site plan to verify that pedestrians take shortest path in both the predicted model and reality. Once this is complete, the cost function is applied to links of the proposed solution site plans. Then the new shortest path is calculated. These paths are then placed into the simulation software to obtain the impact of the new pedestrian routes, both on traffic efficiently and pedestrian safety, via SSAM. This process is illustrated in Figure 5: Site Plan Link Cost Generation Flowchart.

Figure 5: Site Plan Link Cost Generation Flowchart



SAFETY RISK ASSESSMENT

As required by the FAA the currenty safety management system guidance was examined with regard to the non- air-side conflicts proposed by this research. After consulting both the Introduction to Safety Management Systems for Airport Operators and the FAA Safety Management Systems Manual, altering the land-side airport site plans has no inherent safey concerns airport operations.

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TECHNICAL DESIGN

For the application of the described methodology a small general aviation airport, the Vero Beach Municipal Airport is chosen.   This public-use general aviation airport possesses FAR Part 139 certification and maintains three lighted runways. The Vero Beach Municipal Airport accommodates roughly 185,000 take-offs and landings annually. The size of the aircraft serviced range, from smaller general aviation aircraft to larger corporate jets. Within this airport are four full service fixed base operators that ensure the requirements of the airfield users. These services include aircraft fuel (100LL, Jet A) and storage, flight planning, food/drink service, vehicle rentals, charter aircraft service, avionics repair, aircraft parts, airframe and power plant maintenance and auxiliary power units (City of Vero Beach, 2010).

Recently, the Vero Beach Municipal Airport refurbished its existing terminal buildings and added additional retail space. These additions have made the airport a desirable destination for the local community, especially during the mid day peak period (lunch time) from 11:30AM to 1:30PM. The current site plan is designed to accommodate typical airport traffic operations, drop off and pick up at the terminal building. This results in the parking areas being moved further away from the entrance. Current geometrical design of ground access areas does not provide safe and efficient flow for vehicles and pedestrians. The increase in the attractiveness of the airport buildings resulting from the success of the business locate therein has formed unique traffic problems within the area:

- Pedestrians do not use designated crosswalks
    - Improper signage (pedestrian)
    - Crosswalks do not follow shortest path
    - Crosswalks are not large enough for peak hour flow volume

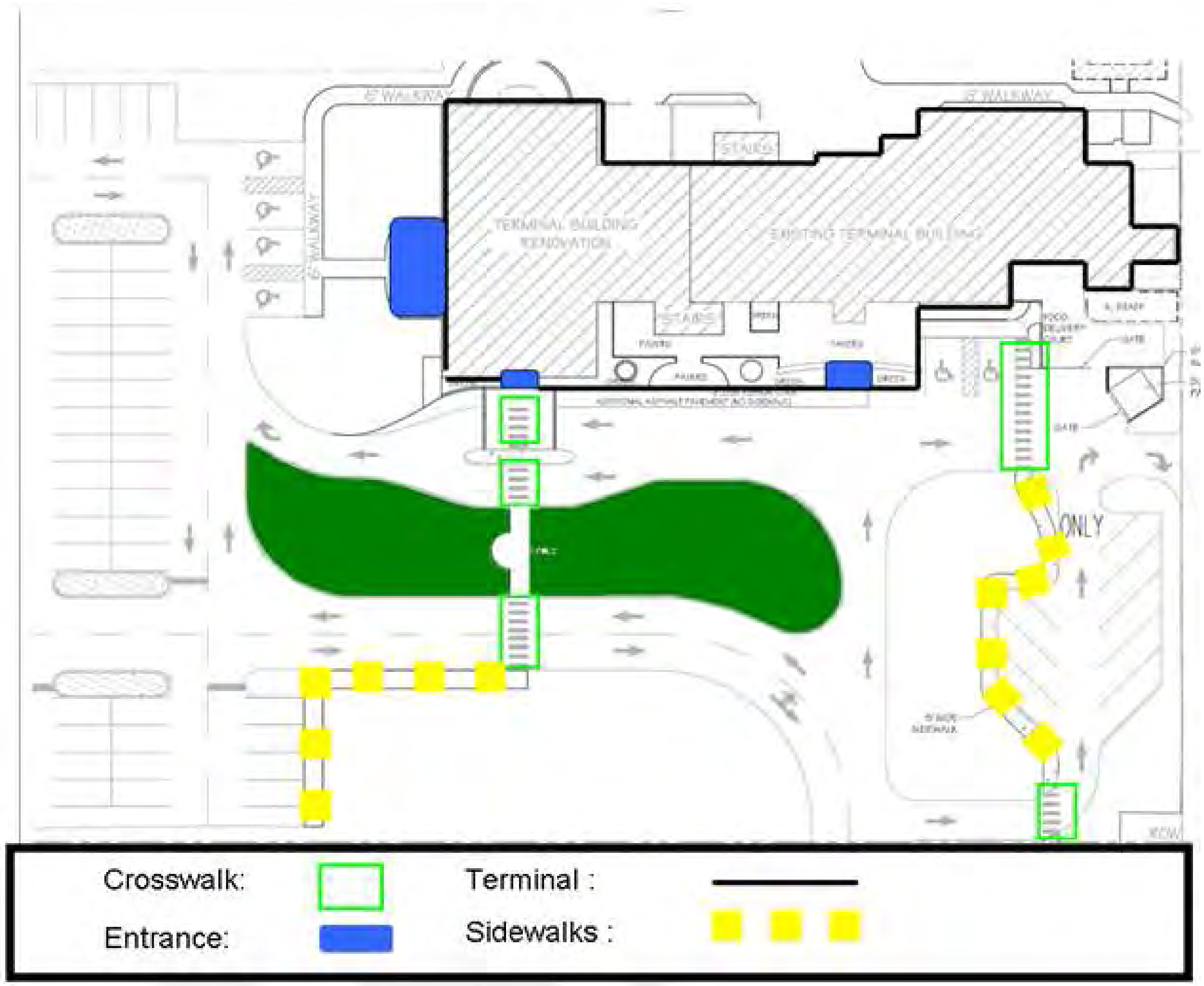
        - Vehicles are parked on crosswalk paths
    - Current crosswalk design does not account for all pedestrian paths
    - Major parking areas are furthest away from most attractive building areas
    - Irregular parking
    - Improper signage for vehicles
    - Drivers do not follow traffic laws
        - Not stopping at stop signs
        - Drivers make illegal turns
        - Drivers drive wrong way down one way streets
    - Turing radii are not properly designed
    - Drivers do unnecessary driving in order to find parking
    - Insufficient handicap parking

In addition to the unpredicted attractiveness of the non-airfield related facilities this improper geometric design stems for the environmental constraints which are prevalent within the area. The city of Vero Beach has stringent landscaping and storm water ordinances which further restrict the options available for site plan development.

Current Site Plan. Figure 7: Current Conditions Site Plan shows the layout for the current conditions of the site plan, at which the lack of crosswalks to connect the parking lot located on the west to the front of the main building can be seen. In addition, as shown by blue squares are the possible entrances of the building as of right now and from the field observations it was noticed the lack of signage to identify this entrances specially the one on the west side of the building. The big green grass area does not have a barrier to prevent pedestrians to walk over it.

However, there is a crosswalk that goes across this grass area that barely used by pedestrians who rather take the shortest route to the restaurant. Notice also that there are not covered sidewalks so it becomes an issue during the raining seasons. Figure 6: Current Conditions Site Plan

Figure 6 – Current Conditions Site Plan



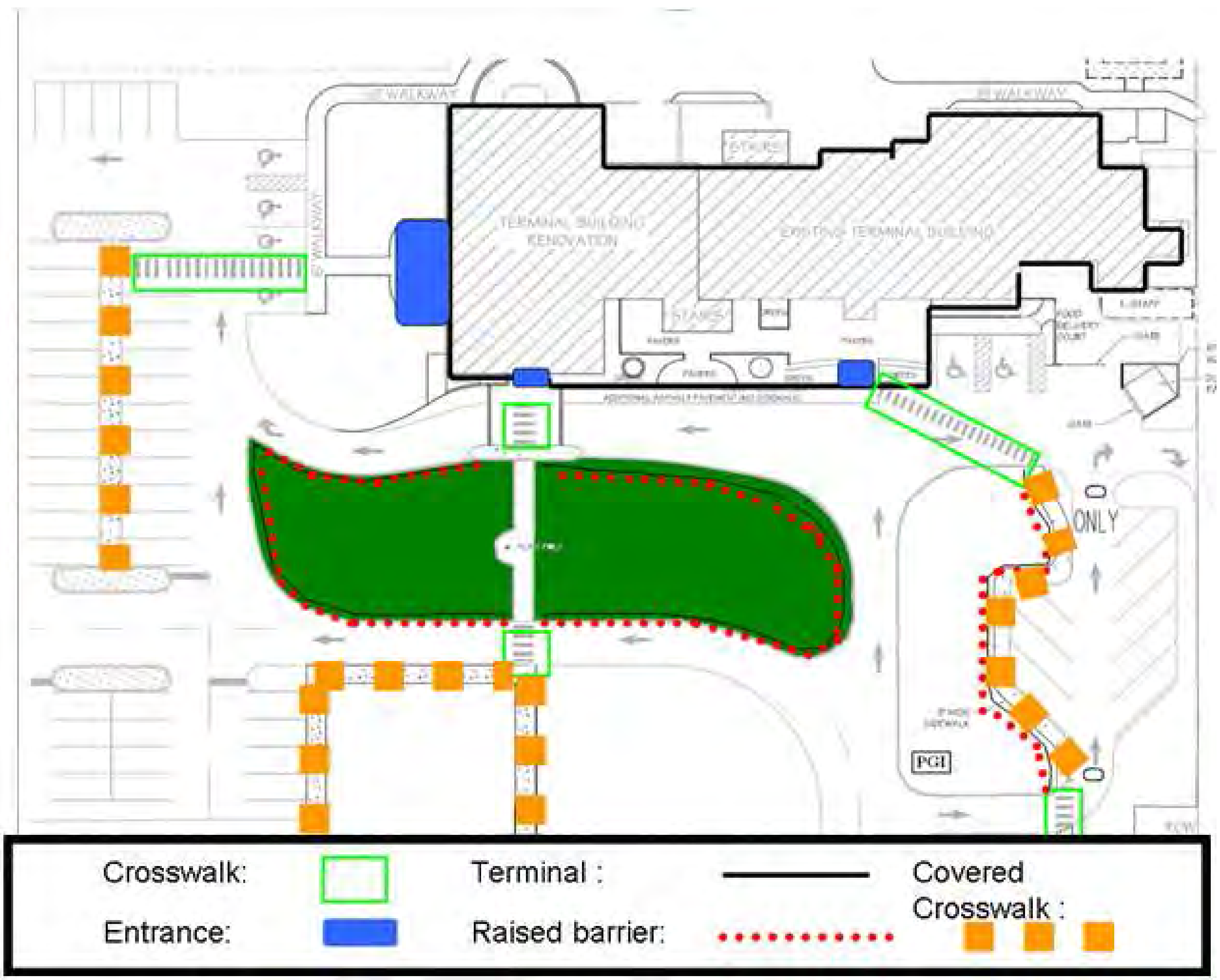
Solution Site Plan 1. In an effort to improve the existing conditions of the current site plan, a few changes are suggested to improve safety of the pedestrians and the efficiency for the vehicles. First of all, a crosswalk is added by the restaurant to the right of the front door to communicate to the parking lot located right across the restaurant. This crosswalk is added because people do not follow the existing crosswalk path that is built on a straight position, they rather take the shortest path by walking on a diagonal until reaching the restaurant's door.

Also, the use of PGI Sign on the parking lot across the restaurant will improve the visibility for people to see its availability. This, use of PGI sign will also prevent people for looping this parking lot and adding extra chaos on the roads and also will prevent illegal left turns on the north of the parking lot.

Moreover this design suppresses two lanes, one of the lanes at the main entrance of the building, and the other one on the opposite side of the grass area. This is in order to maximize the green area to accommodate for more storm water retention and to account for the environmental factor to increase pervious area. Also, the addition of a crosswalk in the form of a concrete bridge by the parking lot on the south of the main entrance will be built in order to use the available parking space across the street from the main building.

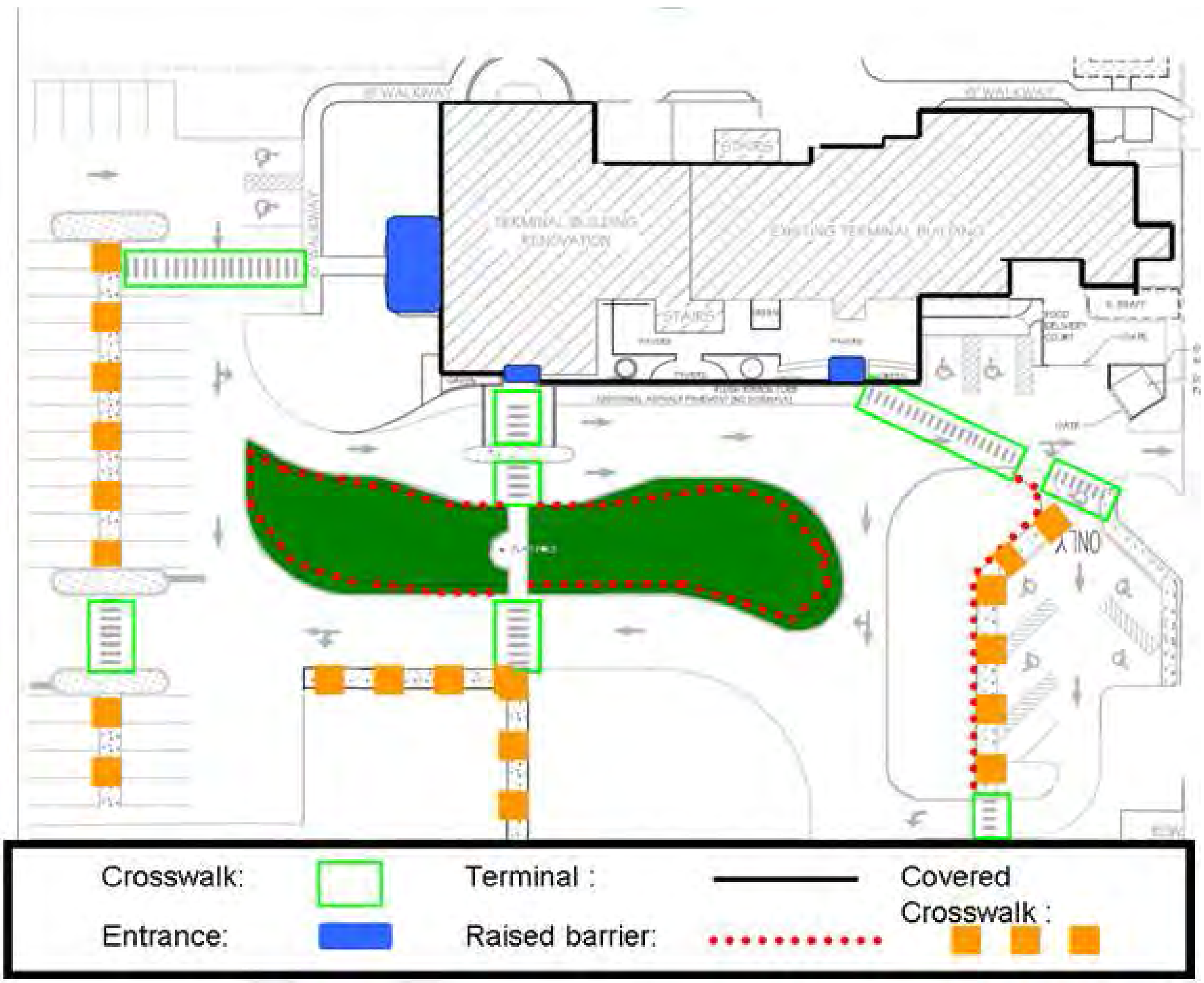
In addition, the flow has been design to be only one way flow around the main roads for two important reasons, first to maximize the incoming flow at main entrance of the facility and second to allow us to expand the parking medium to accommodate covered crosswalks in between for people exiting the vehicles and so make it more attractive to pedestrians to use the crosswalks for safety and efficiency

Figure 7 - Site Plan Solution #1



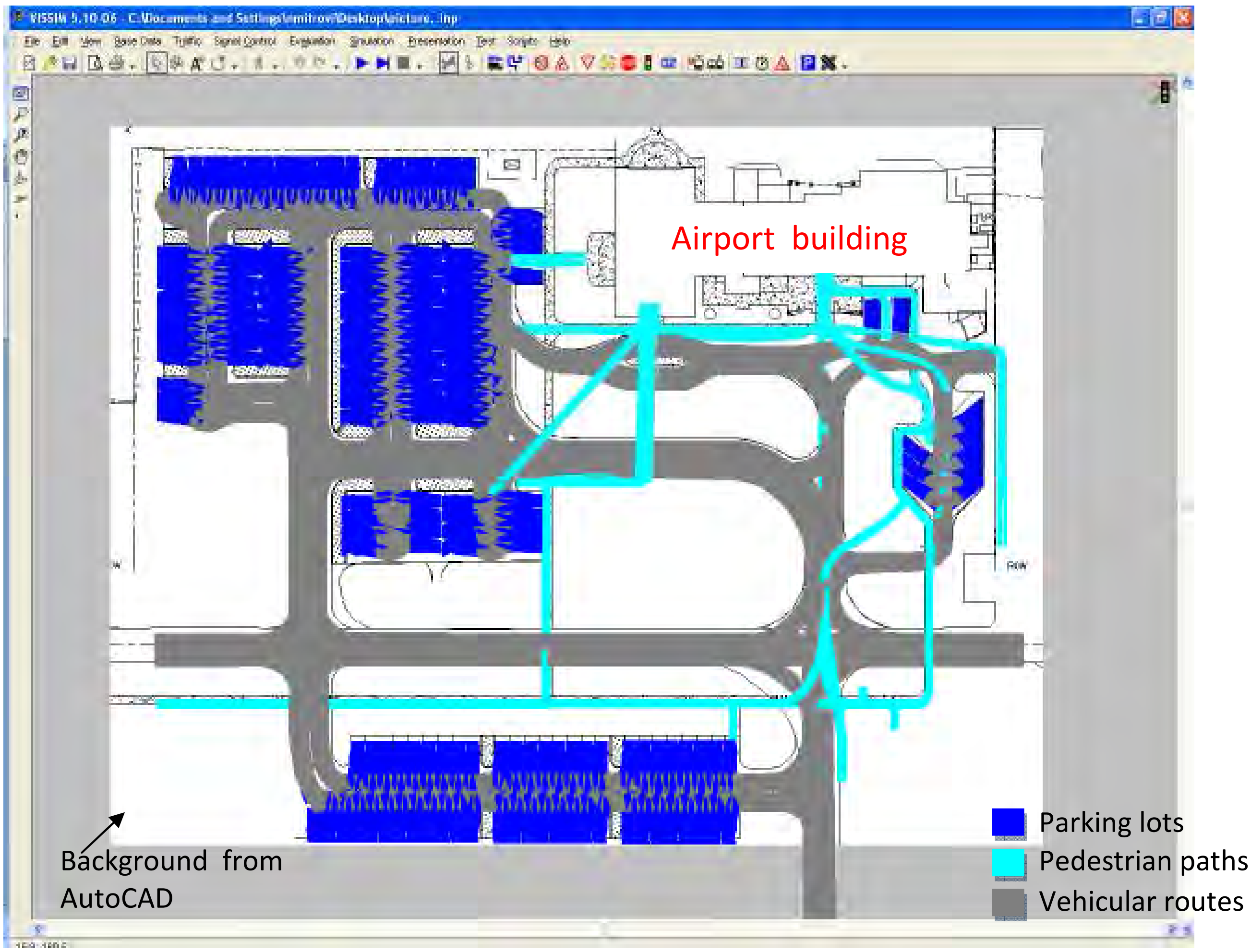
Solution Site Plan 2. This solution focuses on making the main entrance of the building to be located on the west side of the airport facility. This is in order to solve most of the problems that we have at the current conditions, such as pedestrians not using crosswalks to reach the restaurant. By altering the attractiveness to this area, that is going to help a lot to the pedestrian pathways to be used more. This design will still have a one way flow but in a reversed way and the parking medium to accommodate covered crosswalks in between for people exiting the vehicles will be used still. One of the important aspects of this site plan is that the handicapped parking spaces have been relocated to the parking lot in across from the restaurant so in order to expand the covered crosswalk on the new entrance of the building. An additional crosswalk is added to this parking lot for the handicapped people. A diagonal crosswalk that was explained on option numbers one is still added to the right of the front door of the restaurant to communicate to the parking lot located right across the restaurant. A raised barrier which can be a three foot fence around the main grass area in front of the main building is added to prevent pedestrians to walk across the grass to reach the building by using the shortest path. This solution is very cost effective, aesthetically pleasing, and helpful to force the pedestrians to use some of the existing crosswalks.

Figure 8 - Site Plan Solution #2



Simulation Environment. The traffic simulation chosen for the development of the current and site plans is VISSIM 5.10. This software is chosen for its ability to model the intricate details of parking lots.. Furthermore, VISSIM 5.10 offers a wide range of function applicable for building and managing traffic systems. The traffic model is developed using AutoCAD drawing provided by the stakeholder. These images serve as a "background" by which the model is build upon. From this model information such as lane width, parking dimensions and turning radii are captured. Vehicle and pedestrian paths are modeled using the field observation counts during the peak demand period. Figure 9 depicts the current site plan as modeled in VISSIM. Parking lots are colored dark blue. Vehicular paths are outlined in gray and pedestrian paths in light blue.

Figure 9 – VISIM Model



Traffic operations are designed to match the field observations. Desired speed is defined at 10-15 km/h. Mean parking dwell time and associated standard deviation is 3600s and 1800s, respectively. These values are verified within the simulation model. The estimated dwell time shows agreement with dwell time from field i.e. the numbers of vehicles at the end of simulation approximately matches the traffic counts in the field. This correlation is observed throughout the simulation interval. Model calibration is conducted using traffic count information. The entrance and exit locations are selected as the data collection points for the calibration.

Figure 10 displays these locations. Hourly traffic counts within the simulation are compared the field observed traffic counts.

Figure 10: Current Condition AutoCAD Drawing

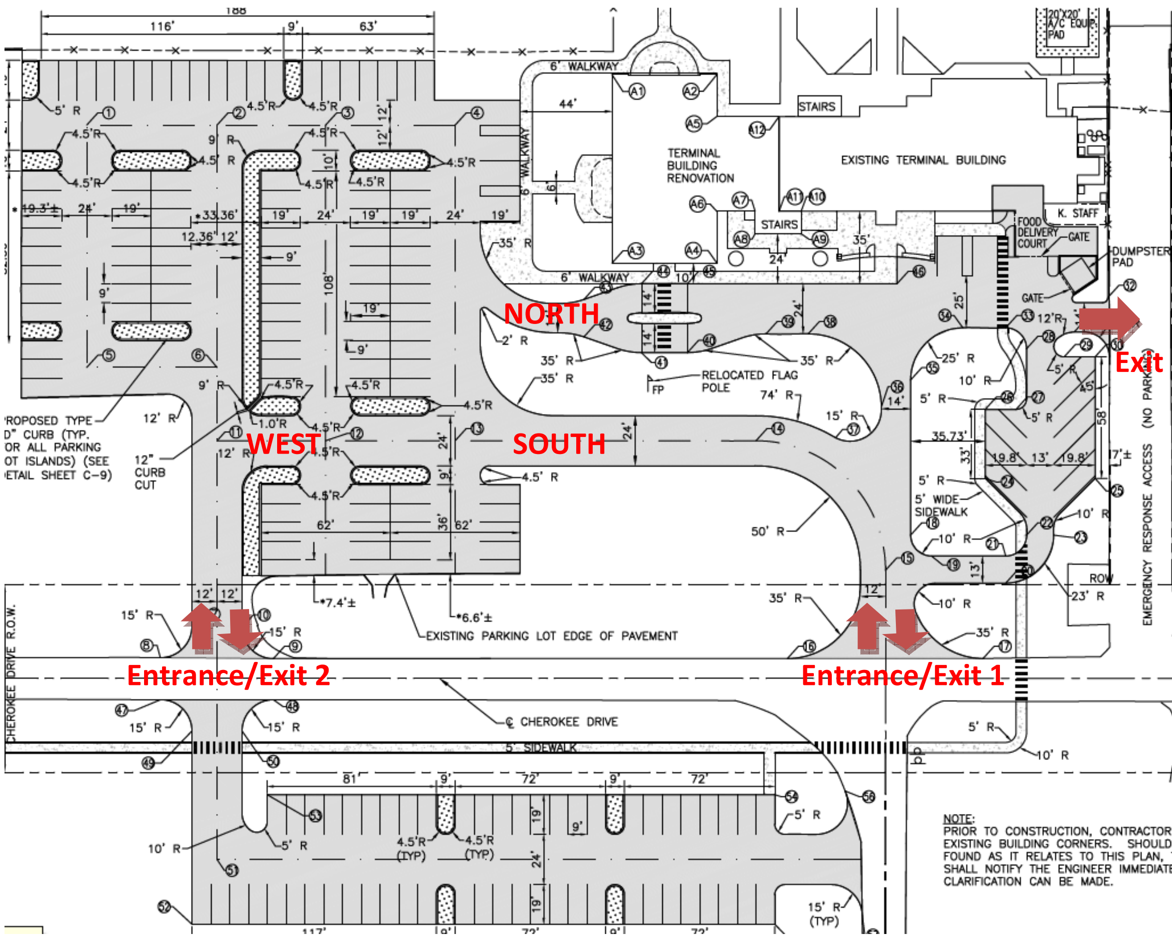
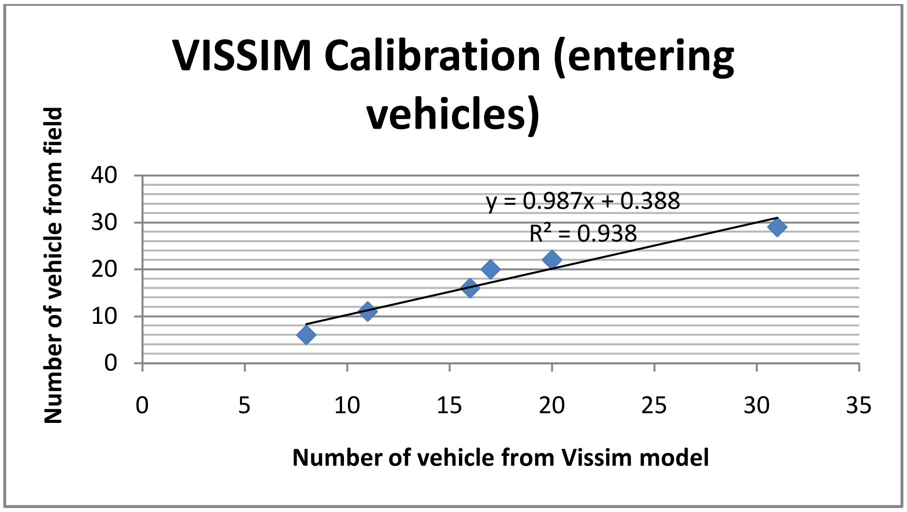


Figure 11 VISSIM Calibration (entering vehicles) displays the calibration results for vehicle entering the site. The X-axis represents the vehicles observed entering the network in the VISSIM model. The Y-axis shows the field observations entering the site. The root mean squared error (RMSE) is observed to be 0.93. This value indicates that the model and the field observations are closely linked.

Figure 11: VISSIM Calibration (entering vehicles)



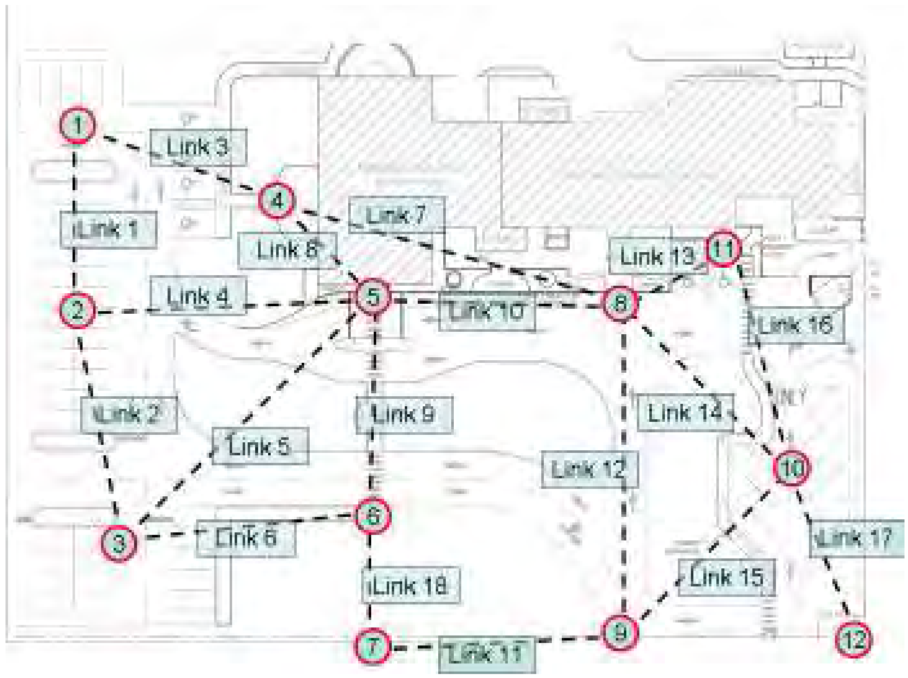
(Located in Appendix D) displays the vehicle counts exiting the network in the same fashion. This RMSE is observed to be 0.9955, showing that the field observations and simulation performance is nearly identical. Additionally, pedestrian counts were collected within the simulation environment and subsequently compared to that of field observations. The results of the calibrated network are shown in Figure 17: VISSIM Calibration (pedestrians) (Located in Appendix D). The RMSE for the pedestrian counts is calculated to be 0.9372.

Once the model is calibrated, it is ready to test the site plan solutions. The first step in the process is generating AutoCAD files by which to capture the geometric design of the new site plan. Then traffic information identical to calibrated model is imported into the simulation software. Finally, the results from the pedestrian cost function (pedestrian flow and turnings) are modeled in the new simulation environment. This process allows for accurate comparison for the efficiency the proposed solutions. Furthermore, the simulation provided trajectory files for the conflicts between vehicle and pedestrian used in the safety analysis.

Link Node Networks. The currently site plan was modeling in a link node network (Figure 12: Current Site Plan Network). The nodes represented by circles are pedestrian origins (parking lots), destinations (building entrances) or locations where path convergence or divergence. Links represented by dashed lines are pedestrian paths. (Located in Appendix D) displays the observed counts collected during the peak demand period at the site. The areas of interest on this figure are the pedestrian behaviors with regard to nodes 3, 4, 5 and nodes 8, 9, 10. Pedestrian originating at node 3 are observed to take two routes to their destination at node 5. One is directly across the grass and the other is through node 6 where the sidewalks and crosswalks are located. For this origin-destination pair 70% of the population is observed to travel through the grass and 30% use the sidewalk/crosswalk combination path. Similarly for nodes 8, 9, 10 approximately 27% are observe to take the longer path which traverse a sidewalk/crosswalk combination while the remaining pedestrian use the shortest distance path. Therefore, two pedestrian cost functions apply to the case study, one for risk neutral pedestrians and one for risk adverse pedestrian. The risk neutral pedestrians represent 71.36% of the population (average between the observed discrepancies) with the remaining 28.64% being that of the risk adverse population. These values are similar to the ones found in the literature review of 75% and 25%

.

Figure 12: Current Site Plan Network



Risk neutral pedestrians are assumed to travel on shortest path regardless of any other factors. Therefore, the result of cost function for these populations is simple the travel distance and no calibration is needed (Figure 17: Current Site Plan Network Located in Appendix G). On this figure displayed on the links is the unit-less travel distance measured from scaled AutoCAD files. The shortest path from each origin location to each destination location is marked with a solid line. Because link 18 travels over current storm water retention area, this link is not available for use under the current conditions. For risk adverse pedestrians the Cost Function Calibration Algorithm has two additional constraints: $K_6 + K_9 \leq K_5$ and $K_{15} + K_{14} \leq K_{12}$ which are counter to the shortest link length. When these are paired with the constraints of the general form, the calibration coefficients a, b, c are found to be approximately 0.057, 0.01, and 0.120 respectively. Figure 20: Risk Adverse Network for Current Site Plan (Located in Appendix D) shows the link cost after applying the calibrated cost function. Once again the shorts path from origin to destination is marked with a solid line. Once the calibration variables are known for the study area, the cost function can be applied to the proposed solution site plans. From these networks and the observed counts, pedestrian flow is modeled in the simulation environment. This approach to modeling proposed site plans assumes that origin and destination demand remains consistent. However, for solution two this is not the case. By transforming node 10 into disabled parking only and arranging node 4 to be the main entrance of the terminal building the demand for these nodes will ultimately change. Nevertheless, because these changes will reduce the average pedestrian travel distance the assumption only hinders the solutions performance and therefore represents a worst case scenario.

INTERACTIONS WITH AIRPORT OPERATORS

Stakeholder Interview. Mr. Eric Merger Vero Beach Municipal Airport director walked with our team of engineers and professor to show the current situation of the site plan outside the facility. He mentioned that during the development of the first site plan there were some environmental constrains that prevented the design Engineers to develop the most efficient site plan design for the outside of the airport for cars and pedestrian to mobilize in a better way.

Stakeholder concerns. According to the Airport director the most issues seen at the current conditions site are the following:

- Safety for pedestrians
- Pedestrians cannot access to the main building when it is raining
- People walk on the roads
- People do not walk thru the lobby to access the restaurant
- Signals, signage and markings are not visible
- Crosswalks are rarely used
- Pedestrians cannot find their way to their destination (which is normally 90% of the time the restaurant on the terminal)
- Parking lot across the other side of the street is not used during
- Walkways are not covered and subject to Florida rainy season
- Sidewalks but the signage is poor
- Current geometric design needs improvement because cars and pedestrian movement is not efficient

Stakeholder ideas/solutions:

- Provide overhang or covered crosswalks
- Provide a barrier across the grass
- Signage for everything for all aspects is needed
- Build a bridge where the storm water retention is so pedestrians can cross directly from the parking lot across the street.

Limitations:

- Trees need to remain untouched
- Storm water retention areas need to meet code
- City ordinances for green space must be maintained
- The cost is a big factor so the new ideas or new design for site plan should be feasible.

PROJECTED IMPACTS

The two proposed site plan solutions as well as the current conditions are evaluated with respect to four decision criteria: effective movement of vehicles, the safety of pedestrian, environmental impact of the proposed site plan solutions and projected cost of implementation. VISSIM microscopic simulation platform 5.10 was used to model the three options. The simulation run time considered for the scenarios was 8,400 seconds with a warm-up period of 1,200 seconds. The two-hour simulation run time corresponds to the data collection period conducted during the site observation. Ten different replications with random seeds were used to ensure that there are not significant discrepancies in the results obtained. The necessary measures of effectiveness for the evaluation of the effective movement of vehicles were extracted from the simulation software. Delay is the primary measure of effectiveness used to determine the level of service of a facility. Therefore, average delay time is selected as the performance measure to compare the effectiveness of vehicle movements throughout the three alternative site plans.

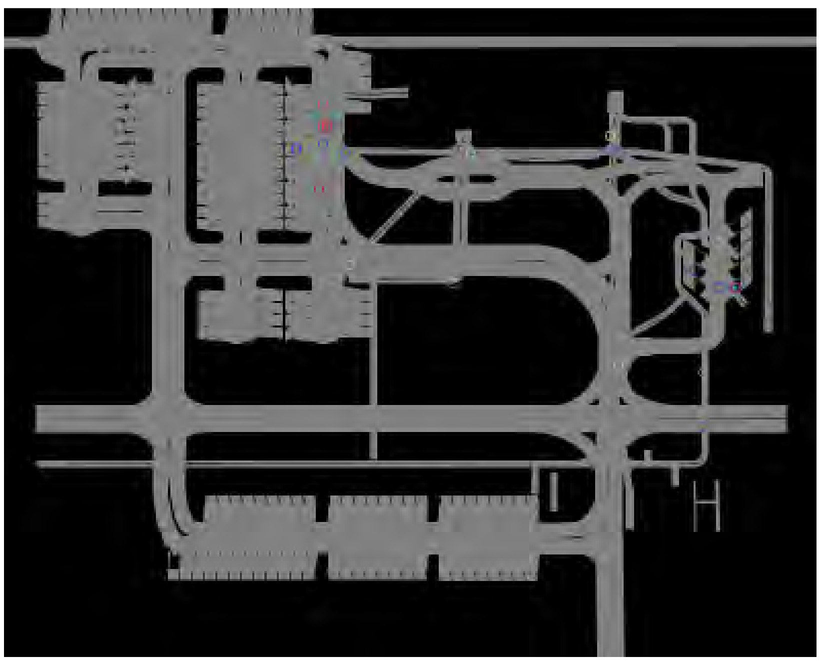
The simulation of the current site plan resulted in an average delay time of 14.217 seconds per vehicle for all vehicle types. Solution site plan 1 consists of an added crosswalk by the restaurant located in the terminal building in order to link the front door of the building to the parking lot located across from the restaurant; parking guidance information (PGI) system to indicate availability of the most frequented parking lot in an effort to reduce unnecessary driving; and one directional flow. The simulation of the solution site plan 1 yields an average delay of 5.063 seconds per vehicle. Solution site plan 2, similar to solution 1, considers one directional flow throughout the site but in the opposite direction; relocates the handicapped spaces across the restaurant in order to expand the covered crosswalk on the new entrance building; and provides an additional crosswalk to this particular parking lot for disabled users. In addition, a raised barrier around the main grass area prevents pedestrians from walking across the grass. After this scenario was simulated, an average delay time of 3.834 seconds per vehicle was obtained. Both solutions 1 and 2 reduce the average delay time of the facility. Users of the proposed solution 1 experience an average delay time reduction of nearly 65 percent while the proposed solution 2 reduces the average delay time for users by nearly 75 percent compared to the current condition at the Vero Beach Municipal Airport.

The introduction of one directional flow and techniques, such as the PGI system, not only reduce delay for the users but also minimize excess driving throughout the site as was observed in the current condition with people consistently attempting to find parking spaces that are closest to the restaurant entrance. This reduction in driving and delay time minimizes the amount of excess fuel that is spent while searching for a parking space. Therefore, it can be deduced that solution 1 and 2 are more environmentally friendly than the current scenario. Moreover, by reducing one driving lane as seen in figure 8, the proposed solution 1 increases the amount of green space from the current site plan by 20 percent. In the proposed solution 2, however, the turning radii in the existing site plan had to be maintained for safe driving. Hence, no significant changes in green space were achieved in solution 2, which makes solution 1 the most environmentally friendly solution.

While the simulation is run for each of the alternatives to provide traffic operations statistics, VISSIM also yields vehicle and pedestrian trajectory files. These trajectory files are analyzed using Surrogate Safety Assessment Model (SSAM) developed by the Federal Highway Administration (FHWA), which outputs safety measures based on the occurrence of conflicts during the simulation. In this study, pedestrians are considered a vehicle type. After simulating each alternative, the trajectory files were obtained from VISSIM and imputed in the Surrogate

Safety Assessment Model to generate the necessary safety measures. Aside from the surrogate safety measures, SSAM provides the number of conflict points in a scenario as well as differentiate the different types of conflict. Figure 23 illustrates how SSAM presents the conflicts in the current site plan. The green circles in Figure 23 represent rear-end conflicts; the red circles represent lance-change conflicts, and the blue circles represent crossing conflicts. Refer to the Appendix G for the conflict representation of the two proposed solutions. The results of the SSAM analysis for the three different cases are discussed below.

Figure 13: SSAM Conflict Representation for the Current Site Plan at Vero Beach Municipal Airport



For the current condition, the mean time-to-collision, as seen in Table 2 is zero which indicates that if a conflict exists between two vehicles, there would be no time to stop and an accident would therefore be inevitable. Moreover, the maximum vehicle velocity change for the current condition was found to be 4.74 with a mean value of 1.26. As seen in Table 3, the Safety Surrogate Assessment Model found 63 total conflict points in the current condition, which consists of 44 crossing, 13 rear-end, and 6 lane-change conflicts. The results for the proposed solutions are also presented in order to draw a comparison between the three options.

SSAM Measure	Min	Max	Mean	Variance
TTC	0	0.1	0	0
MaxDeltaV	0.07	4.74	1.26	0.61

Table 2: SSAM Measure Results for the Current Condition

Total	Unclassified	Crossing	Rear-end	Lane-change
63	0	44	13	6

Table 3: Number of Conflict Points for the Current Condition

As seen in Table 4 (Located in Appendix G), the mean time-to-collision for the proposed solution 1 has increased from zero in the current condition to 0.03 which means that if an accident is to occur between two conflicting vehicles or a vehicle and a pedestrian, the driver would have time to react and perhaps avoid that accident. Table 5 (Located in Appendix G) however, shows that there are a total of 206 conflict points at this particular scenario. The number of conflict points has more than tripled when compared to the current condition, which indicates that there are more possibilities for accident between conflicting vehicles. Between the four types of conflicts, accident resulted from crossing conflicts are more severe and the number of crossing conflicts for solution 1 is twice that of the current condition therefore it can be deduced that this scenario is less safe comparing to the current condition.

In The proposed solution 2, the mean time-to-collision is doubled that of solution 1. Moreover, the number of conflict points is significantly reduced from both the solution 1 and field condition which means that out of the three scenarios, the proposed solution 2 is the safest choice.

Depending on the value of first-length and second length from the conflict tables from the SSAM, The three types of conflicts can be separated into three categories: vehicle to vehicle conflicts, vehicle to pedestrian conflicts, and pedestrian to pedestrian conflicts. The most important category is the vehicle to pedestrian conflicts because an accident between the two could result in grave injury or even fatality. Table 8 shows that based on this criterion, the proposed solution 2 is indeed the safest option.

Option	Vehicle-vehicle	Vehicle-pedestrian	Pedestrian-pedestrian	total
Current site plan	19	31	13	63
Solution 1	103	98	5	206
Solution 2	23	5	9	37

Table 4: Conflict Comparison between the Three Alternatives

Cost Analysis. A cost analysis was performed to determine the cost of implementation of the two proposed solutions. Research was conducted mostly using the internet to obtain prices of the proposed changes. Several recent bid projects in the state of Florida were reviewed to obtain prices for pavement and grass. The cost per cubic yard to remove pavement is $109.2. The cost to add pavement and grass is $112.4 and $3.49 per square feet respectively. As for the PGI system, research was conducted by accessing commercial vendor websites as well as past projects throughout the United States where similar systems were implemented. There are four components to implementing a PGI system: vehicle monitoring, communication, installation control system, and variable message signs. Monitoring equipment must be installed at parking areas in order to calculate the number of available spaces. PGI software is needed to process the car park count data which are transmitted to the central location. Communication system between the central location and VMS is needed to display the information to users. From the reviewed projects, it was determined that the price for central computer system, VMS controllers, communications system, and PGI software $11,540, $99,675, $9,500, and $95,000 respectively (Smith, 2008) Solution 1 includes added pavement for new crosswalk designs, removal of pavement and added green space, and a parking guidance information system. Solution 2 simply included added pavements for new crosswalk designs. Table 9 summarizes and compares the implementation cost of the two proposed solutions. As shown in the table, the price to implement solution 1 is estimated at approximately $480,000 while it would cost approximately $70,000 to implement solution 2. The price for basic signage, pavement markings were omitted for the purpose of this case study.

Component Description	Price ($)	Solution 1	Solution 2
Pavement Removal (Labor + Equipment) (CY)	109.2	1747.2	--
Pavement (Labor + Equipment)(SF)	112.4	44,960	67,440
Sod / Grass (SF)	3.49	1,284.32	--
Central Computer System, Hardware and Software	11,540	11,540	--
VMS Controllers & Cabinets (quantity 2)	99,675	99,675	--
VMS Structures & Installation (Quantity: 2)	70,000	70,000	--
Communications System Hardware	5,900	5,900	--
Communications System Labor	3,600	3,600	--
Software Development	95,000	95,000	--
Consultant Services	146,000	146,000	--
Telephone Line Cost/Year	300	300	--
Total	--	480,006.5	67,440

Table 5: Comparison of Implementation Cost for the Proposed Solution

Finally, the results for effective movement of vehicles, the safety of pedestrian, environmental impact the proposed site plan solutions and projected cost of implementation are compared by developing an alternative analysis matrix. A rating system of 1-3 points is used where a score of three is awarded to the option that best satisfies the corresponding criterion. A stakeholder survey was created to obtain the weights of each criterion. A scale of 1 to 10 was used where a score of 1 indicates a low importance and 10 being of high importance. The survey was emailed to Mr. Erik Menger who provided the following weights for the criteria:

- Effective movement of vehicles: **7**
- Safety of pedestrian: **10**
- Environmental aspects: **4**
- Cost of implementation **8**

Each alternative was first analyzed separately. The weights were then added and the matrix was developed to compare the alternatives. The alternative analysis matrix is presented in Table 10. Solution 2 yielded the lowest average delay time and therefore received the highest rate of 3 for the effective movement of vehicle criterion. The current site plan had the highest average delay time while the average delay time from solution 1 fell between the two. Thus, a rate of 1 and 2 was assigned to the current condition and solution 1 respectively. The Surrogate Safety Analysis Model results showed that the current conditions had a total of 63 conflict points whereas solution 1 had 206 and solution 2 had 37 conflict points. Ratings of 2, 1, and 3 were correspondingly assigned to the current site plan, solution 1, and solution 2. For the environmental aspects criterion, solution 1 was the best alternative and was rated the highest. However, since the cost of implementation of solution 1 was the highest, a rate of 1 was attributed. The current condition received a 3 for the cost of implementation criterion because there no changes are required. The current site plan and solution 1 both scored 7 points for the un-weighted analysis. Solution 2 had an un-weighted total of 10 points. The weights provided by the stakeholder were factored in order to determine the best weighted solution. The weight for each criterion was multiplied the rate assigned to each option for the corresponding criterion. As seen in Table 10, the current site plan had a total of 55 points while solution 1 accumulated 43 points; and finally solution 2 with 75 points total. Solution 2 prevailed over the other options for both the un-weighted and weighted analysis.

Criteria	Weight	Current		Solution 1		Solution 2	
Effective Movement of Vehicles	7	1	7	2	14	3	21
Safety of Pedestrians	10	2	20	1	10	3	30
Environmental Aspects	4	1	4	3	11	2	8
Cost of Implementation	8	3	24	1	8	2	16
Total	--	7	55	7	43	10	75

Table 6: Weighted Analysis for the Three Site Plans

In many cases, the rating scale and the weights assigned to the criteria may have a great impact on the outcome of the weighted analysis. The rating scale used in this analysis was selected so that the results are fair and balanced. For instance, a rating system of 1, 5, and 10 may be used to rate the options where 1 would be assigned to the option that least satisfies the corresponding criterion and conversely, 10 to the one that best meets the goal set by the criterion. Using that particular scale would favor any of the option that receives a 10 for a criterion even if this option is not the best in all the categories. However, using a rating system of low, medium, and high (1-3) ensures that the results are consistent and fair by assigning a 3 to the highest option and a 1 to the lowest. For the Vero Beach Municipal Airport, pedestrian safety was the primary concern and was attributed the highest weight by the airport stakeholder. However, at another airport, environmental aspects or any of the other criteria may be the most critical issue. A sensitivity analysis was conducted to ensure that solution two would still be the winner of the weighted analysis under some other circumstances. This was achieved by changing the weights of the criteria and recalculating the weighted points for the three options. For example, assume that another airport assigns the following weights to the criteria:

- Effective movement of vehicles: **5**
- Safety of pedestrian: **6**
- Environmental aspects: **10**
- Cost of implementation **6**

Considering the same rates in table 10, the current site plan would accumulate a weighted score of 45 while solutions 1 and 2 would accumulate a score of 52 and 65 respectively. Different scenarios were examined and solution 2 always prevailed. Therefore it is recommended that a similar rating system be used when performing an alternative analysis to guarantee that the results are valid. It should also be noted that the airport stakeholders must be the ones to assign the weights to the criteria so that the design meets the needs of the clients.

Project Conclusions: The purpose of the research was to evaluate current and proposed "land-side" airport site plans in order to improve pedestrian safety and vehicular flow while minimizing environmental construction impacts within the airport's perimeter. The proposed solution site plan 2 provides for a 75% decrease in vehicular travel time providing for increased vehicular flow throughout the Vero Beach Municipal Airport. These improvements also reduce the vehicle-to-pedestrian conflicts by 84%, allowing for safe movements to and from the airport terminal buildings. Based on current local construction bids, these improvements will cost the airport a one-time fee of approximately 70,000$. Furthermore, the design and layout of this new site plan does not violate any of the environmental constraints and the increase in efficiency will reduce carbon footprint of the facility. The proposed methodology was able to evaluate these alternatives with minimal research cost and is applicable to all airports that are looking to increase pedestrian safety and traffic efficiency of their ground access areas while maintaining environmental stewardship.

APPENDIX A

Contact Information

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APPENDIX B
DESCRIPTION OF THE UNIVERSITY

Founded in 1964, Florida Atlantic University (FAU) was the first public university in Southeast Florida. The former Boca Raton Army Airfield, FAU became the fifth public university in the state. Since that time the school has 140 degree programs, 40 research centers, and reputation for excellence.

FAU is a very community oriented and diverse facility. It not only strives to provide the best education for its students but also encourages the community to further their education and careers. It has helped in accomplishing this by becoming one of the first Information Age Universities. In the late 1990s, the school began a distance learning program, which has become very successful.

Within this past decade FAU formed the ABET accredited Civil Engineering Department under the guidance of Dr. Stephan Nix. The department has currently expanded to include not only Civil but Environmental and Geomatics Engineering. The combination of these three engineering disciplines within one department has created a very successful and competitive program enjoyed by its students. The department is committed to continue improving upon itself, not only academically but as a conduit creating productive citizens striving to make a positive impact on this nation's infrastructure.

APPENDIX C

DESCRIPTION OF NON-UNIVERSITY PARTNERS

The team did not have any active partnerships with anyone not affiliated with Florida Atlantic University.

APPENDIX E
Evaluation of Educational Experience

Scott:

1. **Did the FAA Design Competition provide a meaningful learning experience for you? Why or why not?**

The meaningful experience taken from this project is the collaboration of individual efforts culminating in the completion of this research. The group came together in the beginning of the project and this effort carried on throughout the research. The management and focus of the team has afforded me experience which I will be able to continue in my next research endeavor.

2. **What challenges did you and/or your team encounter in undertaking the Competition? How did you overcome them?**

The primary challenge undertaken by the team was discovering ways to test proposed site plan solutions. To understand how pedestrian would reach to a changes in their environment without actually changing it. It is one matter to present pedestrians with a new situation and see how they react, it is another to model this behavior without making any alterations. Furthermore, the process of using observed pedestrian shortest paths as constraints to generated relative link cost and the associated spanning tree has not been seen in the literature and was developed for this project.
Additional challenges were presented in the form of group communication. Florida Atlantic University is has a very successful distance learning program. Lectures are recorded and posted on the internet for students studying abroad to view. Not actually meeting with all the group members made the completion of the project more difficult. The problem was overcome by the use of teleconferencing and information dissemination.

3. **Describe the process you or your team used for developing your hypothesis.**

The hypothesis development began while interviewing the airport director. He stated his concerns and what he would like to see done. After this, the problem was examined first hand by conducting a two hour observation during the peak demand period. During such time notes were taken regarding the problems of current site plan. These notes were when combined and addressed in a conference held by the research group.

4. **Was participation by industry in the project appropriate, meaningful and useful? Why or why not?**

During the beginning of the project the industry stakeholder provided the insight needed to direct our field observations. He also gave meaningful ideas and suggestions as starting points to solve the problem. Additionally, the stakeholder quantified how import each of the four grading criteria was to him (Safety, Efficiency, Environmental, and Cost).

5. What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?

My contribution to the project afforded me the opportunity to practice my operation research skill, articulating the problem and then formulating it using mathematical programming. These skill sets are difficult for employers to come by and thus make me an attractive candidate for employment. Also during this project I served as Project Manager and Team Lead. The responsibility of coordinating the student resources and ultimately getting the job completed fell on my shoulders. From this experience I have discovered the difficulties associated with project management and now know how to avoid the potential pitfalls for leading a research team.

Claudia:

1. **Did the FAA Design Competition provide a meaningful learning experience for you? Why or why not?**

Yes, it provided a significant learning experience because I had the opportunity to design, test, and analyze different scenarios for new site plans and as Civil Engineers that is useful for our work. Also the research amount was extensive in order to provide good literature and support to everything we were proposing in the paper. Thus, it is always good to work in teams.

2. **What challenges did you and/or your team encounter in undertaking the Competition? How did you overcome them?**

At the beginning of our research we proposed to follow a methodology to come up with the solutions to the new designs and it turned out not be the best alternative to be used so we had to change the methodology and that caused a delay in all other activities that were projected in the schedule. As a result, we had to work extra during weekends and nights to be able to finish the testing and calibrating of the models and to draw conclusions.

3. **Describe the process you or your team used for developing your hypothesis.**

First of all we conducted a site visit to understand the issues that we needed to address. Then, we conducted a survey with the airport operators and/or stakeholders to understand their point of view and their needs. After that, we proposed many solutions to these issues and selected the software to test it.

4. **Was participation by industry in the project appropriate, meaningful and useful? Why or why not?**

Participation by the City of Vero Beach Airport director was very helpful to understand their concerns and how we would be able to help them overcome these issues.

5. **What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?**

From this study I learned how to conduct a research to support the topics, I also learned to develop methodologies (different ones) to proceed with the solutions and I also learned that simple and non very expensive solutions can help on a great deal to solve issues.

Yueqiong:

1. **Did the FAA Design Competition provide a meaningful learning experience for you? Why or why not?**

Yes, during the process, I was encouraged to study something which was new to me, and the project is developed for the real airport, which can provide me more meaningful learning experience not only the knowledge, but also the how to apply this knowledge into the reality.

2. **What challenges did you and/or your team encounter in undertaking the Competition? How did you overcome them?**

Firstly, we need to think about the solutions which have their value under those limitation in the reality, and how to apply the knowledge into this case is another big challenges, for me, I need to study the SSAM software which I have never approached before, there are many things about it I need to familiar and know professional. What is more is how link the work by different students is a big challenge.

3. **Describe the process you or your team used for developing your hypothesis.**

After providing topic for competition, firstly, our team visited the Vero Beach airport to familiar it as well as get the information and data which we need to develop the project.
Secondly, through many meetings did by the team, we decides three options which includes the current and 2 another solutions. Then the following work (such as build the model in VISSIM, safety analysis, shortest path search, results analysis, etc.)was separated by different part to each team member, and finally, all of our work need to combine and organized to finish the report.

4. **Was participation by industry in the project appropriate, meaningful and useful? Why or why not?**

The people from of Vero Beach Airport were provides us much information about the current problems and limitations, and what we need to overcame or solved by this proposal.

5. **What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?**

To do this project, I was encouraged to study and familiar with the VISSIM, SSAM software which are very good for future traffic analysis and design. And to finish the report, I have learned how to write the proposal, and other skills which are needed during this work.

Nicola:

1. **Did the FAA Design Competition provide a meaningful learning experience for you? Why or why not?**

Yes, I was encouraged to investigate, find out and provide some information for this project. Resolving problems from real life is always meaningful experience. Also, modeling parking spaces and building model for this purpose are interesting and very useful experience**.**

2. **What challenges did you and/or your team encounter in undertaking the Competition? How did you overcome them?**

We faced with different challenges. First, application for FAA Competition, providing topic and managing entire team represent one challenge. Second, during preparing paper each of us supervenes to obstacles entire his/her part. The way to overcome obstacles were group work or advising with faculty member.

3. **Describe the process you or your team used for developing your hypothesis.**

After providing topic for competition, our team decided to visit a site on order to collecting a huge range of data which are needed for one study. We get information from airport operators and/or stakeholders, did survey in the field and also get some important drawings of cite. We operate with that information and recommended our solutions, evaluate them and propose final solution.

4. **Was participation by industry in the project appropriate, meaningful and useful? Why or why not?**

We get information, data and advices from director of Vero Beach Airport. That alleviated our work and without that we couldn't finish our study.

5. **What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?**

I learn how some problems from real world can be done, some theoretical thing about steps entire methodology and some practical thing as collecting data (survey) in field or building real model.

Steve:

1. **Did the FAA Design Competition provide a meaningful learning experience for you? Why or why not?**

Yes, there is a significant learning experience for I had experience for studying much more knowledge, especially solving problems in reality.

2. **What challenges did you and/or your team encounter in undertaking the Competition? How did you overcome them?**

Because this work is teamwork, so how to combine and balance our work and ideas is the challenge we met. and how to apply the software and theories to this specific project is another challenge, there are many limitations and problems we need to overcame.

3. **Describe the process you or your team used for developing your hypothesis.**

   Firstly, we came to the Vero Beach Airport to get the information which we need, and familiar the problems which we need to solved, and we collected the data which was necessary for our work. After those work, we considered the solutions for them then tested and analyzed the results.

4. **Was participation by industry in the project appropriate, meaningful and useful? Why or why not?**

We get information, data and advices from director of Vero Beach Airport which provides us some ideas from different aspects.

5. **What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?**

Firstly, I learned some ideas for this kinds of problems through this work, and how to analysis and compare the results outputted by different software for different scenarios is the most important skill I learned because I have to study it much more for finishing this part of this work. The last and not least, I learned how to work with others in the team, which is important for me in future work.

Jeffrey Sanon:

1. **Did the FAA Design Competition provide a meaningful learning experience for you? Why or why not?**

I felt that the design competition provided a meaningful experience for me because it enable me to use not only the information learned within the classroom but also I was able to incorporate tools that every successful company uses such as team work, time management, research, task delegation, project management, and even client relationships.

2. **What challenges did you and/or your team encounter in undertaking the Competition? How did you overcome them?**

One of the challenges for the team was setting up the model correctly. Making sure it simulated the existing condition at the project site. My personal challenge was having to work on this project remotely. Since I am an online student I was not able to meet for class lectures and project meetings, but we were able to find effective ways of communicating and combining our resources together.

3. **Describe the process you or your team used for developing your hypothesis.**

Our project selection derived from an issue that was of significant concern at an airport a few hours always from the campus. Once the exact problem was identified we were to begin our study and data collection.

4. **Was participation by industry in the project appropriate, meaningful and useful? Why or why not?**

Involving industry personnel, such as the airport staff and stakeholders, to participate was very helpful and provided a great resource for the team.

5. **What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study?**

Why or why not? The project helped me to realize that there is more to an engineering education than going to class and taking exams. It is about how and when to apply the knowledge base you have acquired during the years to provide your client with the best solutions for their problem. After all, engineering is all about problem solving.

APPENDIX F

REFERENCES

[1] Federal Aviation Administration. Advisory Circular 150/5200-37 – Introduction to Safety Management Systems for Airport Operators. Retrieved January 31, 2010, from http://www.faa.gov/airports_airtraffic/airport/resources/advisory_circular/media/150-5200-37/150_5200_37.pdf

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[12] "Surrogate Safety Assessment Model(SSAM)-SOFTWARE USER MANUAL" Federal Highway Administration. May 2008:1-100

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[14] Smith, Lauren. "A Gateway to Understanding and Applying Intelegent Transportation Systems". ITS Dcisions. 14 March 2010

Appendix G: Additional Figures and Tables

Figure 14: Illuminated overhead crosswalk sign (Nitzburg and Knoblaunch, 2001)

Figure 15: Current Condition AutoCAD Drawing

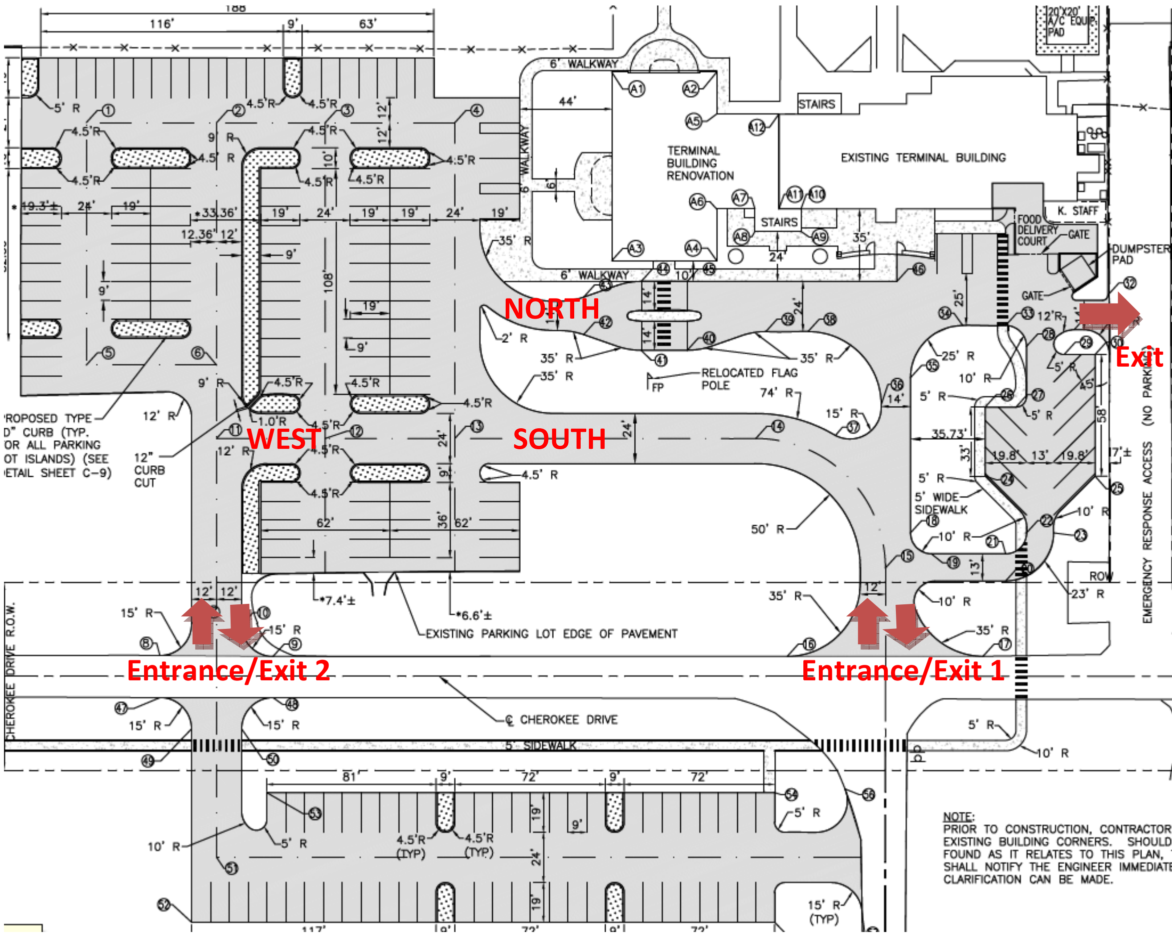


Figure 16: VISSIM Calibration (exiting vehicles)

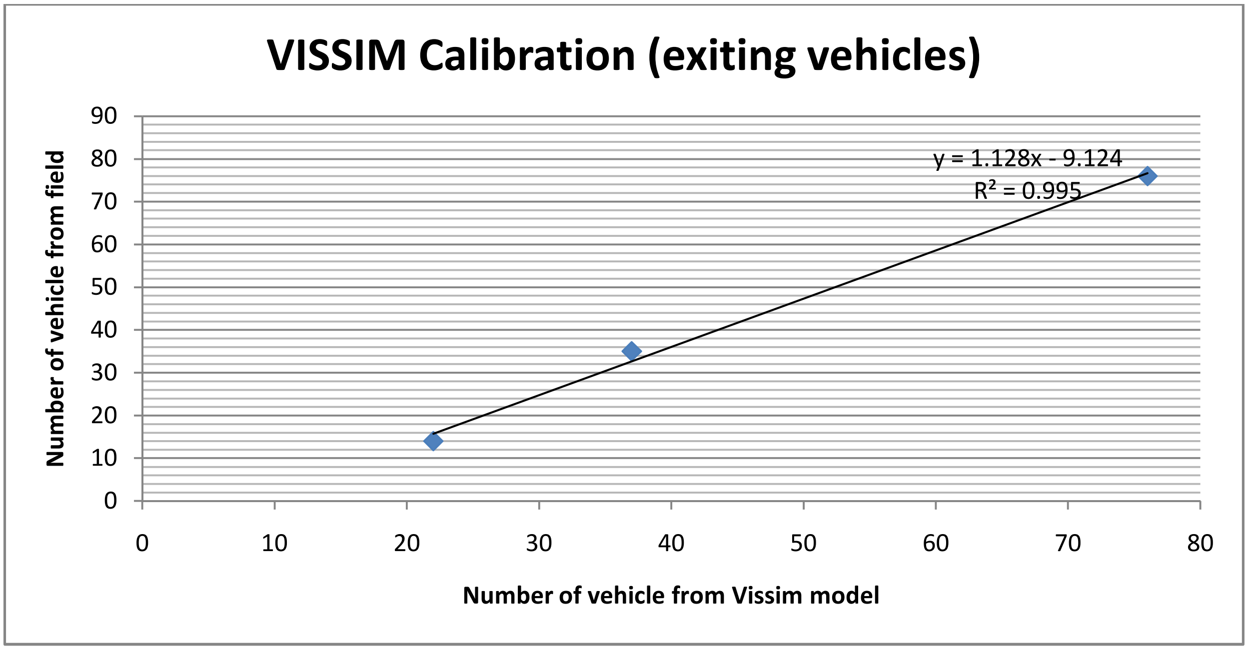


Figure 17: VISSIM Calibration (pedestrians)

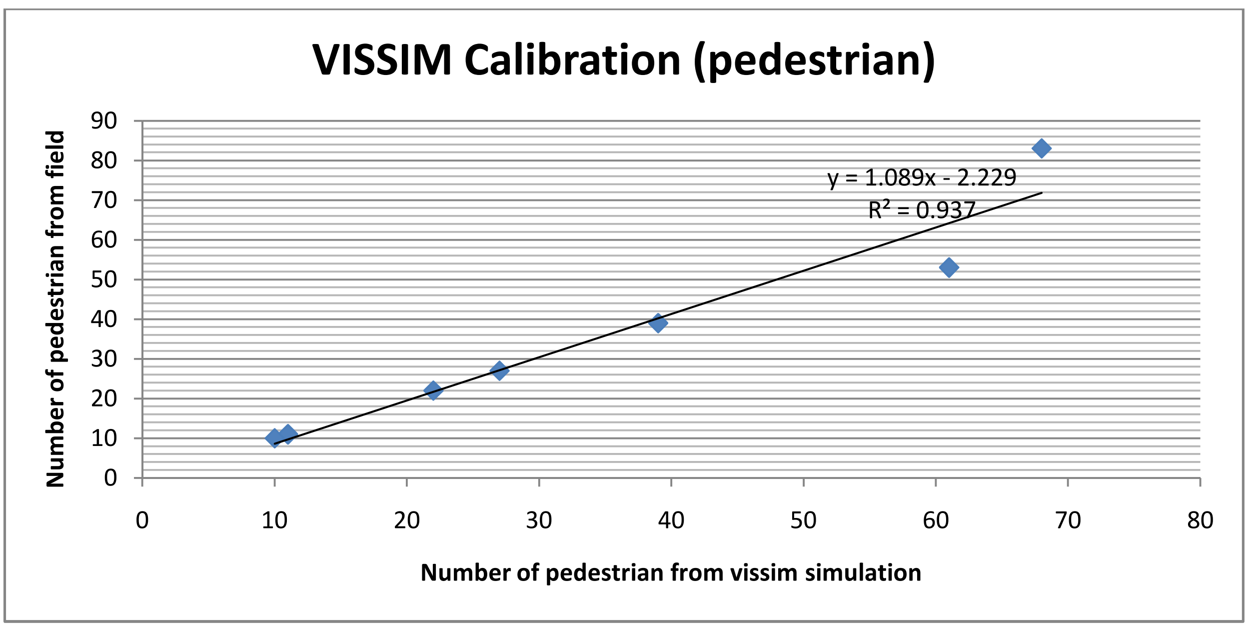


Figure 18: Observed Pedestrian Counts

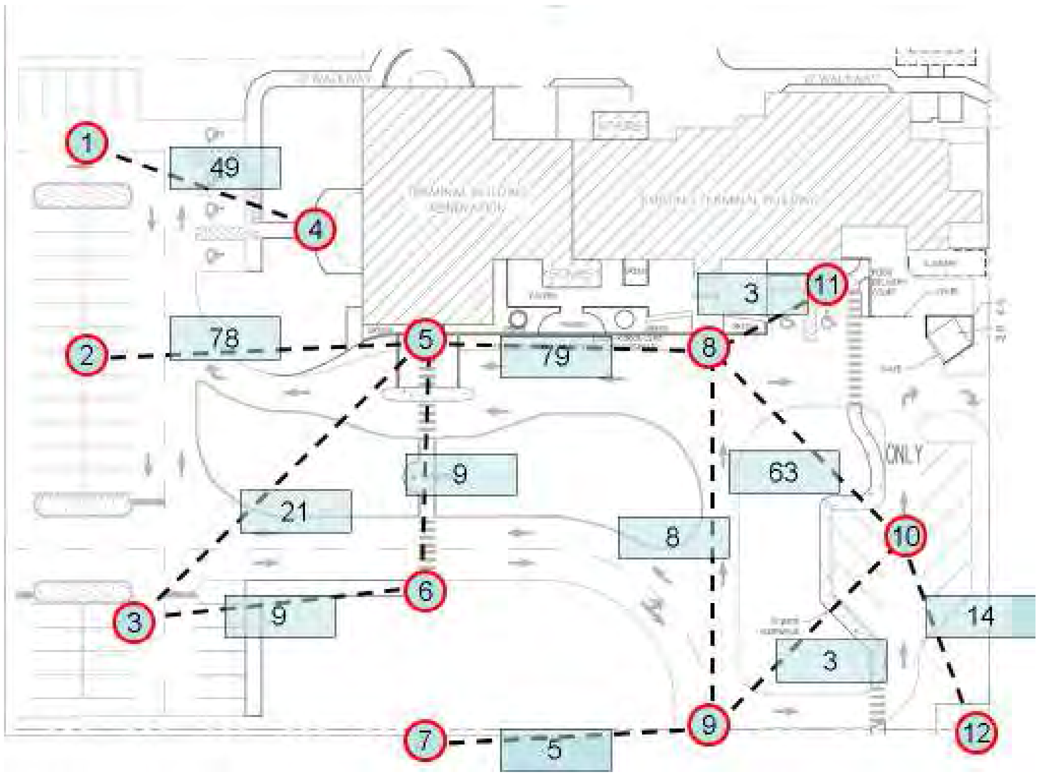


Figure 19: Risk Neutral Network for Current Site Plan

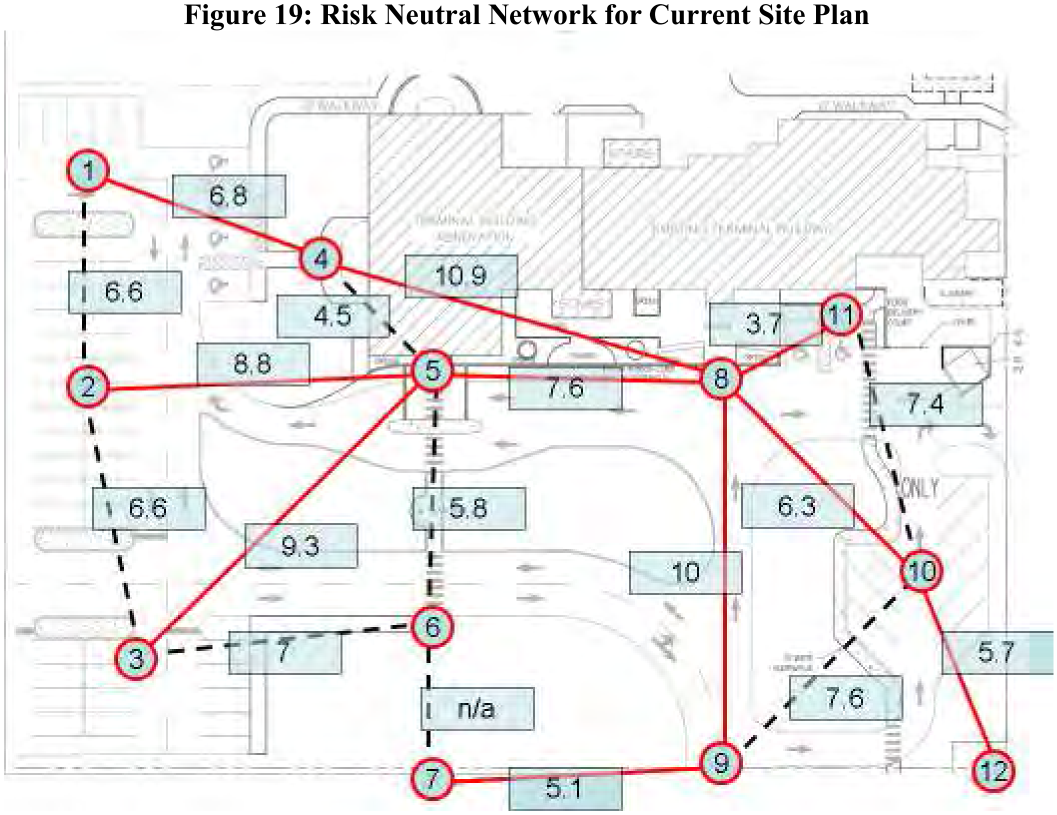


Figure 20: Risk Adverse Network for Current Site Plan

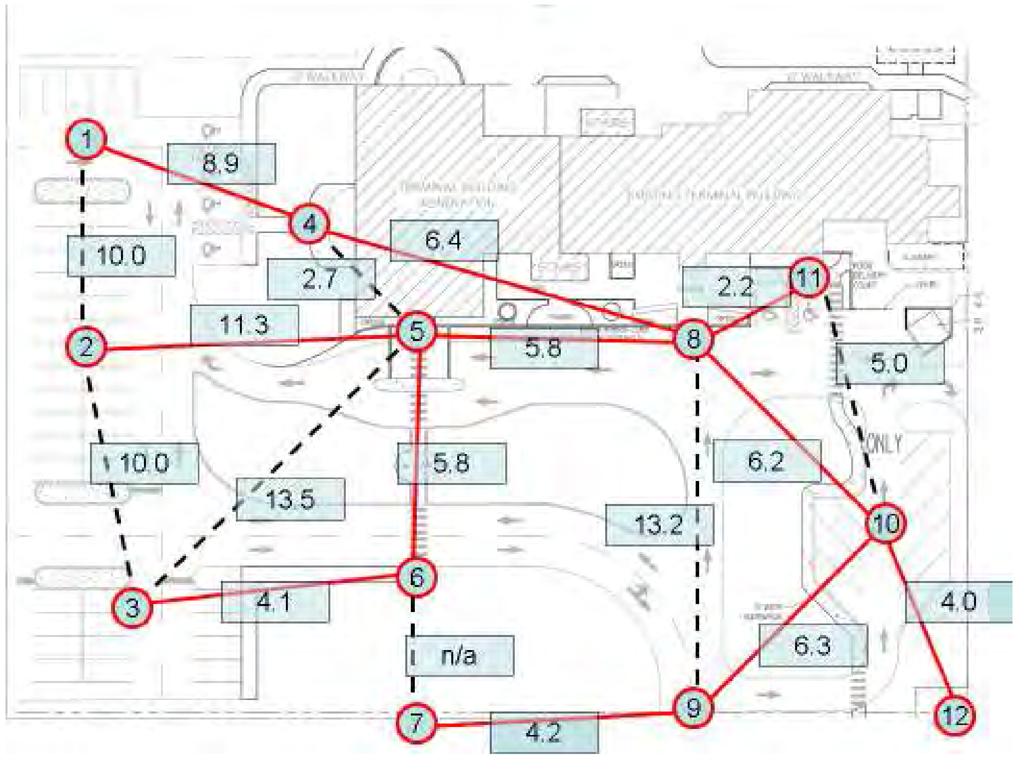


Figure 21: Risk Neutral Network for Solution Site Plan I

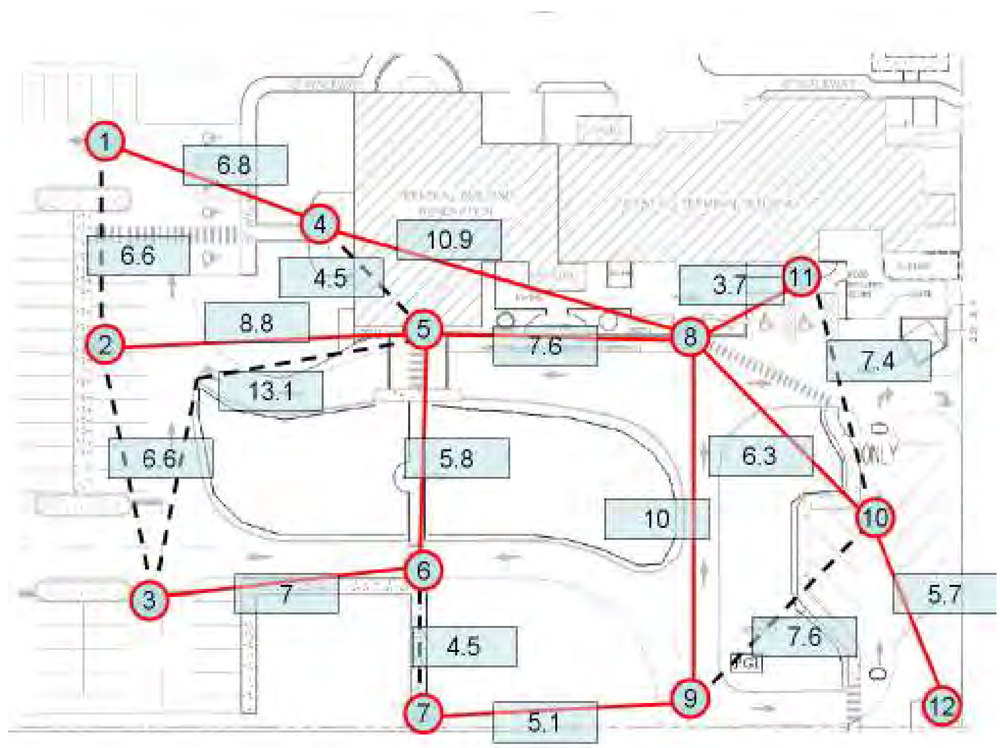


Figure 22: Risk Adverse Network for Solution Site Plan I

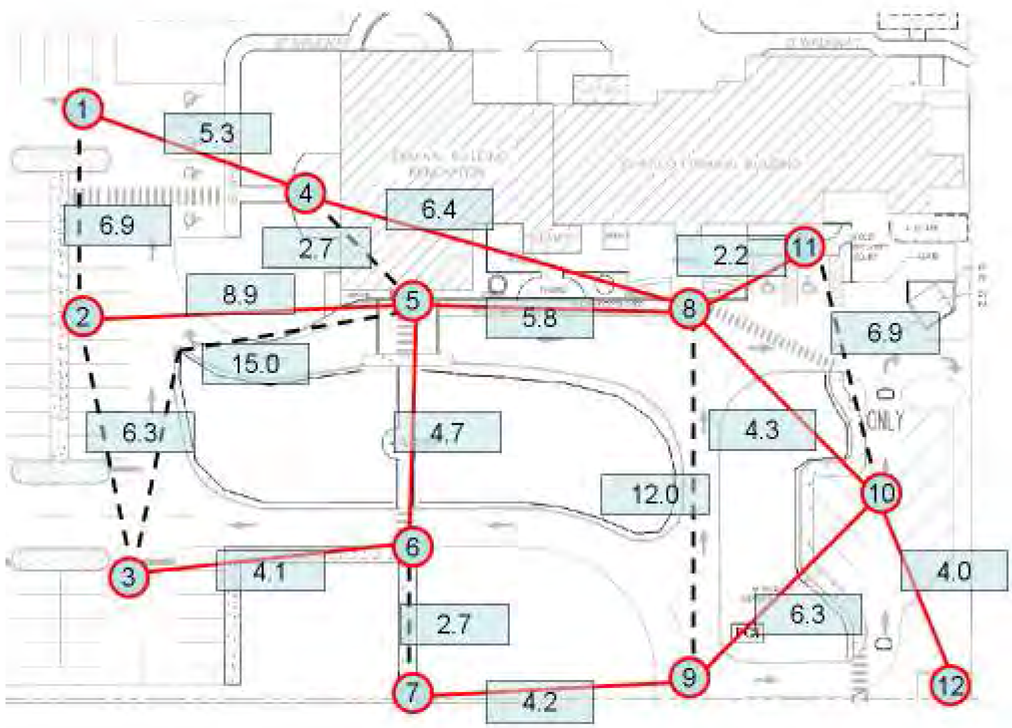


Figure 23: Risk Neutral Network for Solution Site Plan II

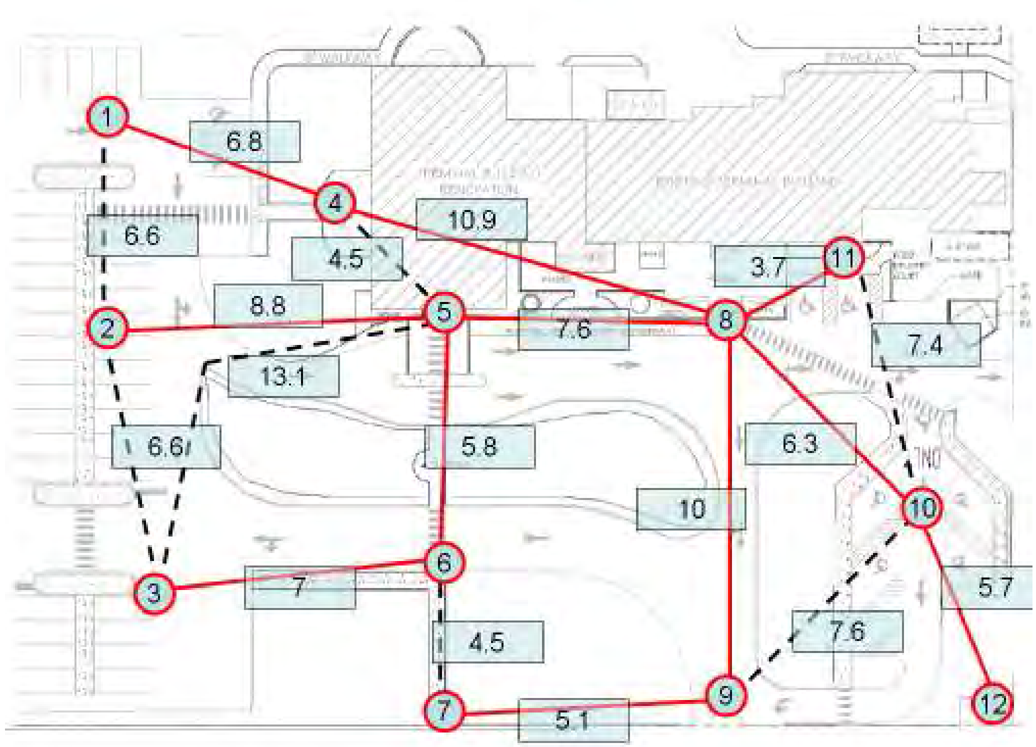


Figure 24: Risk Adverse Network for Solution Site Plan II

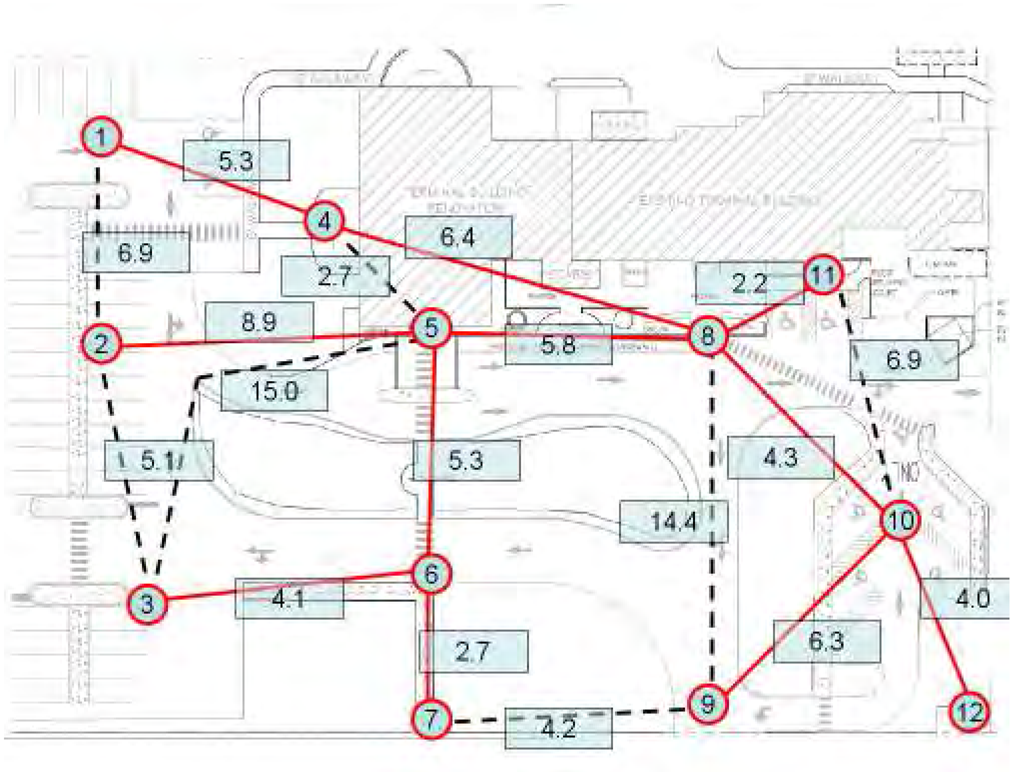


Figure 25: SSAM Conflict Representation for Proposed Solution 1

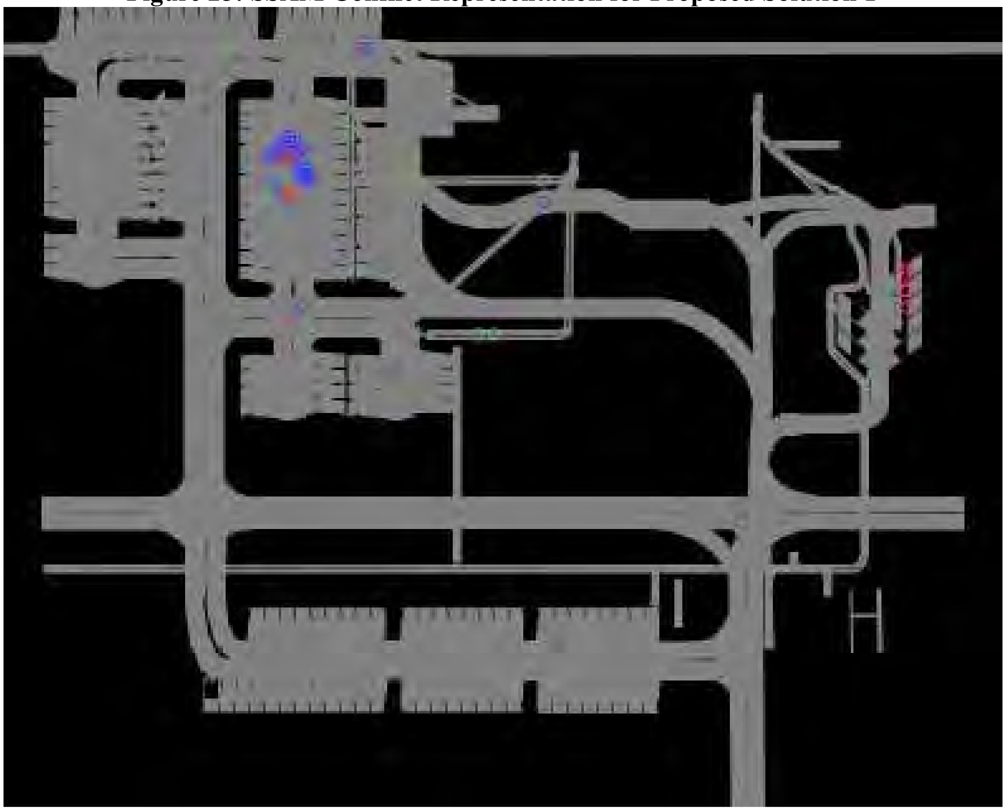
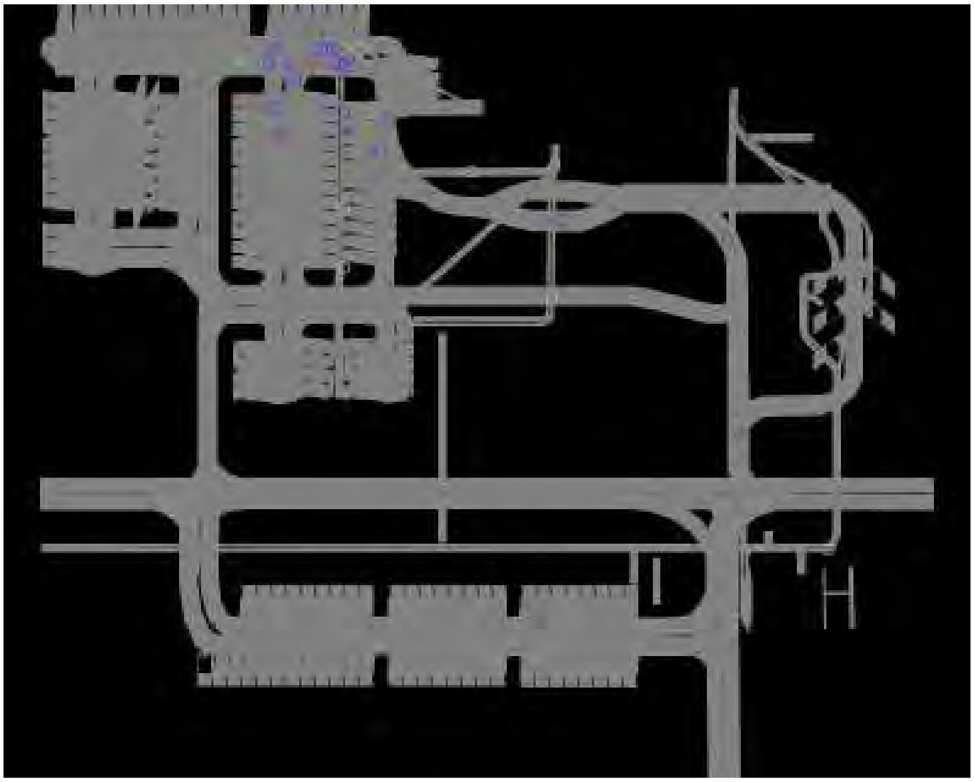


Figure 26: SSAM Conflict Representation for Proposed Solution 2



SSAM Measure	Min	Max	Mean	Variance
TTC	0.00	1.50	0.03	0.04
MaxDeltaV	0.04	5.23	1.52	0.43

Table 7: SSAM Measure Results for Proposed Solution 1

Total	Unclassified	Crossing	Rear-end	Lane-change
206	0	80	17	109

Table 8: Conflict Types for the Proposed Solution 1

SSAM Measure	Min	Max	Mean	Variance
TTC	0.00	1.40	0.08	0.10
MaxDeltaV	0.05	4.67	1.74	1.74

Table 9: SSAM Measure for the Proposed Solution 2

Total	Unclassified	Crossing	Rear-end	Lane-change
37	0	21	10	6

Table 10: Conflict Types for the Proposed Solution 2