DEVELOPMENT OF A PROCEDURE FOR PRIORITIZING INTERSECTIONS FOR IMPROVEMENTS CONSIDERING SAFETY AND OPERATIONAL FACTORS

DEVELOPMENT OF A PROCEDURE FOR PRIORITIZING INTERSECTIONS FOR IMPROVEMENTS CONSIDERING SAFETY AND OPERATIONAL FACTORS

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16. Abstract

Improvements are required at many intersections in Florida to eliminate safety or operational deficiencies. Because the annual budget is limited, it is essential for the Florida Department of Transportation (FDOT) to implement a prioritizing procedure to select intersections for improvement to achieve effectiveness under financial restrictions. The existing prioritizing procedure is based on safety factor only by ranking the intersections according to benefit-cost ratio for safety without considering operational effectiveness.

This report presents results obtained from a research project performed to develop a new procedure considering both safety and operational factors, therefore to generate a more reasonable priority list for programming intersection improvement projects. In this procedure, safety performance is evaluated by utilizing benefit-cost ratios obtained from the existing prioritizing method. Criteria of operational performance are delay reduction due to improvements and existing delay. These two criteria are estimated based on algorithms in HCM 2000.

To combine safety and operational factors, the Multi-Layer Prioritizing (MLP) method is implemented with the three criteria. This method assigns each criterion to a layer according to its relative importance: a higher layer owns a higher importance level. Intersections are prioritized in a first layer, and then clustered into several groups based on their relative similarity. Within each group, intersections are ranked in a second layer, and grouped into subgroups again. The final priority list is derived from the ranking of intersections within each subgroup in a third layer. Two kinds of priority sequences are adopted in this study. One indicates that safety effectiveness has precedence over operational effectiveness; meanwhile another one represents an opposite effectiveness priority.

A case study was performed in this research project to demonstrate the new prioritizing procedure. Data from 34 intersections in District 7 in Florida were collected for operational analysis. These data included peak hour volume, traffic control, and geometric design. Two kinds of priority lists were produced as a result of implementation of the new procedure: safety preferred and operations preferred. A comparison between these priority lists and lists based on existing procedure was conducted finally to evaluate merits of the new procedure.

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ABSTRACT

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Keywords *–Intersection improvement, Prioritize, Hierarchical Clustering, B/C, Delay*

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1. INTRODUCTION

1.1 Background

With the continuous increase of urban population and traffic volumes in Florida, travel conditions such as traffic safety, traffic operations and environmental pollution will continue to deteriorate in the roadway system, especially at intersections establishing urban arterial system capacity and operations conditions. It is essential that transportation planners and traffic engineers program and develop highway improvements periodically to resolve these problems. However the controversy between demand for intersection improvements and limited budget often makes it is necessary for transportation administrators to make a reasonable selection of intersection improvement projects to reduce the severity of traffic deterioration with the anticipated funds.

Improvement programs for the highway system including intersections are developed and implemented in each state of the United States. Currently, the Federal Highway Administration sets the policy for the improvement program called Highway Safety Improvement Program (HSIP). The overall objective of the HSIP is to reduce the number and severity of crashes and decrease the potential of crashes. This program contains components for planning, implementation, and evaluation of safety projects and programs. The procedures of the HSIP are appropriate for individual highway systems and any portion of the highway, including all public roads.

The HSIP mostly refers to safety concerns, and many state departments of transportation use methodologies based on safety conditions to analyze highway improvements. In relation to intersections, the procedures used by most transportation agencies to prioritize their improvements are based on crash data and construction costs without considering operational factors such as delay and Level of Service [1]. The prioritization process is mostly done using the economic analysis denominated benefit-cost ratio (B/C). This B/C ratio analyzes cost effectiveness of an intersection improvement cost, based on the benefit of preventable crashes at a location due to proposed safety improvements and the total cost to implement the proposed improvements. This implicates that problems such as traffic congestion, vehicle delays, and vehicle emissions along with their cost are not addressed in the methodologies. Another aspect to be considered is the possible relationship between traffic volume and crash number, as it is referred in several studies. Jadaan and Nicholson [2] concluded that this relationship for urban road links is statistically significant.

In Florida, the existing prioritizing method is also based on B/C analysis. The most important parameter of this method is Crash Reduction Factors (CRFs) which is defined as the percentage of crash reduction due to particular improvements. Crash Reduction Analysis System Hub (CRASH), a web-based database application, was developed to systematically maintain statewide safety improvement project data to update CRFs based on the latest available improvement project and crash data, to apply calculated CRFs in the benefit-cost analyses of specific projects, and to perform before-and-after analyses to evaluate the effectiveness of safety programs [3]. As with the HSIP, the existing prioritizing method only considers safety factor but misses other factors such as traffic operations and roadside environment which are very important features to evaluate the effectiveness of an intersection improvement project for intersection. Unfortunately, an improvement countermeasure for intersections with good safety effectiveness can not insure a good operational effectiveness; even sometimes result in a disadvantage on traffic operations, and vice versa. Therefore, it is necessary to develop a new procedure considering both safety and operational factors for transportation planners and engineers to make a reasonable and comprehensive decision on intersection improvements.

In 1999, the University of South Florida conducted a research project, sponsored by Hillsborough County, Florida, concerning both safety and operational factors for intersection improvements [1]. As the result of this research project, a procedure was developed to generate three kinds of priority list for intersections improvements. List I ranks the intersections for improvements based on traffic safety concerns (B/C); List II gives the priority of intersection improvements based on traffic operations concerns (Average Control Delay Reduction); and List III combines both safety and operation factors by using a logit model which was estimated based on the data in 1994, 1995 and 1996.

1.2 Research Approach

In this research, a new procedure was developed to prioritize intersection improvement projects considering both safety and operational factors. Three processes were included in this procedure: Safety Analysis, Operational Analysis, and Prioritizing. For safety analysis, benefit-cost ratio (B/C) was calculated as the criterion for evaluation of safety performance. For operational analysis, the average control delay based on the Highway Capacity Manual 2000 (HCM 2000) was adopted to assess the operational performance. Finally, the two kinds of factors were combined by using a Multi-Layer Prioritizing (MLP) method to generate the priority list for intersection improvements.

As a case study, the data for 34 intersection improvement projects were collected from the FDOT District 7 safety database to validate the new procedure. The basic data types include safety related data (the number, type, and severity of crashes), operational related data (traffic volumes, traffic signal timing, and intersection control methods), geometric condition related data (number of lanes, channelization …), and improvement countermeasures. Finally, two priority lists considering both safety and operational factors were produced: in one of them, safety factors have higher weight than operational factors; the other is based on reversed standard. These priority lists are used to compare with the priority list based on safety factors only to evaluate the new procedure.

1.3 Research Objectives

The primary objective of this research is to develop a new procedure to evaluate existing safety and operational conditions of intersections and to estimate the effectiveness of proposed countermeasures in order to provide a priority list of intersection improvements considering safety and operational factors. By applying this procedure to all intersections that need to be improved in Florida, a rank of intersection improvement projects was produced based on the effectiveness of improvements from highest to lowest. Because of limited annual budget, some intersections on the top of the list will be selected by FDOT to implement improvements. The prioritization and selection, which maximizes the utility of the limited investment on intersection improvements, will provide a more reasonable scheme for arranging intersection improvements in Florida than the traditional method that was based on only safety factors. This priority list can be used as a reference by the transportation administration to make decisions on short- to medium-term planning of intersection improvement.

The goal is reached in part through the satisfaction of the following objectives:

- based on engineering studies
- objective and logical
- easy to use
- able to use easily obtainable data
- able to adapt to changing standards
- accepted by operation engineers, management, and planners

This research project focused on traffic operational analysis and a successive prioritizing method. Benefit-cost ratio has been a mature method for safety analysis; the safety performance can be obtained directly from the existing methods such as CRASH. Traffic operational analysis was based on HCM 2000. Two algorithms for calculating the average control delay were used in this research: Quick Estimation Method for Signalized Intersection (Chapter 10, HCM2000) and Delay Estimation for Unsignalized Intersections (Chapter 17, HCM 2000). The Multi-Layer Prioritizing (MLP) method which combined both safety and operational factors in a straightforward, feasible and extensible way was the key step of this research project.

Another objective of this research project is to develop a computer-based decision-making system to generate the priority list for intersection improvements automatically by implementing the procedure developed in this research. This system provides a user-friendly interface to input data and to output a priority list in a standard format. Meanwhile, the function of operational analysis also was integrated in this system. Microsoft Visual Basic 6.0 compiler was adopted to develop the code for this system. The details of this system were described in Appendix A.

1.4 Outline of the Report

This report consists of five chapters. Chapter 1 provides a brief introduction of the research. Chapter 2 describes a summary of past studies in this area. Chapter 3 explains the methodology employed in achieving the research objectives. A case study is presented in Chapter 4. Finally, Chapter 5 provides summary, conclusions, and recommendations of this research.

2. LITERATURE REVIEW

2.1 Prioritizing Methods for Highway Improvements

Many methods for prioritizing highway improvement projects have been proposed; several transportation agencies have adopted rational methods to assist transportation administrators in the selection of projects for programming. Although each of these methods follows a rational procedure, they vary widely in their degree of objectivity and reliance on data. Some methods rely exclusively on objective data, whereas others incorporate subjective but expert opinions in their evaluation of the merits of proposed projects. Some methods arrive at a rank-ordered list of proposed projects, whereas others serve more of a supporting role, leaving greater flexibility to the decision maker [4]. Most methods include elements related to estimated cost, safety impacts, and traffic operation as evaluation measures for potential improvements.

2.1.1 Ohio TRAC Project Prioritization Policy [4, 5]

In Ohio, the programming decisions for highway improvement projects are governed by a set of policies (data-driven criteria) made by the Transportation Review Advisory Council (TRAC) to facilitate the objective evaluation of proposed projects. These criteria are used to arrive at a score for each large-scale capacity project under consideration in TRAC's annual review cycle. The traffic-related factors considered in the criteria for highway projects are total traffic volume, truck traffic volume, congestion (v/c), roadway functional classification, accident rate, and external funding sources.

This prioritization method is a highly objective scheme for assigning points to potential transportation projects that fall under the purview of TRAC. The resultant scores for the proposed projects stand alone, independent of the scores of other competing proposal, and, therefore, lack a direct measure of relative merit.

2.1.2 Delaware Prioritization Process [4, 6]

The Delaware Department of Transportation adopts 10 equally weighted factors to revise and update its project prioritization process for system expansion projects. These factors include safety, mobility, transit, bicycle, pedestrians, support of existing communities, environmental impacts, other economic impacts, sustainability, and mitigation. For each factor, 2 or 3 criteria are defined and scored with a scale of +5 to -5. Higher benefits on traffic impacts will generate higher scores. Then the average score of each factor was determined and summed to a total score as the criterion of prioritization.

In contrast to the method used in Ohio, the Delaware's method is more subjective since some factors cannot be quantified.

2.1.3 Sacramento Transportation Programming Guide [4, 7]

A series of criteria for several categories of transportation improvements were developed in the *Transportation Programming Guide* published in the City of Sacramento, California. In this guide, seven program areas were defined: major street improvements, street maintenance, street reconstruction, traffic signals, bikeways, bridge replacement and rehabilitation, and development-driven projects. Most of these criteria are based on available data, and others are addressed with a series of simple "yes or no" question. A set of scores for proposed projects are generated as the output of the prioritization method.

2.1.4 Hampton Roads Project Selection Process [4, 8]

The Hampton Roads Planning District Commission, Virginia developed a prioritization method to evaluate the potential improvements and to ensure that rate of progress and budgetary constraints are met. Projects for transportation program are divided into 12 categories and each category has a unique set of evaluation criteria. Scores are assigned along each criterion; some criteria employ available data whereas others require subjective judgments. This process is similar to the method used in Sacramento, but some criteria that employ questions without guidance regarding the assignment of scores are more subjective. Using a mix of objective and subjective evaluation criteria, this prioritization method addresses all potential projects on a category-specific basis.

2.1.5 Taking the Politics Out of Planning [4, 9]

In 1999, the Virginia Chamber of Commerce developed a prioritization method to evaluate major transportation projects at a statewide level. Factors considered in this process include congestion relief, safety, cost-effectiveness, multimodality, intermodal connectivity, economic vitality, quality of life, and "other". This process is highly subjective because it does not employ quantified measures within these criteria. Actually, four assessments were assigned along each criterion: a significant impact, a moderate impact, a minimum impact, or no impact.

Such a method provides greater latitude on programming decision-making than completely objective approaches, whereas may have deficiency of agreement on the scores within criteria. Therefore, application of this process on large-scale projects will be better than on smaller, localized projects.

2.1.6 Multi-Objective Comparison Tool [4, 10, 11]

A multi-objective approach to establish the relative worth of potential highway improvements was developed for Virginia Department of Transportation. Rather than the processes based on scoring measures, this multi-objective comparison tool displays a graphical representation of project merits according to available data. Three criteria are showed in the chart: estimated cost, anticipated crash reduction, and expected travel time reduction. Figure 2-1 is an example of such a graph. The vertical axis represents the anticipated crash reduction; the horizontal axis indicates the travel time reduction; and the icon area is proportional to estimated project cost. With this graph, decision makers are able to check the relative merits of proposed projects and reach their conclusion about project priorities.

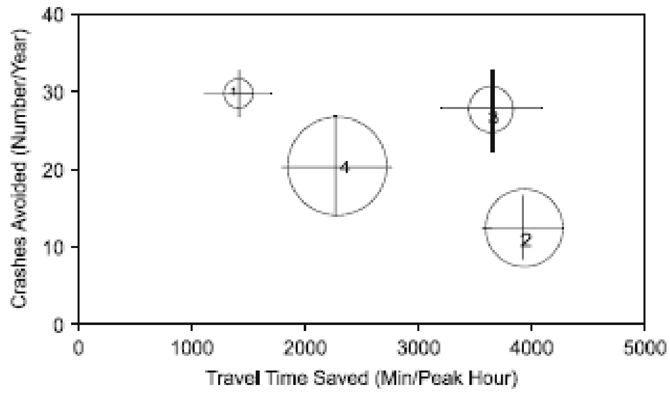

Figure 2-1 Multi-Objective Comparison Tool Applied to Four Proposed Projects [4]

The multi-objective approach has greater flexibility than other typical prioritization methods. However, the tool is not an explicitly prioritizing method and is limited to three criteria for evaluation. VDOT has adopted this tool to assess safety-related improvements.

2.1.7 Successive Subsetting Method [4, 12, 13]

A set of quantified criteria are adopted by this process to evaluate the potential transportation projects. Rather than weights assigned to the criteria in the traditional process, the criteria are prioritized in terms of their relative importance in selecting highway projects. The quantified scores of the top two priority criteria are plotted on a two-dimension graph. The points on the graph represent proposed projects, and then are grouped into several groups based on a serial of diagonal lines at the apparent break points. Within each new group, the plotting and grouping are going to generate subgroups based on the second and third important criteria. This process is continued until all criteria have been applied.

The successive subsetting method requires a decision on the relative importance of the criteria and expert opinion on how to group projects. Therefore this method not only relies on quantified data, but also needs subjective judgments.

2.1.8 Comparison

A brief comparison of these prioritization methods is presented in Table 2-1. In this table, the degree of objectivity of the methods, the types of scores assigned to projects, the categories of evaluation factors utilized, and the types of projects to which the method applied are compared. Highly objective methods are based on highly quantified data and little subjective opinions. Medium objective methods require some judgments on the evaluation of criteria. And low objective methods apply subjective judgments on most of the evaluation criteria. The type of scores assigned to projects can be stand-alone, where other proposed projects do not affect a given project's score, otherwise relative worth is adopted.

Table 2-1 Comparison of Project Prioritization Methods [4]

Method	Objectivity	Score Type	Factors Evaluated [a]	Application Domain
Ohio TRAC	High	Stand-alone	T,E,S,C	Major new capacity
Delaware	Medium	Stand-alone	I,M,T,S,E,N	System expansion and management
Sacramento	Medium	Relative worth	T,S,C,N,E,R	All capacity Projects
Hampton Roads	Low	Stand-alone	T,C,N,S,I,M	CMAQ and RSTP [b]
Multi-Objective Comparison Tool	High	Stand-alone	T,S,C	Safety and intersection improvement
Taking the Politics Out of Planning	Low	Stand-alone	T,C,N,M,E,I	Major
Successive Subsetting	Medium	Relative worth	R,S,C,T	Bridge rehabilitation

[a] T=traffic-related; S=safety-related; C=cost; E=economic development; I=impacts om community or environment; M=multimodality; N=network connectivity; R=ratings of infrastructure condition.

[b] CMAQ=Congestion Mitigation and Air Quality; RSTP=Regional Surface Transportation Program

2.2 Prioritization Methods for Intersection Improvements

The most popular prioritization method for Intersection Improvements is based on benefit cost ratios (B/C) which consider safety or operational factor only. In fact, intersection safety performance is somehow related to traffic operational performance at the intersection or nearby area. For comprehensively evaluating the effectiveness of improvement projects at intersections, some prioritization methods for intersection improvements were proposed in several states.

2.2.1 Procedure used in Tucson, Arizona [14]

In Tucson, Arizona, a two-level screening process is described for evaluating and ranking short- to medium-term improvements for signalized intersections. In the first screening, the safety and operational deficiencies of all intersections are evaluated and ranked separately based on selected criteria. After the first screening, intersections with the highest deficiencies ranking are selected for a more detailed assessment where safety and operational improvements are compared to determine where improvements should be combined since they address related problems. The second screening is an evaluation of cost-effectiveness analysis which is used to establish the final prioritizing list for safety, operational, and both safety and operational improvements. As a key element in the development of this prioritizing process, a deficiency index (DI), which is a linear utility function, is developed to combine the various criteria (safety and operations) into a single index.

2.2.2 Priority Ranking of Problem Intersections in Brooklyn, NY [15]

A quantitative ranking formula was developed in North Brooklyn to evaluate the severity of delay and the frequency of accidents at each intersection. Severity of conditions for the accident and delay variables was measured as the observed value at an intersection divided by the average value for all intersections:

$$\text{Severity for Delay} = \frac{(\text{Average Stop Delay }(i))}{(\sum_{i=1}^{n}(\text{Average Stop Delay }(i))/n}\times 100$$

$$\text{Severity for Accidents} = \frac{(\text{Accident Rate}\,(i))}{(\sum_{i=1}^{n}(\text{Accident Rate}\,(i))/n} \times 100$$

After obtaining the delay severity scores and the accident serverity scores, a two-dimension graph is created with the two kinds of scores assigned to vertical and horizontal axis respectively (Figure 2-2). Two dashed lines on this figure, which represent average scores for stop delay and accidents, divide the plotted points that denote intersections into four quadrants. Those intersections located in Quadrant I experiencing higher delay severity and safety serverity should have highest priority; intersections located in Quadrant IV experiencing both lower delay severity and lower safety severity will own the lowest priority. The ranking of intersections located in either Quadrant II (higher delay severity and lower accident severity) or Quadrant III (higher accident severity and lower delay severity) will be determined based on a judgment as to the related importance of safety and operational factors.

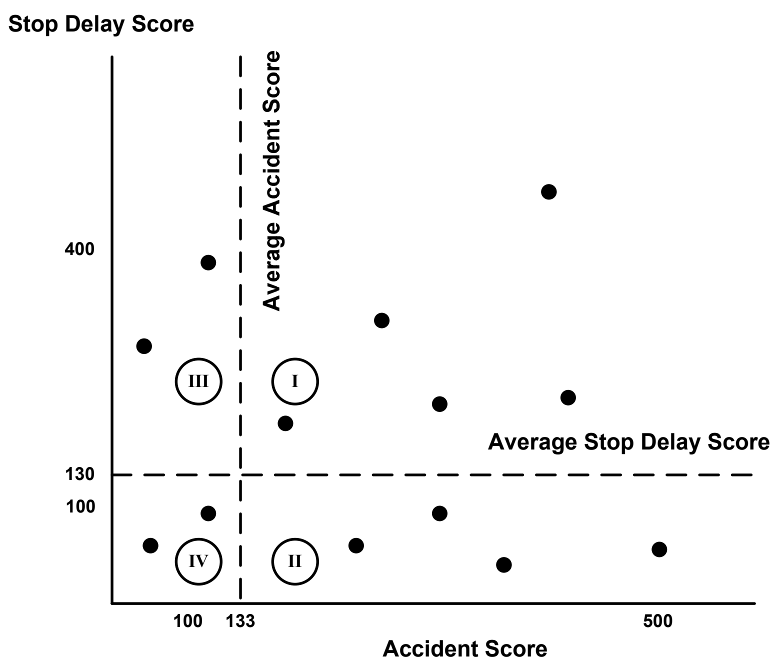

Figure 2-2 Stop Delay Score vs. Accident Score based on Ranking Formula [15]

2.2.3 The procedure in Hillsborough County, Florida [1]

For considering both safety and operational factors to prioritize intersection improvements, a procedure was developed for Hillsborough County, Florida by transportation group of the University of South Florida in 1999 (See Figure 2-2). In this procedure, the delay reduction due to improvements and the existing delay are used as the operational criteria, and the benefit-cost ratio (B/C) is taken as the criterion for safety. Three priority lists are generated as the output of the procedure. The priority list I is determined by ranking the intersections according to the B/C. Each intersection should have a B/C greater than one in order to be considered beneficial. The priority list II is determined based on an average total delay rank. This average total delay is obtained by adding the ranks of the existing delay and delay reduction. For the priority list III, a utility function is used as the following linear equation:

$$U = a_0 + a_1 \times B / C + a_2 \times d_1 + a_3 \times \Delta d$$

Where

U = utility,
B/C = benefit/cost ratio,
d_1 = delay before improvements,
Δd = delay reduction due to improvements, and
$a_0, a_1, a_2,$ and a_3 = coefficients

In fact, the selection of intersections for safety improvements is a discrete choice problem which can be modeled with a logit model. A reasonable interpretation of the output of a logit model is the probability ($0 \leq p \leq 1$) to select a particular intersection for safety improvements. Thus, the logit model was proposed to generate the priority list. The logit model has the following form:

$$p = \frac{e^U}{1 + e^U}$$

Where

p = output of the logit model, and

U = utility

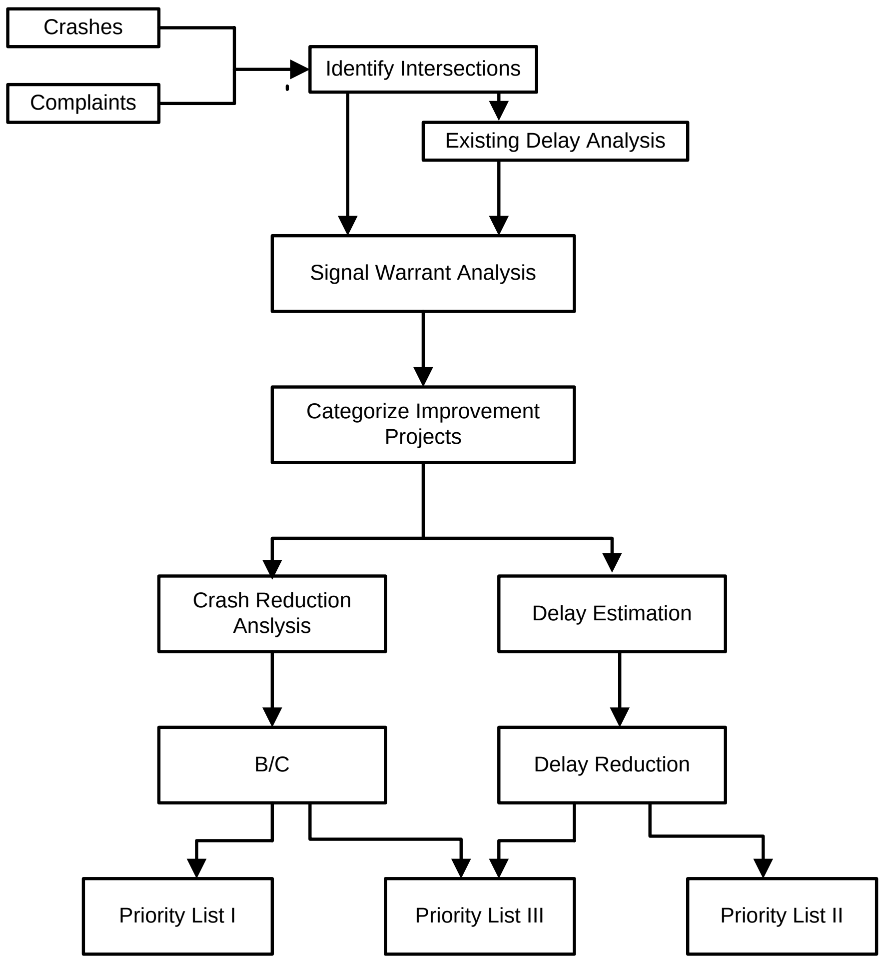

Figure 2-3 Proposed Methodology to Prioritize Intersections Improvements

3. METHODOLOGY

In this chapter, a new procedure for prioritizing intersection improvements to reach the objective of this research project is presented in detail. The content of this chapter includes the introduction of the new procedure, the procedure flowchart, safety analysis, operational analysis, and the Multi-Layer Prioritizing method.

3.1 Introduction

From the brief review of past studies in Chapter 2, we know that several methods have been developed to evaluate and prioritize intersection improvement projects comprehensively and several factors were considered in these methods: safety, operations, environmental impact, economic impact, and impact on transit / pedestrian. Among these factors, safety and operational impacts are the two most important factors to influence the effectiveness of intersection improvements. Therefore, in this procedure, only the two factors are considered.

To combine safety and operational effectiveness into a uniform index is the key step of this procedure, and it is a complex problem since it is difficult to describe the relationship between safety and operational criteria in a quantified value. To resolve this problem, some methods were proposed. The first common method is the weighted equation, the procedure used in Hillsborough, Florida. This method assigns a weight to each criterion in a utility function to reflect the related worth of safety and operational factors. However it is difficult to determine the coefficients of the function. Another way is successive subsetting which is introduced in Chapter 2. The idea of this method is that the criteria are merely prioritized in terms of their relative importance rather than weights being assigned to evaluation criteria in the process of arriving at scores for each project [4]. The existing successive subsetting method, which is based on a certain criterion, uses plotted graphs to group projects. And it has two deficiencies:

(1) There is no quantified guidance provided on how to cluster intersections;

(2) Expert interference on determining break line on plotted graph is essential, so it is difficult to achieve this method on computer.

The new procedure developed in this research is similar to the successive subsetting method; meanwhile a quantified value for clustering intersection improvement projects is provided.

3.2 The Flowchart of the Procedure

Figure 3-1 presents the conceptual steps of the new procedure developed in this study.

Step 1: The first step in the new procedure is to produce a preliminary list which includes intersections that need to be improved and corresponding proposed improvements for each intersection.

Step 2: In second step, safety analysis and operational analysis are processed to evaluate separately the safety and operational effectiveness of proposed improvements for each intersection in the preliminary list.

Step 3: The third step is to combine the safety and operational effectiveness into a uniform ranking index. A final priority list considering both safety and operational factors is produced as the result of this step.

Step 4: The last step is to select the top intersections in the priority list to implement the proposed improvements on these intersections

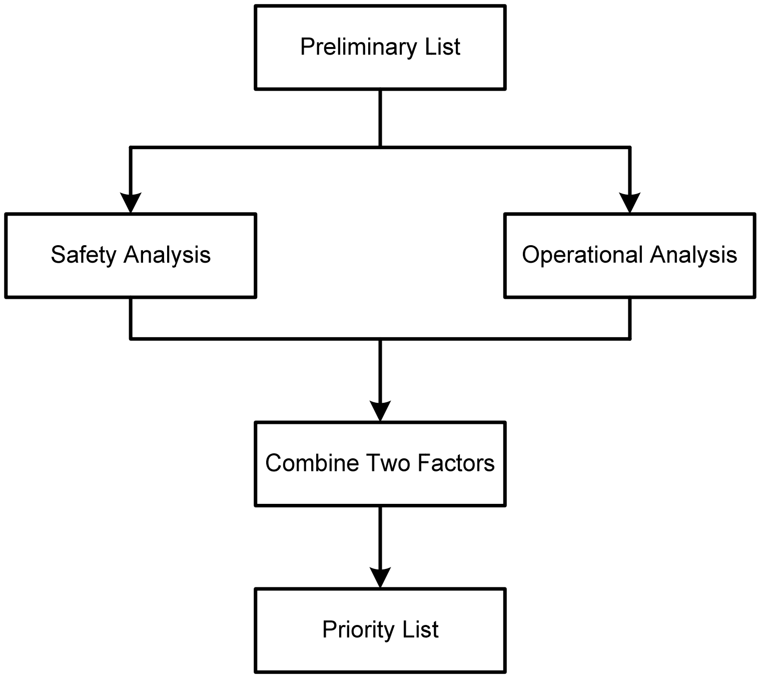

Figure 3-1 Flow Chart of the New Procedure

3.3 The Preliminary List

The preliminary list provides a set of intersections for improvement and the proposed countermeasures for each candidate intersection as the objects of the successive analysis processes. The number of preventable crashes at each location determines the intersections on this list. Intersections are firstly identified according to number of crashes. For each crash listed at each location, the crash type is determined by checking the corresponding crash report. The crash type allows an estimate of the number of crashes that could be prevented if improvements are implemented at the intersection. The intersections with the greatest number of preventable crashes would be included in the preliminary list for prioritization. The preliminary list can be obtained directly from the existing procedure of the Florida Department of Transportation's (FDOT) existing procedure.

3.4 Safety Analysis

Safety analysis is used to evaluate the effectiveness of proposed improvements on each intersection. In this study, the benefit-cost ratio (B/C) is used as the criterion to assess safety performance for two reasons:

(1) This criterion integrates information on both safety effectiveness and projects cost.

(2) B/C is used in existing prioritizing methods for intersection improvements making it easy to be obtained.

For safety analysis, two different steps need to be considered. First, the number of preventable crashes due to improvements should be estimated. Each proposed improvement will specifically reduce the number of crashes with a particular crash type. The main way to estimate the number of preventable crashes is using the equation:

$$N_R = (N_{Fatal} \times CRF_{Fatal}) + (N_{Injury} \times CRF_{Injury}) + (N_{PDO} \times CRF_{PDO}) \qquad (3\text{-}1)$$

where

N_R − the number of crashes reduction due to improvments

N_{Fatal}, N_{Injury}, N_{PDO} − the estimated number of crashes with Fatalities, Injuries, or Property Damage Only (PDO)

CRF_{Fatal}, CRF_{Injury}, CRF_{PDO} − the Crash Reduction Factor (CRF) for crash type Fatality, Injury, or PDO

The CRFs, the percentage of a particular crash reduction after implementing improvements in an intersection, is described in reference [16] and updated in FDOT's Crash Reduction Analysis System Hub (CRASH) [3].

Second, based on preventable crashes and proposed improvements, the B/C can be calculated. The total annual benefit for each intersection is determined by multiplying the number of preventable crashes by the crash cost, which is based on fatalities, injuries, and PDO. The equation is given as follows:

$$B = N_R \times C_{ave} \tag{3-2}$$

where

B − Benefit due to improvements

C_{ave} − the Average Crash Cost for crashes involving in Fatalities, Injuries, or PDO

The total annual cost of the improvements includes costs resulted from items such as right of way, preliminary engineering and construction inspection factors (P.E.-C.E.I), roadway, and signals. The cost of right-of-way is estimated by FDOT for planning purposes. The P.E.-C.E.I. is calculated based on a FDOT procedure. According to the service life of a specific intersection improvement, a Capital Recovery Factor is assigned. Each cost item needs to be multiplied by its Capital Recovery Factor and the sum of all these products gives an annual cost. The cost for crash clean up should be subtracted from this annual cost. The final result is the total annual cost for improvements for an intersection. The B/C ratio is then calculated by dividing the total annual benefit by the total annual cost.

3.5 Operational Analysis

Operational analysis is used to evaluate the operational effectiveness of proposed improvements for each candidate intersection. This analysis is based on the Highway Capacity Manual 2000 (HCM 2000) with two outputs: the average delay reduction (Δd) and the existing average delay (d_B).

3.5.1 Criteria Selection

The criteria used in the analysis of operational performance must possess several important characteristics defined as [13]: technical reliability, importance, availability, and independence.

According to the HCM 2000, traffic delay is defined as follows:

The difference between the travel time actually experienced and the reference travel time that would result during ideal conditions; in the absence of traffic control, in the absence of geometric delay, in the absence of any incidents, and when there are no other vehicles on the road.

There are several different types of delay that can be measured at an intersection, and each serves a different purpose to the transportation engineer. The intersection capacity and Level of Service (LOS) are built around the concept of average control delay per vehicle which is the portion of the total delay attributed to traffic control operation for signalized and unsignalized intersections. Therefore, the control delay is selected as the criterion of operational analysis in this study.

3.5.2 Flow Chart of Operational Analysis

The procedure of operational analysis is shown in Figure 3-2.

Step 1: Check if proposed countermeasures have effectiveness on traffic operations. If answer is "yes", the procedure will go to step 2, otherwise go to step 6.

Step 2: Input data that will be needed in successive steps.

Step 3: Calculate the average control delay before improvements (d_b) using the model in Chapter 10, HCM 2000 for signalized intersections or the model in Chapter 17, HCM 2000 for unsignalized intersections.

Step 4: Calculate the average control delay after improvements (d_a) using model for signalized or unsignalized intersection.

Step 5: Compute the delay reduction (Δd) that is equal to the average control delay before improvements minus the average control delay after improvements, and then go to end.

Step 6: Let the delay reduction (Δd) equal to zero, and then go to end.

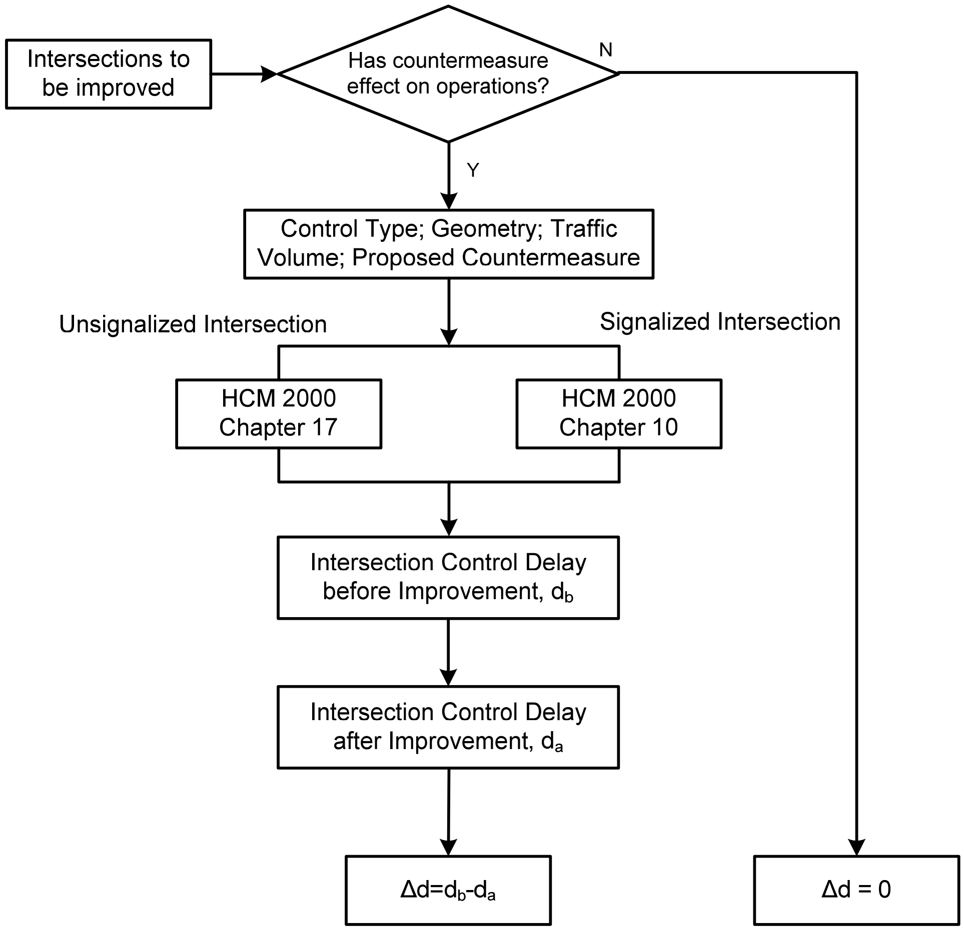

Figure 3-2 Flow Chart of Operational Analysis

3.5.3 Improvement Countermeasures

In the first step, intersections on the preliminary list with proposed improvement countermeasures are checked for operational effectiveness. These improvements for each intersection need to be discussed based on engineering considerations, identified crash types, warrant study results, and field diagnosis. Usually, one or two improvement countermeasures can be determined for a particular intersection. Many countermeasures for safety and operational improvements have been implemented in the United States. The countermeasures that can be analyzed by the HCM 2000 are listed in Table 3-1. Some countermeasures which are not covered by HCM 2000 should be obtained from simulation or field survey.

Table 3-1 Operational Effectiveness of Countermeasures

Countermeasures		Intersection Type	Operational effectiveness?
Signalization	Install signalized control in a unsignalized intersection	Unsignalized	Yes
Signing	Directional sign	Both	No
	Warning Sign		
Reconstruction	Add left turn lane	Both	Yes
	Add right turn lane		
	Add through lane		
Traffic Marking	Intersection general marking	Both	No
Lighting	New lighting at intersections	Both	No
	Upgrade lighting at intersections		
Channelization	Add channelized right lane	Unsignalized	Yes
	Add flared approach		
Median	Raised curb	Unsignalized	Yes
	Two Way Left Turn Lane		

3.5.4 Data Input

The second step is to input the necessary data that is categorized into four categories: Geometric information, Demand data, Traffic control information, and countermeasures. The data type is given in Table 3-2.

Table 3-2 Data Input

Category	Item	Intersection Type	Default Value
Demand Data	Traffic Volume (peak hour), vph	Both	-
	PHF		0.9
	Analysis Period, hour		0.25
	PHV, %		10%
Traffic Control	Control Type	Both	-
	Cycle Max, sec	Signalized	120
	Cycle Min, sec		60
Geometric Information	Lane Design	Both	-
	Channelization	Unsignalized	-
	Flared Approach		-
	Median		-
	CBD	Signalized	-
	Parking	Signalized	No
Countermeasures	Table 3.1	Both	-

3.5.5 **Signalized Intersection & Unsignalized Intersection**

Two different models in the HCM 2000 are used to calculate the average control delay for signalized and unsignalized intersections.

For signalized intersections, a quick estimation method is adopted because only minimal data is needed for this procedure (Chapter 10, HCM 2000). Signal timing which is always difficult to obtain can be estimated in this procedure. The quick estimation method consists of six steps: assembly of the input data, determination of left-turn treatment, lane volume computations, estimation of signal timing plan, calculation of the critical v/c ratio, and calculation of average vehicle delay. The detailed calculating process is given in reference [17].

The value derived from this procedure represents the average control delay experienced by all vehicles that arrive in the analysis period. The average control delay per vehicle for a given lane group is given by Equation 3-3[17].

$$d = d_1(PF) + d_2 + d_3 \tag{3-3}$$

where

d = control delay per vehicle (s/veh);

d_1 = uniform control delay (s/veh);

PF = uniform delay progress adjustment factor;

d_2 = incremental delay (s/veh);

d_3 = initial queue delay (s/veh).

Uniform delay is given in Equation 3-4[17] assuming uniform arrivals, stable flow, and no initial queue.

$$d_1 = \frac{0.5C\left(1 - \frac{g}{C}\right)^2}{1 - \left[\min(1, X)\frac{g}{C}\right]} \tag{3-4}$$

where

C = cycle length (s);

G = effective green time for lane group (s);

X = v/c ratio or degree of saturation for lane group.

Incremental delay accounts for effect of random arrivals and oversaturation queues, and is given in Equation 3-5[17].

$$d_2 = 900T\left[(X-1) + \sqrt{(X-1)^2 + \frac{8klX}{cT}}\right] \tag{3-5}$$

where

T = duration of analysis period (h);

k = incremental delay factor

l = upstream filtering/metering factor;

c = lane group capacity (veh/h); and

X = lane group v/c ratio or degree of saturation.

For unsignalized intersection, the procedure in Chapter 17, HCM 2000 can be used to analyze the capacity and level of service of two-way stop-controlled (TWSC) and all-way stop-controlled (AWSC) intersections. Each type of unsignalized intersection (TWSC, AWSC) is addressed in a separate procedure.

For TWSC, average control delay for any particular minor movement is given in Equation 3-6[17].

$$d = \frac{3600}{c_{m,x}} + 900T\left[\frac{v_x}{c_{m,x}} - 1 + \sqrt{\left(\frac{v_x}{c_{m,x}} - 1\right)^2 + \frac{\left(\frac{3600}{c_{m,x}}\right)\left(\frac{v_x}{c_{m,x}}\right)}{450T}}\right] + 5 \quad (3\text{-}6)$$

where

v_x = flow rate for movement x (veh/h);

$c_{m,x}$ = capacity of movement x (veh/h);

T = analysis time period

Average control delay for AWSC is given in Equation 3-7[].

$$d = t_s + 900T\left[(x-1) + \sqrt{(x-1)^2 + \frac{h_d x}{450T}}\right] + 5 \quad (3\text{-}7)$$

where

x = degree of utilization ($vh_d/3600$);

t_s = service time (s);

h_d = departure headway (s);

T = analysis period (h)

For both signalized and TWSC intersections, the average delay calculated above is a disaggregated value for each lane group; but what is needed in successive analysis is the intersection delay. Therefore, aggregated delay estimation is going to be processed by using equation 3-8, 3-9[17].

$$d_A = \frac{\sum d_i v_i}{\sum v_i} \tag{3-8}$$

where

d_A = delay for Approcach A (s/veh);

d_i = delay for lane group i (on Approach A) (s/veh);

v_i = adjusted flow for lane group i (veh/h).

$$d_I = \frac{\sum d_A v_A}{\sum v_A} \tag{3-9}$$

where

d_I = delay per vehicle for intersections (s/veh);

d_A = delay for Approcach A (s/veh);

v_A = adjusted flow for Approach A (veh/h).

3.5.6 Delay Reduction

Delay reduction, the criterion for evaluation of operational effectiveness of proposed improvements, is the difference between the average intersection delay (Eq. 3-9) before the implementation of improvement countermeasures and the average intersection delay after improvements. In this study, the delay reduction is given in Equation 3-10.

$$\Delta d = d_b - d_a \tag{3-10}$$

where

Δd = delay reduction (s/veh);

d_b = the average intersection delay before improvements (s/veh);

d_a = the average intersection delay after improvements 9s/veh).

Finally, delay reduction (Δd) and the existing delay (d_b) are the outputs of operational analysis.

3.6 Multi-Layer Prioritizing

After safety and operational analysis, the two factors should be combined to evaluate the effectiveness of proposed improvements comprehensively. Based on this integrated criterion, a priority list of intersection improvement projects is produced. In this study, the Multi-Layer Prioritizing method is developed to combine the safety and operational factors. The idea of Multi-Layer Prioritizing method is presented as following:

Assign each criterion to one layer according to the relative importance of this criterion with other criteria; a higher layer represents greater importance, and the first layer represents the most important level. Rank intersection improvement projects based on criterion in the first layer, then cluster these projects based on similarity of the criterion value (first level) into several groups. In each group, if the differences of the first criterion between projects are small enough so that these intersections can be considering identical, then rank and cluster improvement projects in each group based on the criterion in the second layer. Do this iteration until reach the last layer is reached.

3.6.1 The Criteria Priority

In the description of the Multi-Layer Prioritizing method, a very important step is to determine the criteria priority. In this method, three criteria were considered: Benefit-Cost Ratio for safety *(B/C)*, delay reduction *(Δd)*, and existing delay *(d_b)*. The first one is a safety related criterion, the others are operational factors.

There are two basic considerations: (1) safety effectiveness is more important than operational effectiveness; (2) operational effectiveness is more important. This importance is determined in practice by expert experience. In this study, two priority sequences of criteria are provided for the two considerations respectively.

For the first consideration, safety effectiveness is more important, the priority sequence is B/C, delay reduction, existing delay. And for the second consideration, the priority sequence is delay reduction, B/C, existing delay.

3.6.2 The Procedure of Multi-Layer Prioritizing Method

Since three criteria are considered in the Multi-Layer Prioritizing method, the structure of this method includes three layers. Two procedures were designed for the two priority sequences respectively.

The first procedure which represents that safety factor is more important is shown as Figure 3-3.

Layer 1: Select B/C for safety as the first layer criterion which has the most importance;

Rank intersections based on B/C in descending order (the first priority list);

Cluster intersections based on similarity of B/C value into several groups.

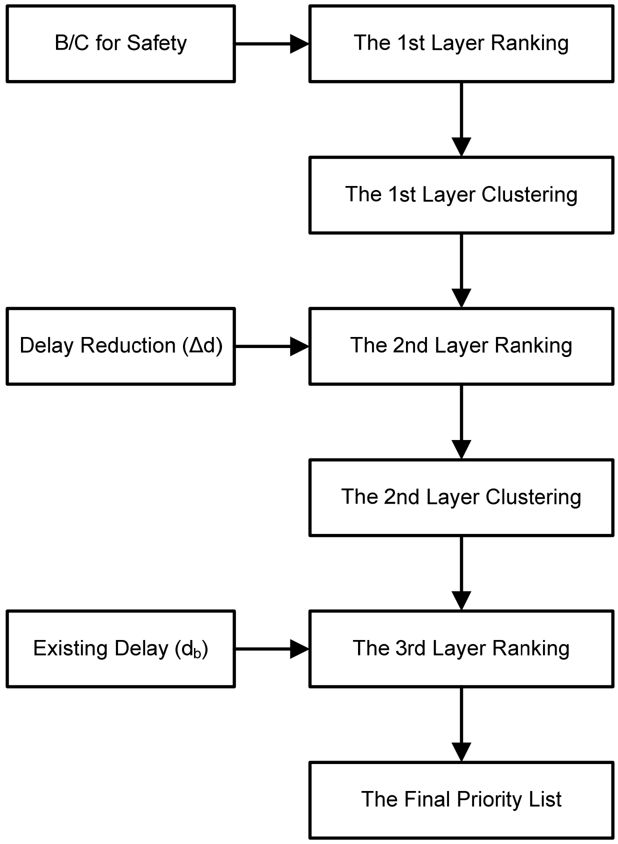

Figure 3-3 Procedure of Multi-Layer Prioritizing Method (safety prioritized)

Layer 2: Select delay reduction (Δd) as the second layer criterion which has the second most importance;

Rank intersections for each group based on Δd in descending order (the second priority list);

Cluster intersections for each group based on similarity of Δd value into several subgroups.

Layer 3: Select existing delay (d_b) for safety as the third layer criterion which has the third most importance;

Rank the candidate intersections for each subgroup based on Δd in descending order (the final priority list).

This procedure including three layers of ranking (prioritizing) and two layers of clustering generates a priority list of intersection improvement projects with the first consideration. The procedure with the second consideration is given in Figure 3-4.

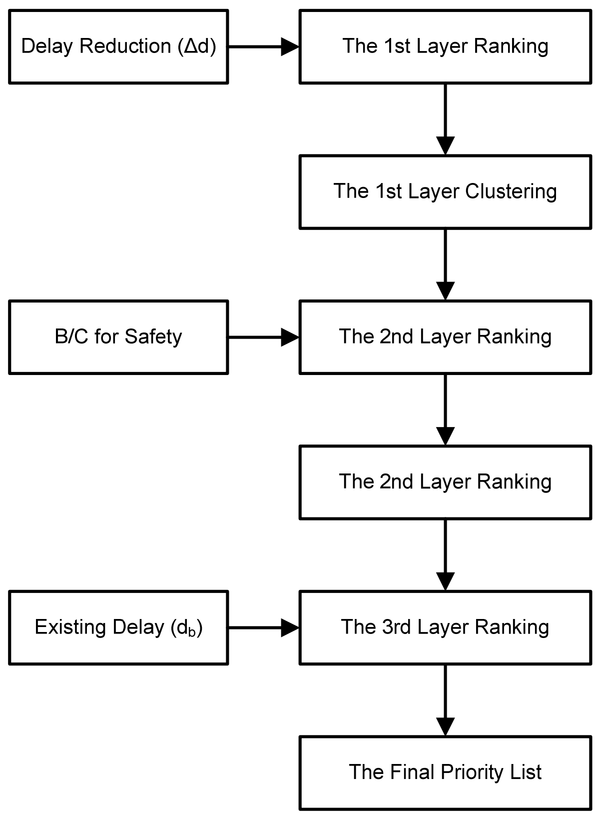

Figure 3-4 Procedure of Multi-Layer Prioritizing Method (operations prioritized)

3.6.3 **Clustering Algorithm**

Clustering is the key step of the Multi-Layer Prioritizing method to provide a quantified process for assigning intersections into groups whose members have similar value on certain criterion. A group (cluster) is a collection of intersections which are similar between them and are dissimilar to the intersections belonging to other groups [18]. The measure of this "similarity" is called distance. Two kinds of distance are defined in this study.

The distance of two points (intersections) is the measure of the similarity of two intersections on a particular criterion which can be B/C, delay reduction, or existing delay in this study. The definition of intersection distance is given in Equation 3-11.

$$d(i,j) = \left| x_j - x_i \right| \tag{3-11}$$

where

$d(i, j)$ = the distance between intersection i and j ;

x_j, x_i = the value of criterion x of intersection j, i.

The distance between two groups (clusters) is the measure of the similarity of two groups on a particular criterion (B/C, Δd, d_b). In this study, the average-linkage distance which considers the group distance to be equal to the average distance from any member of one group to any member of the other group was adopted. The definition of group distance is given in Equation 3-12.

$$D(A,B) = \frac{1}{n_A \times n_B} \sum_{i \in A} \sum_{j \in B} d(i,j) \tag{3-12}$$

where

$D(A, B)$ = the distance between group A and group B;

$d(i, j)$ = the distance between intersection i and j ;

n_A, n_B = the numbers of intersections in group A and group B respectively.

The procedure of hierarchical clustering algorithm adopted in Multi-Layer Prioritizing method is given as following (See Figure 3-5):

Step 1: Start by assigning each intersection to a group, so that if there are N intersections in preliminary list, N groups is produced in step 1, each group containing just one intersection. Let the distance (similarity) between the groups the same as the distance between the intersections they contain.

Step 2: Find the closet (most similar) pair of group and merge then into a single group, so that one group is reduced.

Step 3: Compute distances between the new group and each of the old groups.

Step 4: Repeat step 2 and 3 until distance of the closet pair of group is equal to or greater than a threshold, or all intersections are clustered into a single group.

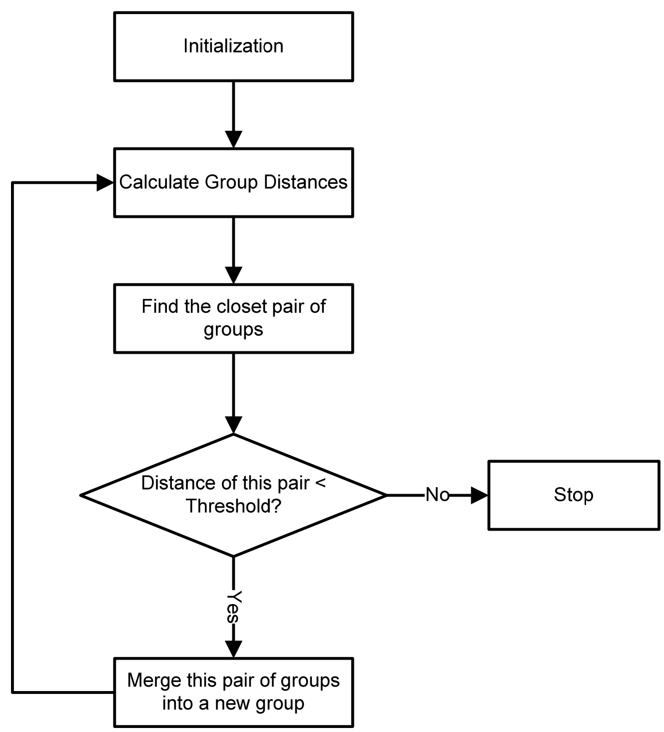

Figure 3-5 Procedure of Hierarchical Clustering Algorithm

Threshold, the trigger for stopping the iteration, reflects the relative importance for two criteria. It is always defined based on subjective experiences of experts.

A simple example of hierarchical clustering algorithm is given in Figure 3-6. There are four intersections, so that four groups are produced in the initialized step. To find the minimum group distance *D(B, C)* which is less than threshold, merge group B, C into an new group B. Re-calculate the group distances and find the closet pair of groups (B, C) to check distance of this pair being still less than threshold, so merge B,C into new group B. Now, with two groups left; calculate the distance between the two groups, and it is greater than threshold, so stop iteration.

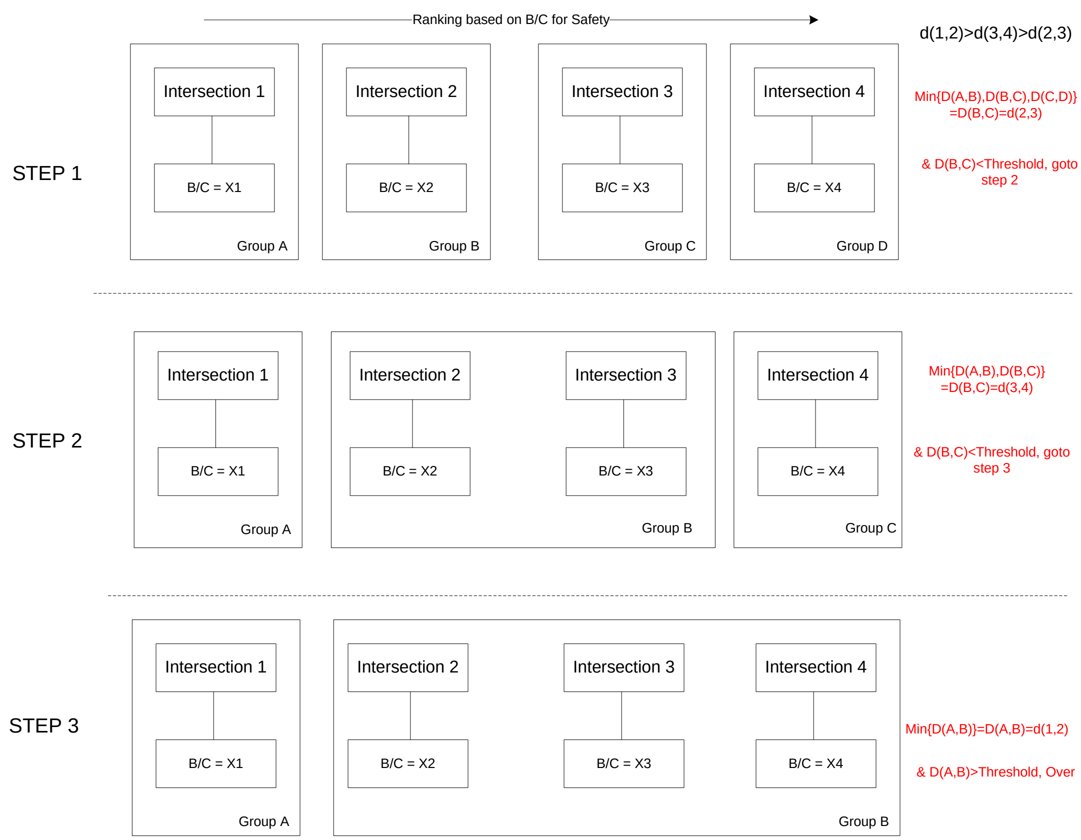

Figure 3-6 Example of Hierarchical Clustering Algorithm

4. CASE STUDY

In this chapter, a case study was done to apply the new procedure developed in this study to evaluate and prioritize intersection improvement projects included in the "Annual Report on Highway Safety Improvements Programs " compiled in 2004 by the FDOT District 7 Safety Office. This case study resulted in two priority lists, safety prioritized, and operations prioritized.

4.1 Identification of Intersections for Preliminary List

The intersections studied in this case study were obtained from the "Annual Report on Highway Safety Improvements Programs (2004)" which included 62 existing intersection improvement projects in District 7, Florida from 1994 to 2003. The information of project date, intersection location, proposed countermeasures, project cost, safety-related were also provided in this report. In this case study, 35 intersection improvement projects were selected for the preliminary list according to two rules: (1) the data of the intersection were available or easy to collect; (2) the proposed countermeasures could be analyzed by using HCM 2000. The preliminary list is shown in Table 4-1.

Table 4-1 Preliminary List

ITEM	CONSTRUCTION DATES		PROJECT SCOPE	B/C
ID	BEGIN	FINISH	DESCRIPTION	
403749	7/30/2001	9/14/2001	Gunn Hwy @ Wayne Rd: **Add LT lane**	2.01
403748	11/26/2001	1/4/2002	Brooker Road @ Lithia Pinecrest Rd: **Add LT lanes**	5.08
406557	8/10/2002	1/6/2003	Fletcher from Dale Mabry to Orange Grove:**Add Raised Median & Turn Lanes**	18.63
411088	8/27/2003	10/8/2003	SR 200 at SR 45(US 41): **Channelization**	13.76
406222	6/28/2002	8/19/2002	SR 43 at SR 574:**Street Lighting**	4.35
255887	5/3/2000	8/4/2000	US 41 from Fowler Ave to Fletcher Ave: **Street Lighting**	4.71
255694	4/17/1997	7/15/1997	SR 45 from s/o Miller Mac to n/o Big Bend Road: **Lighting**	1.60
411201	7/15/2002	9/5/2002	I-75 Off Ramp at Gibsonton Drive:**Traffic Signal**	11.57
255837	9/28/1998	1/11/1999	SR 574 @ Sydney-Dover: **Traffic Signals**	30.70
255871	11/1/1999	1/25/2000	SR 574 @ Bethlehem: **Add EB Left Turn Lane**	6.35
255875	3/15/1999	8/18/1999	SR 60 from Glendale to Varico: **Street Lighting**	7.50
255771	2/17/1997	6/20/1998	SR 60 @ Dover Road: **Add turn lane and Traffic Signal**	5.90
255831	2/4/1998	2/1/1999	SR 60 from Varico to Dover: **Street Lighting**	4.60
255836	2/4/1998	2/1/1999	SR 60 @ Turkey Creek: **Street Lighting**	4.08
255838	10/5/1998	2/1/1999	SR 674 from US 301 to CR 579: **Street Lighting**	4.25
255727	11/1/1994	8/16/1995	SR 674 from SR 45 to I-75: **Street Lighting**	2.41
255791	5/13/1996	9/2/1996	SR 580 @ Countryway Boulevard: **Traffic Signal**	3.80
255679	9/10/1996	5/30/1997	SR 597 @ Lambright: **Add left turn lane and Traffic Signal**	2.47
403859	6/4/2002	1/16/2003	Dale Mabry Hwy at Ehrlich Rd/Bearass Ave: **Add EB LT lane; EB &WB RT lanes**	2.01
255839	11/4/1999	4/13/2000	SR 597 @ Van Dyke: **Add 2nd NB left turn lane**	2.14
255695	2/13/1997	2/27/1998	SR 580 from Hillsborough Ave to Water Ave: **Street Lighting**	2.41
255779	8/2/1994	2/10/1995	SR 45 from 50th Street to Hemlock: **Lighting**	3.40
255724	11/1/1994	6/8/1995	SR 583 from SR 599 to Hillsborough River: **Lighting**	2.40
255859	2/17/2003	9/9/2003	Bearass Avenue from Florida Ave to Nebraska Ave: **Add LT lanes**	6.14
256345	10/28/1996	3/8/1997	SR 54 @ Boyette Road: **Add LT Lane**	6.36
256359	10/28/1996	3/8/1997	SR 54 @ CR 577: **Add LT Lane**	4.25
256420	10/1/2001	3/2/2002	SR 52 @ I-75: **Traffic Signal, Add RT lane and Lights**	6.54
257107	7/22/2001	12/29/2001	Seminole Blvd At Park Blvd:**Add LT and through lanes; Channelization**	2.00
256982	8/19/1996	5/1/1997	SR 595 @ Ponce De Leon and Wyatt: **Add LT Lanes and Modify Traffic Signal**	4.48
257140	8/27/2002	12/3/2002	ALT US 19 at Dixie Hwy.: **Add LT lanes and Flashing Signal**	3.73
257006	12/1/1995	3/19/1996	SR 693 from Bryan Dairy Road to 121st. Avenue: **Lighting**	2.4
257144	5/6/1999	9/8/1999	US 19: Alderman to Lake Street: **Street Lighting**	2.80
257102	7/24/2000	3/31/2001	US 19: Evans Rd to Alderman Rd: **Street Lighting**	3.59
256923	5/18/1995	11/13/1995	SR 682 @ SR 679/Sun Boulevard: **Traffic Signal**	2.80

4.2 Data Collection

Since the B/C for safety for each intersection improvement project is available on the preliminary list, only the operational analysis related data is collected in this case study. These data include traffic volume information, traffic control information, and geometric information. The detailed description of data type is given in Table 3-2.

Among the 35 intersections, the operational analysis data of 25 intersections were directly obtained from the FDOT District 7 office. Field surveys were taken in other 10 intersections. For each intersection, three kinds of data were collected as following:

Geometric design: *number of lanes, channelization, median, flare storage;*

Traffic control: *signalized or unsignalized (TWSC, AWSC);*

Traffic Volume: *peak hour volume (four legs)*

The average hour volume during 6:00 to 9:00 AM in each intersection was collected as the peak hour volume of this intersection.

The data collection which was the input of operational analysis is given in Appendix B.

4.3 Operational Analysis

Because the safety criterion is available in preliminary list, it is the only necessary step after data collection to process operational analysis in this study. The method described in Chapter 3 was implemented to process this analysis.

The necessary data for operational analysis is listed in Appendix B. Geometric information, traffic control, and traffic volume were collected from the FDOT District 7 office or field surveys; other data including PHF, PHV, CBD, and cycle length were adopted, the default value given in Table 3-2 for predigesting the calculation.

For 20 intersections with the effectiveness of proposed countermeasures on operational performance, the calculating procedure was run twice: before improvement and after improvement. As results of the procedure, two criteria were produced: the existing delay

(d_b) and the estimated delay (d_a). Then the delay reduction (Δd) is obtained by subtracting d_a from d_b . For other intersections whose proposed countermeasures have no effectiveness on operational performance, a zero value is assigned to d_b, d_a, and Δd .

The results of operational analysis are given in Table 4-2.

Table 4-2 Results of Operational Analysis

ID	Countermeasures	Effectiveness?	d_b (s/veh)	d_a (s/veh)	Δd (s/veh)
403749	**Add LT lane**	Y	1.4	1.2	0.2
403748	**Add LT lanes**	Y	5.5	5.4	0.1
406557	**Add Raised Median & Turn Lanes**	Y	130.4	236.1	-105.7
411088	**Channelization**	Y	3.2	3.2	0
406222	**Street Lighting**	N	0	0	0
255887	**Street Lighting**	N	0	0	0
255694	**Street Lighting**	N	0	0	0
411201	**Traffic Signal**	Y	108.6	13.2	95.4
255837	**Traffic Signals**	Y	127.9	13.2	114.7
255871	**Add EB Left Turn Lane**	Y	1.1	1	0.1
255875	**Street Lighting**	N	0	0	0
255771	**Add turn lane and Traffic Signal**	Y	293.2	7.7	285.5
255831	**Street Lighting**	N	0	0	0
255836	**Street Lighting**	N	0	0	0
255838	**Street Lighting**	N	0	0	0
255727	**Street Lighting**	N	0	0	0
255791	**Traffic Signal**	Y	19.8	32.6	-12.8
255679	**Add left turn lane; Traffic Signal**	Y	246.4	208.8	37.6
403859	**Add EB LT lane; EB &WB RT lanes**	Y	574.3	521.7	52.6
255839	**Add 2nd NB left turn lane**	Y	137.2	87.4	49.8
255695	**Street Lighting**	N	0	0	0
255779	**Lighting**	N	0	0	0
255724	**Lighting**	N	0	0	0
255859	**Add LT lanes**	Y	83.2	82.3	0.9
256345	**Add LT Lane**	Y	6.7	31.7	-25
256359	**Add LT Lane**	Y	105.5	39.4	66.100
256420	**Traffic Signal, Add RT lane and Lights**	Y	5.4	7.2	-1.8
257107	**Add LT and through lanes; Channelization**	Y	38	31.9	6.1
256982	**Add LT Lanes and Modify Traffic Signal**	Y	6.6	6.3	0.3
257140	**Add LT lanes and Flashing Signal**	Y	2.9	2.8	0.1
257006	**Street Lighting**	N	0	0	0
257144	**Street Lighting**	N	0	0	0
257102	**Street Lighting**	N	0	0	0
256923	**Traffic Signal**	Y	21.2	6	15.2

4.4 Multi-Layer Prioritizing

In this study, two kinds of prioritizing procedures based on the Multi-Layer Prioritizing method were implemented separately: procedure I - safety factor had precedence over the operational factor; and procedure II - operational factor took precedence over safety factor. For each procedure, three priority lists were produced and compared: priority list I (considering safety factor only), priority list II (considering operational factor only), and priority list III (considering both factors). The necessary data for the two procedures included three criteria: *B/C*, d_b, and d_a, which were given in Table 4-3.

4.4.1 Procedure I

In this procedure, the prioritizing sequence was $B/C \rightarrow \Delta d \rightarrow d_b$. In the first layer, the 34 intersections were ranked and clustered based on *B/C*; in the second layer, these intersections were ranked and clustered again based on Δd within each group that was produced in the first layer; in the third layer, the intersection within subgroup produced in second layer were ranked based on d_a.

Table 4-4a represents the first layer prioritization which also is the priority list I considering safety factor only, the existing method to prioritize intersection improvement projects in Florida.

In Figure 4-1, a set of columns indicate the B/C values of intersections. From the graph, we found three groups of intersections with similar B/C value inside. For example, the difference of B/C value of intersections 5, 6, 7, 8, 9, and 10 was small enough (< threshold) and the difference between these intersections and others was big enough (≥ threshold), so that we can put them into one group. Table 4-4b signified the first layer clustering. The threshold for *B/C* in this study is defined as 1.8.

Table 4-4c and Table 4-4d show the second layer ranking and clustering respectively. In Table 4-4c, the second layer ranking of intersections within group 5 according to delay reduction revised the first layer priority. In Table 4-4d, the threshold for delay reduction is defined as 10s.

Finally, Table 4-4e indicates the third layer ranking which updated the second priority of intersections based on existing delay within each second group. This ranking is the priority list III considering both safety and operational factors.

The first layer priority list and the third layer priority list were compared in Figure 4-2. The difference of B/C value of the first 4 intersections was significant, so that they kept same priority in two kinds of lists. For these intersections, operational factors didn't work on the priority. In contrast to the first 4 intersections, most intersections didn't keep the same priority in the two lists. For those intersections with similar B/C value, the ranking in the third layer priority list was revised based on two operational factors to provide a more reasonable priority list.

For example, the intersection 255875 and 255771 in the first layer list located in position 5 and position 10 ranking respectively. These intersections owned similar safety performance (7.5, 5.9), but their operational performances were dissimilar significantly (0, 293.2 - Δd). For the two intersections, priority based on operational factor is more reasonable than based on safety performance. Therefore in the third layer priority list their ranking position is 9 and 5.

Table 4-3 Data Input for Multi-Layer Prioritizing

ID	B/C	d_b (s/veh)	Δd (s/veh)
403749	2.01	1.4	0.2
403748	5.08	5.5	0.1
406557	18.63	130.4	-105.7
411088	13.76	3.2	0
406222	4.35	0	0
255887	4.71	0	0
255694	1.60	0	0
411201	11.57	108.6	95.4
255837	30.70	127.9	114.7
255871	6.35	1.1	0.1
255875	7.50	0	0
255771	5.90	293.2	285.5
255831	4.60	0	0
255836	4.08	0	0
255838	4.25	0	0
255727	2.41	0	0
255791	3.80	19.8	-12.8
255679	2.47	246.4	37.6
403859	2.01	574.3	52.6
255839	2.14	137.2	49.8
255695	2.41	0	0
255779	3.40	0	0
255724	2.40	0	0
255859	6.14	83.2	0.9
256345	6.36	6.7	-25
256359	4.25	105.5	66.100
256420	6.54	5.4	-1.8
257107	2.00	38	6.1
256982	4.48	6.6	0.3
257140	3.73	2.9	0.1
257006	2.4	0	0
257144	2.80	0	0
257102	3.59	0	0
256923	2.80	21.2	15.2

Table 4-4a The First Layer Priority (Procedure I)

The 1st Layer Priority	ID	B/C
1	255837	**30.7**
2	406557	**18.63**
3	411088	**13.76**
4	411201	**11.57**
5	255875	**7.5**
6	256420	**6.54**
7	256345	**6.36**
8	255871	**6.35**
9	255859	**6.14**
10	255771	**5.9**
11	403748	**5.08**
12	255887	**4.71**
13	255831	**4.6**
14	256982	**4.48**
15	406222	**4.35**
16	256359	**4.25**
17	255838	**4.25**
18	255836	**4.08**
19	255791	**3.8**
20	257140	**3.73**
21	257102	**3.59**
22	255779	**3.4**
23	257144	**2.8**
24	256923	**2.8**
25	255679	**2.47**
26	255695	**2.41**
27	255727	**2.41**
28	255724	**2.4**
29	257006	**2.4**
30	255839	**2.14**
31	403749	**2.01**
32	403859	**2.01**
33	257107	**2**
34	255694	**1.6**

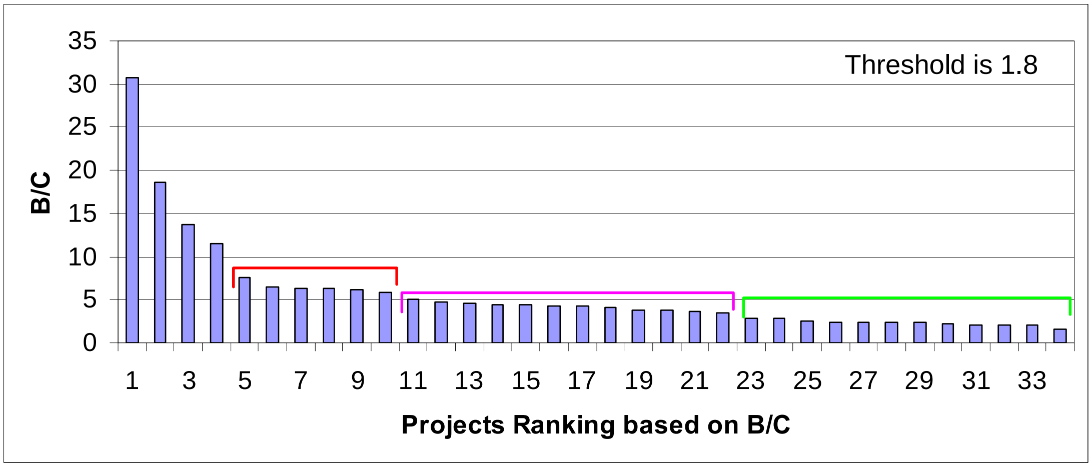

Figure 4-1 The First Layer Clustering

Table 4-4b The First Layer Clustering (Procedure I)

Threshold: 1.8

Group (G_i)	The 1st Layer Priority	ID	B/C	Difference ($G_i - G_{i+1}$)
1	1	255837	30.7	**12.07**
2	2	406557	18.63	**4.87**
3	3	411088	13.76	**2.19**
4	4	411201	11.57	**4.07**
5	5	255875	7.5	**2.065**
	6	256420	6.54	
	7	256345	6.36	
	8	255871	6.35	
	9	255859	6.14	
	10	255771	5.9	
6	11	403748	5.08	**1.906**
	12	255887	4.71	
	13	255831	4.6	
	14	256982	4.48	
	15	406222	4.35	
	16	256359	4.25	
	17	255838	4.25	
	18	255836	4.08	
	19	255791	3.8	
	20	257140	3.73	
	21	257102	3.59	
	22	255779	3.4	
7	23	257144	2.8	–
	24	256923	2.8	
	25	255679	2.47	
	26	255695	2.41	
	27	255727	2.41	
	28	255724	2.4	
	29	257006	2.4	
	30	255839	2.14	
	31	403749	2.01	
	32	403859	2.01	
	33	257107	2	
	34	255694	1.6	

Table 4-4c The Second Layer Priority (Procedure I)

Group	ID	B/C	**Δd** (s/veh)	**The 1st Layer Priority**	**The 2nd Layer Priority**
1	255837	30.7	**114.70**	1	**1**
2	406557	18.63	**-105.70**	2	**2**
3	411088	13.76	**0.00**	3	**3**
4	411201	11.57	**95.40**	4	**4**
5	255771	5.9	**285.50**	10	**5**
	255859	6.14	**0.90**	9	**6**
	255871	6.35	**0.10**	8	**7**
	255875	7.5	**0.00**	5	**8**
	256420	6.54	**-1.80**	6	**9**
	256345	6.36	**-25.00**	7	**10**
6	256359	4.25	**66.10**	16	**11**
	256982	4.48	**0.30**	14	**12**
	403748	5.08	**0.1**	11	**13**
	257140	3.73	**0.1**	20	**14**
	255887	4.71	**0**	12	**15**
	255831	4.6	**0**	13	**16**
	406222	4.35	**0**	15	**17**
	255838	4.25	**0**	17	**18**
	255836	4.08	**0**	18	**19**
	257102	3.59	**0**	21	**20**
	255779	3.4	**0**	22	**21**
	255791	3.8	**-12.80**	19	**22**
7	403859	2.01	**52.60**	32	**23**
	255839	2.14	**49.80**	30	**24**
	255679	2.47	**37.60**	25	**25**
	256923	2.8	**15.20**	24	**26**
	257107	2	**6.10**	33	**27**
	403749	2.01	**0.20**	31	**28**
	257144	2.8	**0**	23	**29**
	255695	2.41	**0**	26	**30**
	255727	2.41	**0**	27	**31**
	257006	2.4	**0**	29	**32**
	255724	2.4	**0**	28	**33**
	255694	1.6	**0**	34	**34**

Table 4-4d The Second Layer Clustering (Procedure I)

Threshold: 10s/veh

Group (G_i)	**The 2nd Group ($G_{i,j}$)**	**ID**	**Δd** (s/veh)	**Difference ($G_{i,j} – G_{i,j+1}$)**
1	1	255837	**114.70**	
2	2	406557	**-105.70**	
3	3	411088	**0.00**	
4	4	411201	**95.40**	
5	5.1	255771	**285.50**	284.6
	5.2	255859	**0.90**	23.2
		255871	**0.10**	
		255875	**0.00**	
		256420	**-1.80**	
	5.3	256345	**-25.00**	
6	6.1	256359	**66.10**	65.8
	6.2	256982	**0.30**	12.8
		403748	**0.1**	
		257140	**0.1**	
		255887	**0**	
		255831	**0**	
		406222	**0**	
		255838	**0**	
		255836	**0**	
		257102	**0**	
		255779	**0**	
	6.3	255791	**-12.80**	
7	7.1	403859	**52.60**	12.2
		255839	**49.80**	
	7.2	255679	**37.60**	22.4
	7.3	256923	**15.20**	
		257107	**6.10**	
		403749	**0.20**	
		257144	**0.00**	
		255695	**0.00**	
		255727	**0.00**	
		257006	**0.00**	
		255724	**0.00**	
		255694	**0.00**	

Table 4-4e The Third Layer Priority (Procedure I)

Group	**The 2nd Group**	**ID**	**B/C**	**d_b** (s/veh)	**Δd** (s/veh)	**The 1st Layer Priority**	**The 2nd Layer Priority**	**The 3rd Layer Priority**
1	1	255837	30.7	**127.9**	114.70	1	1	**1**
2	2	406557	18.63	**130.4**	-105.70	2	2	**2**
3	3	411088	13.76	**3.2**	0.00	3	3	**3**
4	4	411201	11.57	**108.6**	95.40	4	4	**4**
5	5.1	255771	5.9	**293.2**	285.50	10	5	**5**
	5.2	255859	6.14	**83.2**	0.90	9	6	**6**
		256420	6.54	**5.4**	-1.80	6	9	**7**
		255871	6.35	**1.1**	0.10	8	7	**8**
		255875	7.5	**0**	0.00	5	8	**9**
	5.3	256345	6.36	**6.7**	-25.00	7	10	**10**
6	6.1	256359	4.25	**105.5**	66.10	16	11	**11**
	6.2	256982	4.48	**6.6**	0.30	14	12	**12**
		403748	5.08	**5.5**	0.10	11	14	**13**
		257140	3.73	**2.9**	0.10	20	13	**14**
		255887	4.71	**0**	0.00	12	15	**15**
		255831	4.6	**0**	0.00	13	16	**16**
		406222	4.35	**0**	0.00	15	17	**17**
		255838	4.25	**0**	0.00	17	18	**18**
		255836	4.08	**0**	0.00	18	19	**19**
		257102	3.59	**0**	0.00	21	20	**20**
		255779	3.4	**0**	0.00	22	21	**21**
	6.3	255791	3.8	**19.8**	-12.80	19	22	**22**
7	7.1	403859	2.01	**574.3**	52.60	32	23	**23**
		255839	2.14	**137.2**	49.80	30	24	**24**
	7.2	255679	2.47	**246.4**	37.60	25	25	**25**
	7.3	257107	2	**38**	6.10	33	27	**26**
		256923	2.8	**21.2**	15.20	24	26	**27**
		403749	2.01	**1.4**	0.20	31	28	**28**
		257144	2.8	**0**	0.00	23	29	**29**
		255695	2.41	**0**	0.00	26	30	**30**
		255727	2.41	**0**	0.00	27	31	**31**
		257006	2.4	**0**	0.00	29	32	**32**
		255724	2.4	**0**	0.00	28	33	**33**
		255694	1.6	**0**	0.00	34	34	**34**

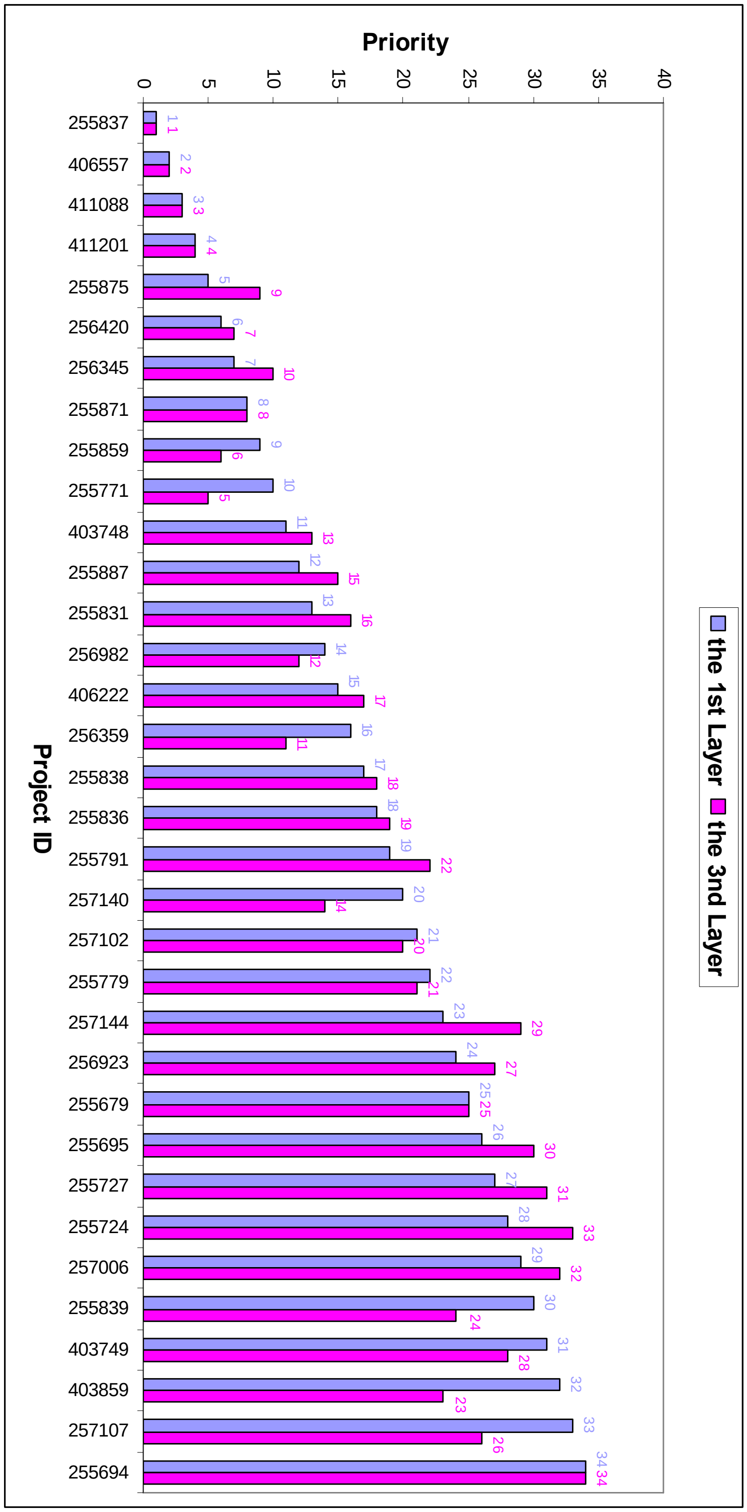

Figure 4-2 Comparison of the First Layer and the Third Layer Priorities (Procedure I)

4.4.2 Procedure II

Another prioritizing sequence is $\Delta d \rightarrow B/C \rightarrow d_b$. In the first layer, the 34 intersections were ranked and clustered based on Δd; in the second layer, these intersections were ranked and clustered again based on *B/C* within each group that was produced in the first layer; in the third layer, the intersection within subgroup produced in the second layer were ranked based on d_a.

Table 4-5a represents the first layer prioritization which also is the priority list II considering operational factor only. Table 4-5b signified the first layer clustering based on the threshold for Δd in this study (10 s/veh).

Table 4-5c and Table 4-5d showed the second layer ranking and clustering respectively. In Table 4-5c, the second layer ranking of intersections according to B/C revised the first layer priority. In Table 4-4d, the threshold for delay reduction is defined 1.8.

Table 4-5e indicates the third layer ranking which updated the second priority of intersections based on existing delay within each second group. This priority list is the output of MLP method considering both safety and operational factors.

The first layer priority list and the third layer priority list were compared in Figure 4-3.

Table 4-5a The First Layer Priority (Procedure II)

The 1st Layer Priority	**ID**	***Δd*** **(s/veh)**
1	255771	**285.50**
2	255837	**114.70**
3	411201	**95.40**
4	256359	**66.10**
5	403859	**52.60**
6	255839	**49.80**
7	255679	**37.60**
8	256923	**15.20**
9	257107	**6.10**
10	255859	**0.90**
11	256982	**0.30**
12	403749	**0.20**
13	257140	**0.10**
14	255871	**0.10**
15	403748	**0.10**
16	255887	**0.00**
17	255694	**0.00**
18	255875	**0.00**
19	255831	**0.00**
20	255836	**0.00**
21	255838	**0.00**
22	255727	**0.00**
23	255695	**0.00**
24	255779	**0.00**
25	255724	**0.00**
26	257006	**0.00**
27	257144	**0.00**
28	257102	**0.00**
29	411088	**0.00**
30	406222	**0.00**
31	256420	**-1.80**
32	255791	**-12.80**
33	256345	**-25.00**
34	406557	**-105.70**

Table 4-5b The First Layer Clustering (Procedure I)

Threshold: 10 s/veh

Group (G_i)	The 1st Layer Priority	ID	Δd (s/veh)	Difference ($G_i - G_{i+1}$)
1	1	255771	285.50	**170.8**
2	2	255837	114.70	**19.3**
3	3	411201	95.40	**29.3**
4	4	256359	66.10	**14.9**
5	5	403859	52.60	**13.6**
	6	255839	49.80	
6	7	255679	37.60	**36.72**
7	8	256923	15.20	**13.68**
	9	257107	6.10	
	10	255859	0.90	
	11	256982	0.30	
	12	403749	0.20	
	13	257140	0.10	
	14	255871	0.10	
	15	403748	0.10	
	16	255887	0.00	
	17	255694	0.00	
	18	255875	0.00	
	19	255831	0.00	
	20	255836	0.00	
	21	255838	0.00	
	22	255727	0.00	
	23	255695	0.00	
	24	255779	0.00	
	25	255724	0.00	
	26	257006	0.00	
	27	257144	0.00	
	28	257102	0.00	
	29	411088	0.00	
	30	406222	0.00	
	31	256420	-1.80	
8	32	255791	-12.80	**12.2**
9	33	256345	-25.00	**80.7**
10	34	406557	-105.70	-

Table 4-5c The Second Layer Priority (Procedure II)

Group (G_i)	ID	*Δd* (s/veh)	B/C	The 1st Layer Priority	The 2nd Layer Priority
1	255771	285.50	**5.9**	1	1
2	255837	114.70	**30.7**	2	2
3	411201	95.40	**11.57**	3	3
4	256359	66.10	**4.25**	4	4
5	255839	52.60	**2.14**	6	5
	403859	49.80	**2.01**	5	6
6	255679	37.60	**2.47**	7	7
7	411088	15.20	**13.76**	29	8
	255875	6.10	**7.5**	18	9
	256420	0.90	**6.54**	31	10
	255871	0.30	**6.35**	14	11
	255859	0.20	**6.14**	10	12
	403748	0.10	**5.08**	15	13
	255887	0.10	**4.71**	16	14
	255831	0.10	**4.6**	19	15
	256982	0.00	**4.48**	11	16
	406222	0.00	**4.35**	30	17
	255838	0.00	**4.25**	21	18
	255836	0.00	**4.08**	20	19
	257140	0.00	**3.73**	13	20
	257102	0.00	**3.59**	28	21
	255779	0.00	**3.4**	24	22
	256923	0.00	**2.8**	8	23
	257144	0.00	**2.8**	27	24
	255727	0.00	**2.41**	22	25
	255695	0.00	**2.41**	23	26
	257006	0.00	**2.4**	26	27
	255724	0.00	**2.4**	25	28
	403749	0.00	**2.01**	12	29
	257107	0.00	**2**	9	30
	255694	-1.80	**1.6**	17	31
8	255791	-12.80	**3.8**	32	32
9	256345	-25.00	**6.36**	33	33
10	406557	-105.70	**18.63**	*34*	34

Table 4-5d The Second Clustering (Procedure II)

Threshold: 1.8

Group (G_i)	**The 2nd Group ($G_{i,j}$)**	**ID**	B/C	**Difference ($G_{i,j} – G_{i,j+1}$)**
1	1	255771	5.9	
2	2	255837	30.7	
3	3	411201	11.57	
4	4	256359	4.25	
5	5	255839	2.14	
		403859	2.01	
6	6	255679	2.47	
7	7.1	411088	13.76	**7.13**
	7.2	255875	7.5	**2.4**
		256420	6.54	
		255871	6.35	
		255859	6.14	
	7.3	403748	5.08	**1.91**
		255887	4.71	
		255831	4.6	
		256982	4.48	
		406222	4.35	
		255838	4.25	
		255836	4.08	
		257140	3.73	
		257102	3.59	
		255779	3.4	
	7.4	256923	2.8	**-**
		257144	2.8	
		255727	2.41	
		255695	2.41	
		257006	2.4	
		255724	2.4	
		403749	2.01	
		257107	2	
		255694	1.6	
8	8	255791	3.8	
9	9	256345	6.36	
10	10	406557	18.63	

Table 4-5e The Third Layer Priority (Procedure II)

Group	The 2nd Group	ID	**Δd** (s/veh)	B/C	d_b (s/veh)	The 1st Layer Priority	The 2nd Layer Priority	The 3rd layer Priority
1	1	255771	285.50	5.9	**293.2**	1	1	**1**
2	2	255837	114.70	30.7	**127.9**	2	2	**2**
3	3	411201	95.40	11.57	**108.6**	3	3	**3**
4	4	256359	66.10	4.25	**105.5**	4	4	**4**
5	5	255839	49.80	2.14	**137.2**	6	5	**5**
		403859	52.60	2.01	**574.3**	5	6	**6**
6	6	255679	37.60	2.47	**246.4**	7	7	**7**
7	7.1	411088	0.00	13.76	**3.2**	29	8	**8**
	7.2	255859	0.90	6.14	**83.2**	10	12	**9**
		256420	-1.80	6.54	**5.4**	31	10	**10**
		255871	0.10	6.35	**1.1**	14	11	**11**
		255875	0.00	7.5	**0**	18	9	**12**
	7.3	256982	0.30	4.48	**6.6**	11	16	**13**
		403748	0.10	5.08	**5.5**	15	13	**14**
		257140	0.10	3.73	**2.9**	13	20	**15**
		255887	0.00	4.71	**0**	16	14	**16**
		255831	0.00	4.6	**0**	19	15	**17**
		406222	0.00	4.35	**0**	30	17	**18**
		255838	0.00	4.25	**0**	21	18	**19**
		255836	0.00	4.08	**0**	20	19	**20**
		257102	0.00	3.59	**0**	28	21	**21**
		255779	0.00	3.4	**0**	24	22	**22**
	7.4	257107	6.10	2	**38**	9	30	**23**
		256923	15.20	2.8	**21.2**	8	23	**24**
		403749	0.20	2.01	**1.4**	12	29	**25**
		257144	0.00	2.8	**0**	27	24	**26**
		255727	0.00	2.41	**0**	22	25	**27**
		255695	0.00	2.41	**0**	23	26	**28**
		257006	0.00	2.4	**0**	26	27	**29**
		255724	0.00	2.4	**0**	25	28	**30**
		255694	0.00	1.6	**0**	17	31	**31**
8	8	255791	-12.80	3.8	**19.8**	32	32	**32**
9	9	256345	-25.00	6.36	**6.7**	33	33	**33**
10	10	406557	-105.70	18.63	**130.4**	34	34	**34**

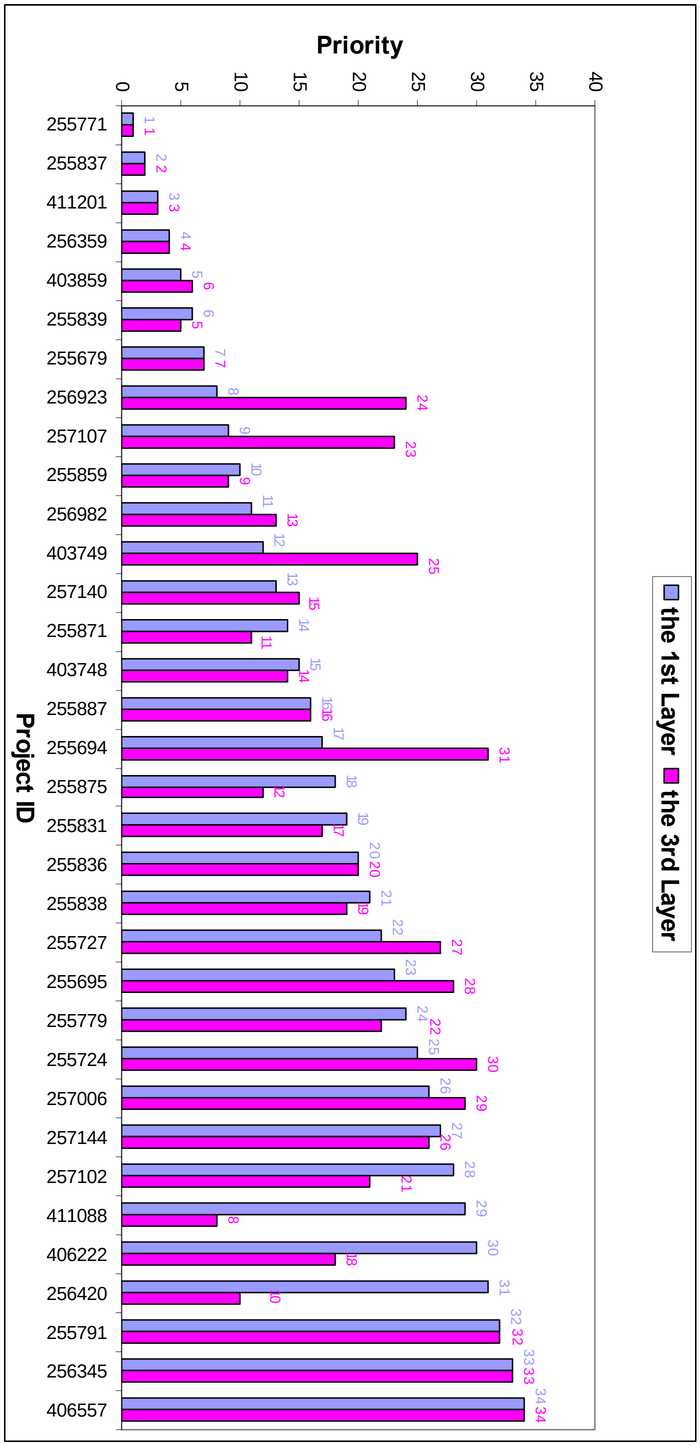

Figure 4-3 Comparison of the First Layer and the Third Layer Priorities (Procedure II)

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

In Florida, many intersections need improvement to eliminate safety or operational deficiencies. Since the budget is limited, it is essential for FDOT to implement a prioritizing procedure to maximize the effectiveness of intersection improvements by selecting intersections annually for improvements in a reasonable way. However, the existing prioritizing procedure has a deficiency that is ranking the intersections according to benefit-cost ratio for safety without considering operational effectiveness.

This study is to generate a new procedure considering both safety and operational factors, and thus to provide a more reasonable priority list of intersection improvements. First, a preliminary list including candidate intersections is determined based on crash rate. Second, safety analysis and operational analysis were implemented to evaluate safety and operational performance of proposed improvements separately. Three criteria were produced in this step: B/C for safety, delay reduction (Δd), and existing delay (d_b). Third, the Multi-Layer Prioritizing (MLP) method was used to combine safety and operational factors. This method assigns each criterion to a layer according to its relative importance; a higher layer owns greater importance. Intersections were prioritized in the first layer, and then were clustered into several groups. Within each group, intersections were similar on the first criterion. Prioritize intersections within each group in the second layer, and cluster them into subgroups (the 2nd groups). In the third layer, intersections within each subgroup were prioritized to generate a final priority list combining safety and operational factors. A hierarchical clustering algorithm was adopted for clustering in each layer. Two kinds of priority sequences can be chosen in the MLP method: Procedure I is $B/C \rightarrow \Delta d \rightarrow d_b$, indicating that safety factor has precedence over operational factor; and Procedure II is $\Delta d \rightarrow B/C \rightarrow d_b$, representing an opposite sequence.

Application of this procedure on 34 intersections in District 7 in Florida is conducted as a case study. Three categories of data collection were necessary to collect in this study: peak hour volume, traffic control, and geometric design. Data of 10 intersections were collected by field survey; others were obtained from District 7 office. Benefit-cost ratio (B/C) values were available from the existing priority procedure; delay reduction and existing delay were calculated by using operational analysis module. MLP method was implemented twice to generate priority lists for priority sequence I and II respectively. For each sequence, the first layer priority list and the third layer priority list were compared to evaluate the merits of the new procedure.

5.2 Conclusions and Recommendations

Through this study, conclusions can be obtained as following:

(1) The new procedure is an extension of the existing priority method; in contrast to prior procedures considering safety factor or operational factor only, the new procedure produces a comprehensive prioritizing by combining both two factors.

(2) MLP method provides an intuitionistic, intelligible, and quantified process to combine safety and operational factors through a hierarchical structure.

(3) It is easy to extend the structure of MLP such as adding/removing a criterion or exchanging the two criteria's position.

(4) Two priority sequences are provided. How to decide the sequence is based on expert opinions.

This study does not focus on threshold for safety and operational criteria. In this study, these threshold values are decided by the operator's subjective decision. Actually, threshold reflects the related importance between two adjacent criteria. Future study should take a survey about expert opinion on what value of threshold is most reasonable.

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APPENDIX

APPENDIX A: DEVELOPMENT OF COMPUTER SYSTEM

A.1 Introduction

This appendix describes a computer-based system that was developed to implement the new procedure considering both safety and operational factors to generate a priority list of intersection improvement projects in an automated manner. This system, called the Prioritization of Intersections for Safety and Operational Improvements, allows the following tasks to be performed:

(1) Provide a user-friend operation interface,

(2) Integrate intersection delay estimation algorithm in HCM 2000,

(3) Realize the new procedure developed in this study fully,

(4) Offer flexible methods for data input.

As a Microsoft Visual Basic 6.0 windows application that works with Microsoft Excel, this system requires following hardware and software environments:

(1) IBM compatible Personal Computer,

(2) Windows 98/2000/XP,

(3) The minimum display resolution is 1024×768,

(4) Microsoft Excel system.

A.2 System Architecture

This system integrates four modules: the data input module, the operational analysis module, the MLP module, and the report output module. The data input module takes charge of importing data that are necessary for successive analysis. The operational analysis module includes three sub-modules: the signalized intersection module, the TWSC intersection module, and the AWSC intersection module. Two kinds of average control delays of intersections, the existing average delay and the estimated average delay, are results of the operational analysis module. The MLP module prioritizes intersection improvement projects based on three criteria: the existing average delay, the estimated average delay reduction due to improvements, and B/C for safety. Finally, the report form module generates a report to show the result of this procedure.

The system architecture is given in Figure A-1.

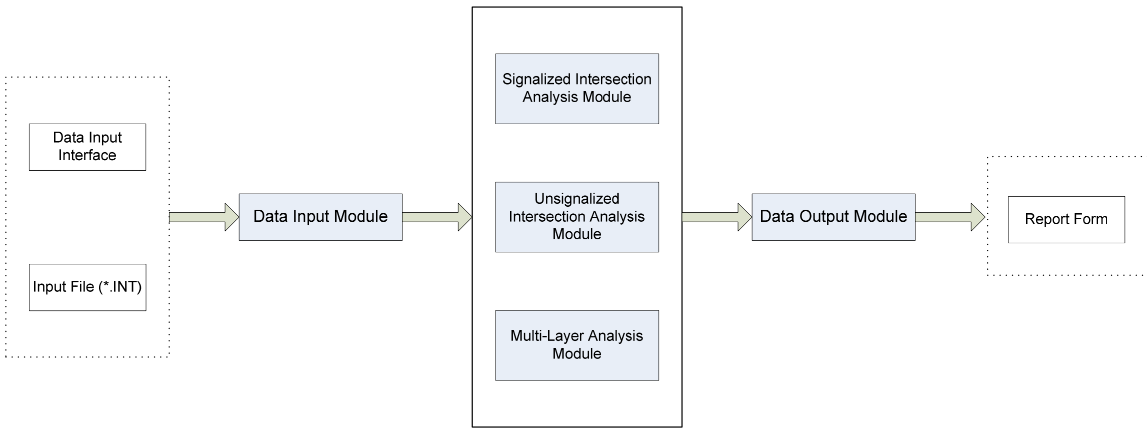


Figure A-1 System Architecture

A.3 Instruction of System Processing

Step 1 – Start program to show the Main Form. Click ***"Start Here"*** to show the Project Form and Click ***"Report"*** to show the Report Form (See Step 7).

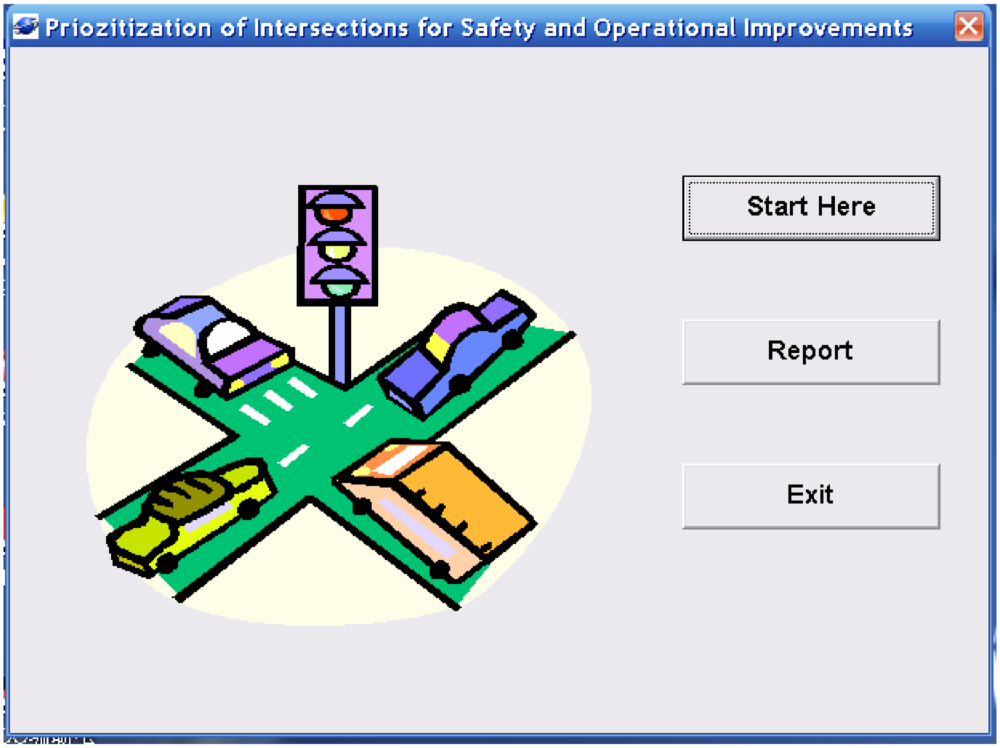


Figure A-2 The Main Form

Step 2 – There are two options on the Project Form: create a new prioritizing project or open an existing prioritizing project. Select option ***"New Project"*** and click ***"Next"*** to show the New Project Form. And select option ***"Open Project"*** and click ***"Next"*** to show the Open Project Form.

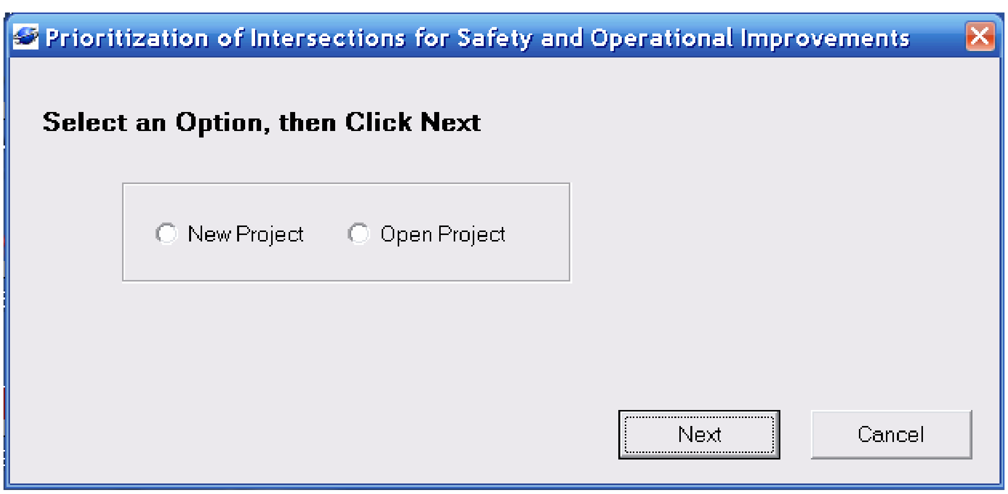


Figure A-2 The Project Form

Step 3a – Input the name of new project on the New/Open Project Form, and click ***"Next"*** to show the Project Information Form.

Figure A-3a The New Project Form

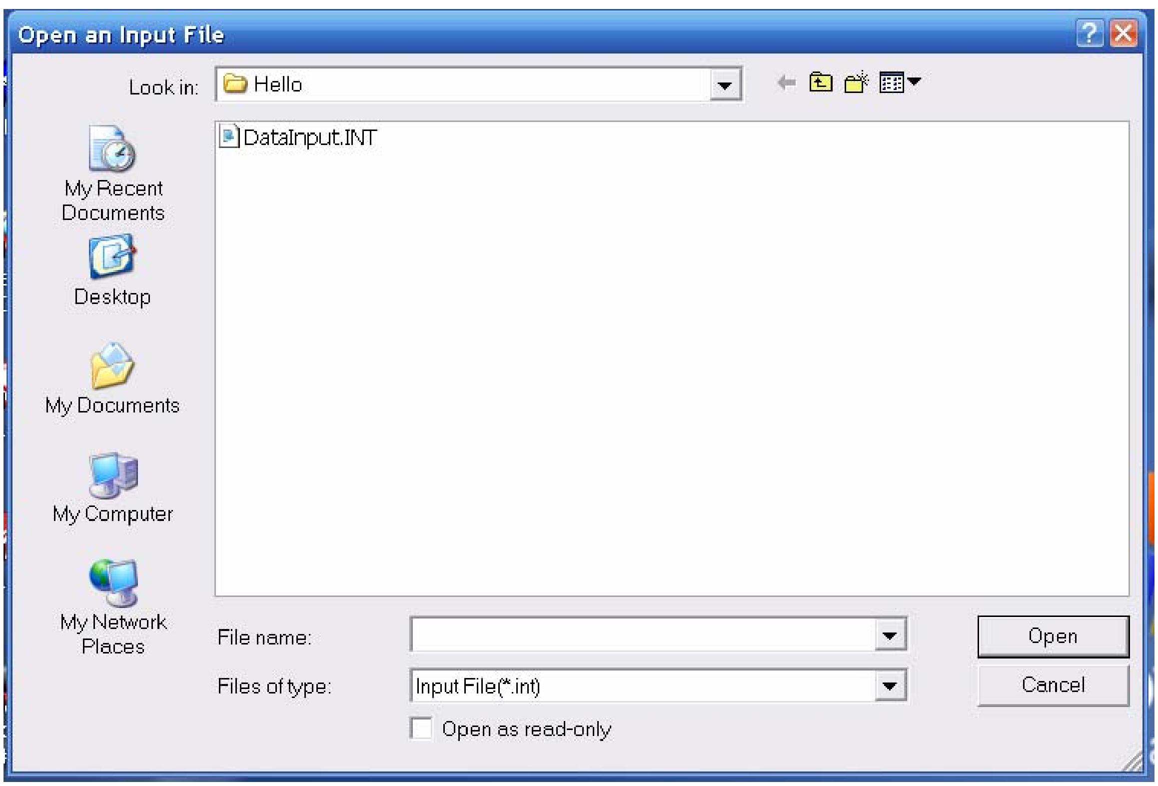


Figure A-3a The Open Project Form

Step 4 –Input the necessary information of project and click ***"Next"*** to show the Data

Input Form.

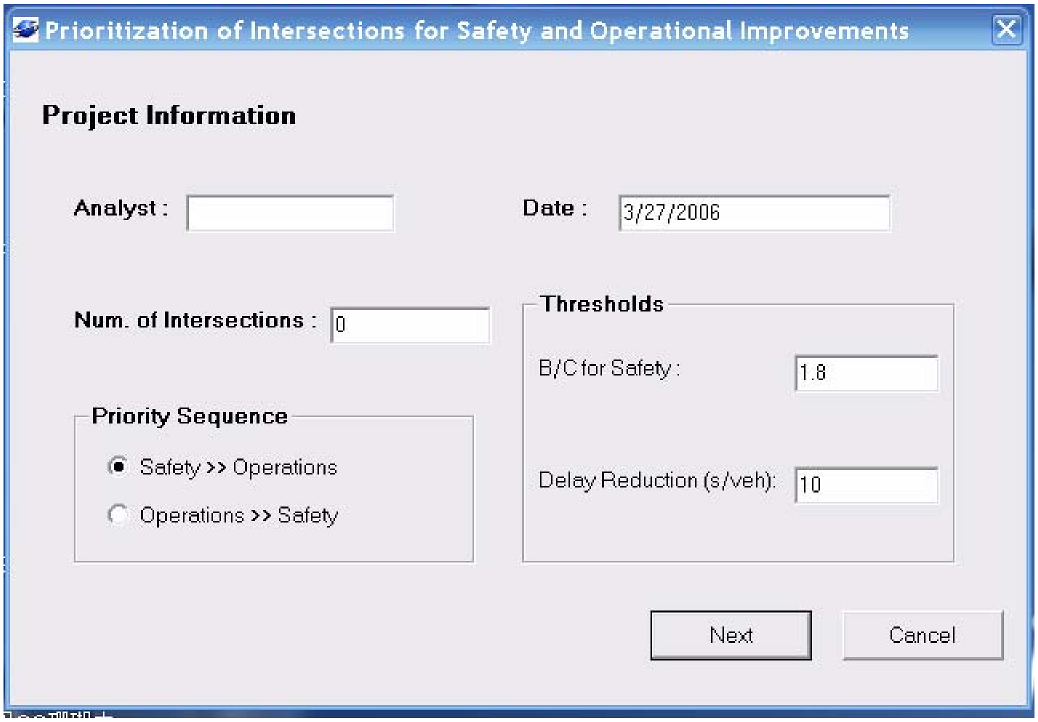


Figure A-3 The Project Information Form

Step 5 – Input the general information of an intersection improvement project on the General Tab and input information related to the operational analysis on the Before Improvement and After Improvement Tabs successively. Click ***"Processing"*** to execute the analysis and show the Processing Form.

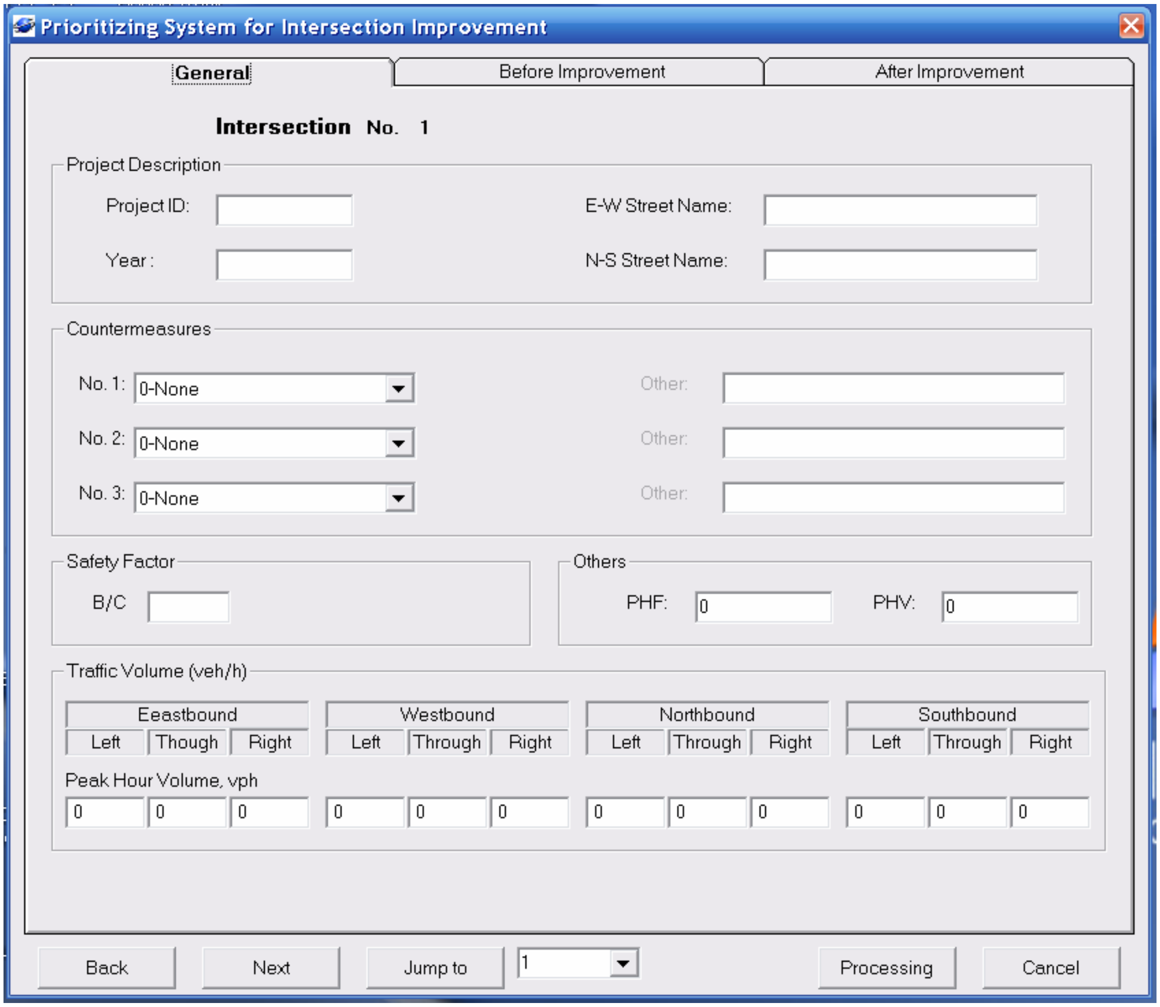


Figure A-4a The Data Input Form – General Tab

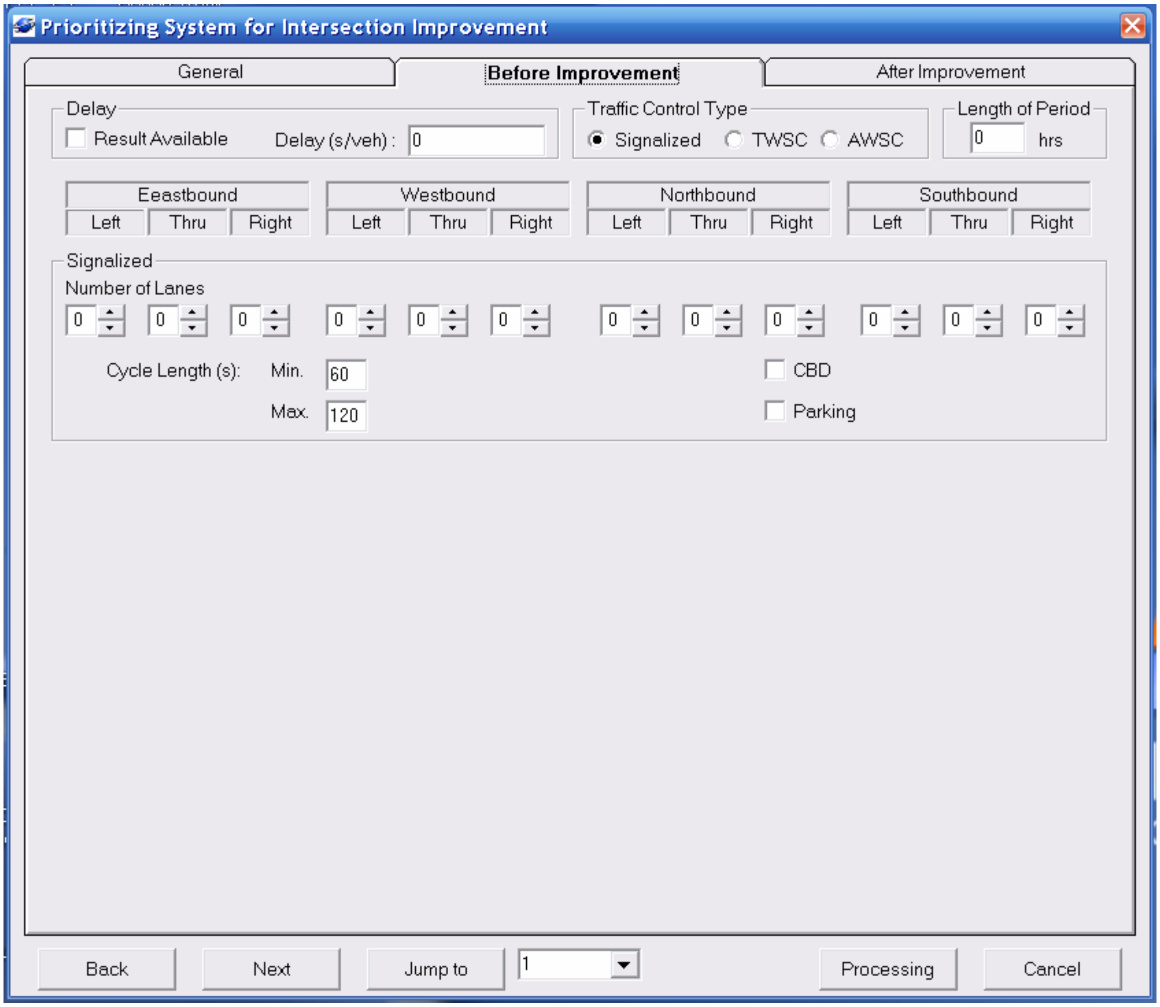


Figure A-4b The Data Input Form – Before Improvement Tab

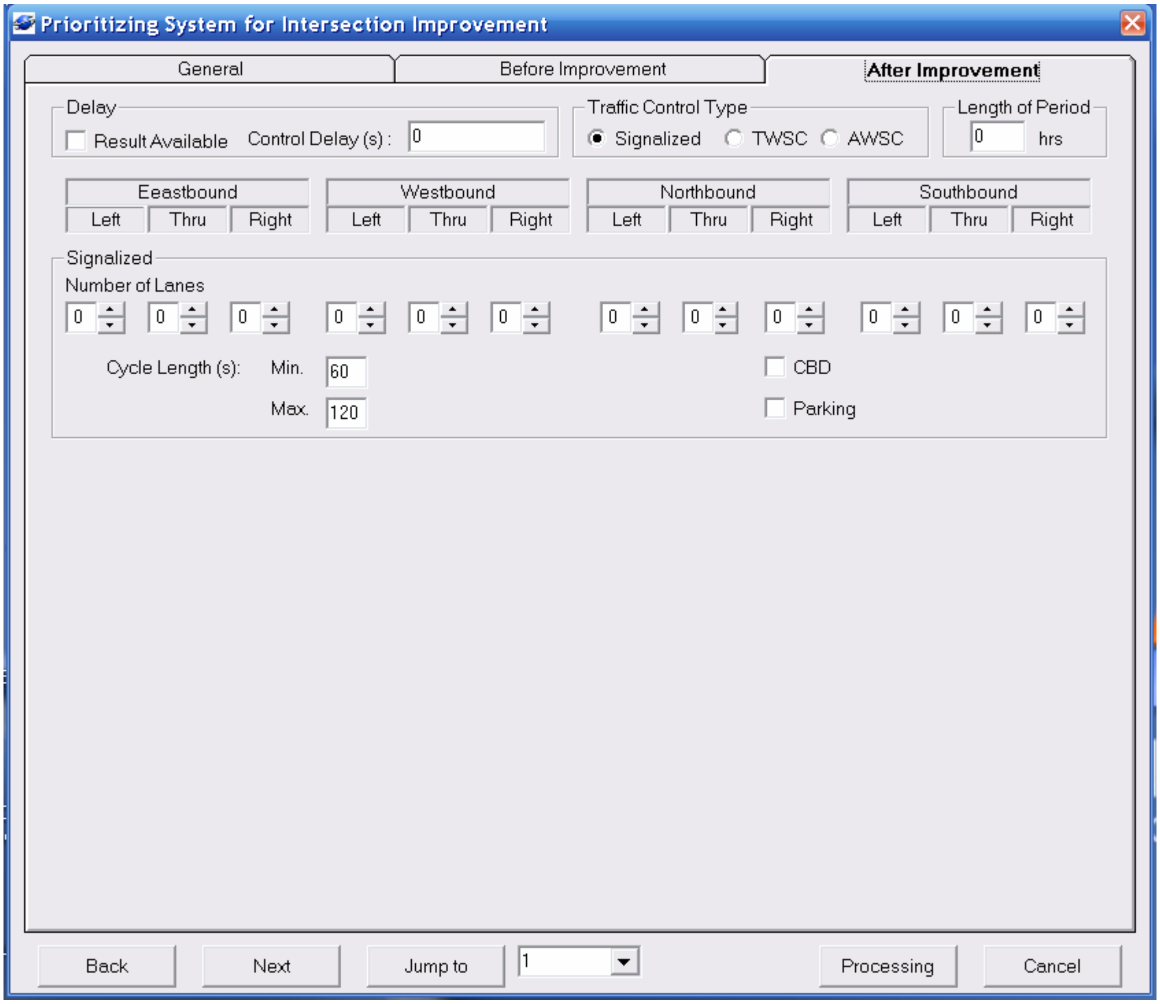


Figure A-4c The Data Input Form – After Improvement Tab

Step 6 – Click ***"Next"*** to Show the Report Form

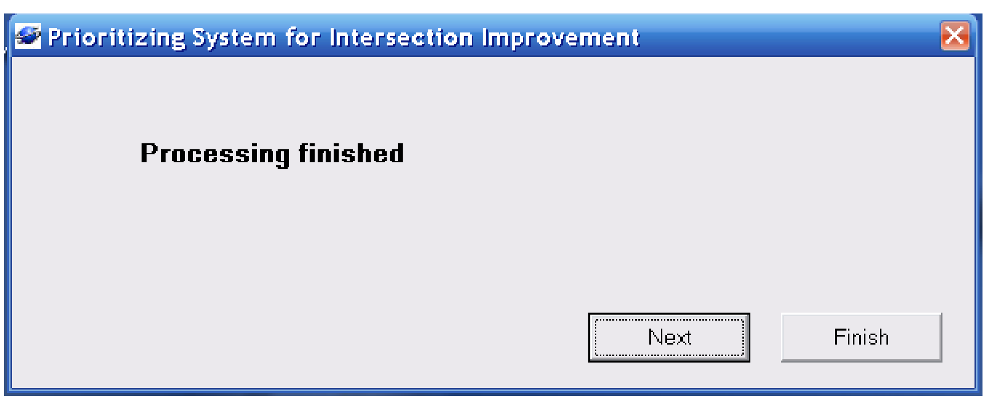
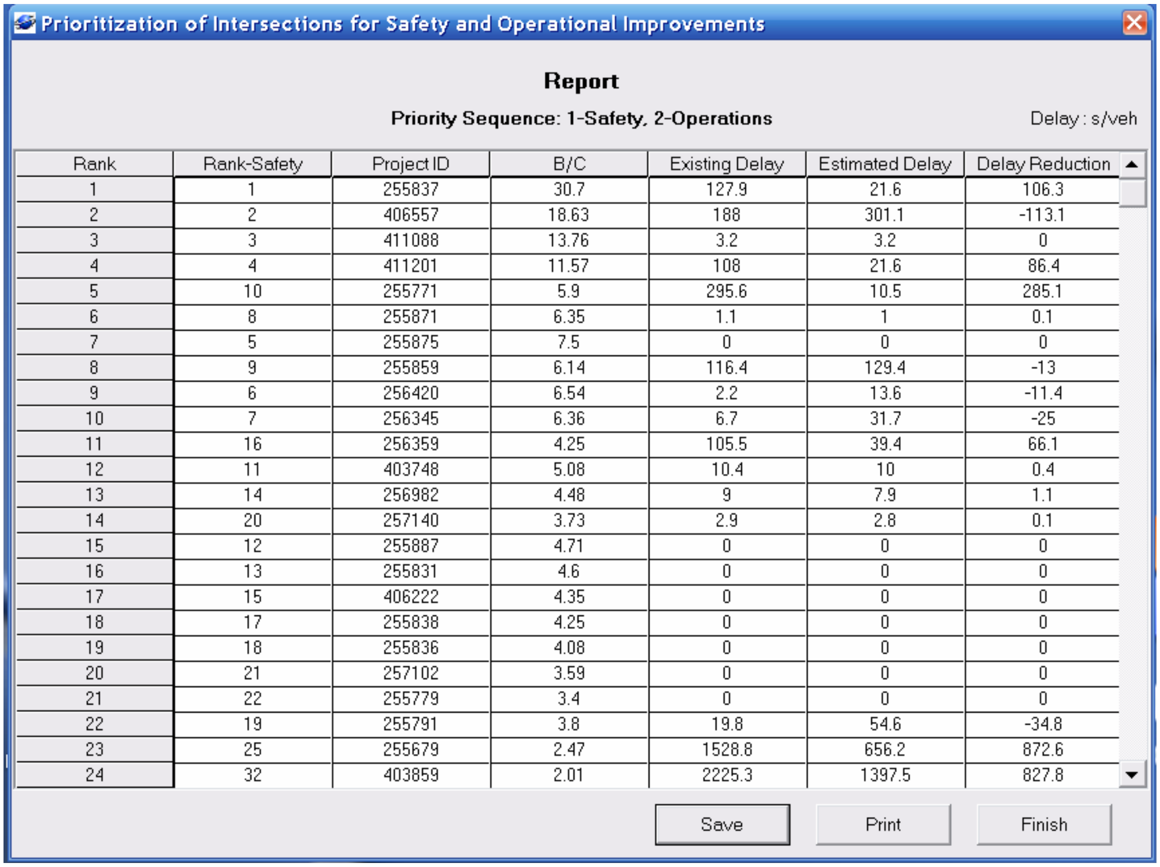


Figure A-5 The Processing Form

Step 7 – Click ***"Save"*** and ***"Print"*** to save the analysis result and print the report form.



Prioritization of Intersections for Safety and Operational Improvements

Report

Priority Sequence: 1-Safety, 2-Operations

Delay : s/veh

Rank	Rank-Safety	Project ID	B/C	Existing Delay	Estimated Delay	Delay Reduction
1	1	255837	30.7	127.9	21.6	106.3
2	2	406557	18.63	188	301.1	-113.1
3	3	411088	13.76	3.2	3.2	0
4	4	411201	11.57	108	21.6	86.4
5	10	255771	5.9	295.6	10.5	285.1
6	8	255871	6.35	1.1	1	0.1
7	5	255875	7.5	0	0	0
8	9	255859	6.14	116.4	129.4	-13
9	6	256420	6.54	2.2	13.6	-11.4
10	7	256345	6.36	6.7	31.7	-25
11	16	256359	4.25	105.5	39.4	66.1
12	11	403748	5.08	10.4	10	0.4
13	14	256982	4.48	9	7.9	1.1
14	20	257140	3.73	2.9	2.8	0.1
15	12	255887	4.71	0	0	0
16	13	255831	4.6	0	0	0
17	15	406222	4.35	0	0	0
18	17	255838	4.25	0	0	0
19	18	255836	4.08	0	0	0
20	21	257102	3.59	0	0	0
21	22	255779	3.4	0	0	0
22	19	255791	3.8	19.8	54.6	-34.8
23	25	255679	2.47	1528.8	656.2	872.6
24	32	403859	2.01	2225.3	1397.5	827.8

Save Print Finish

Figure A-6 The Report Form

APPENDIX B: DATA INPUT

This appendix includes a set of data forms which were inputs of operational analysis in case study. Each form has four data input areas: general information, peak volume, before improvement, and after improvement. Some notations used in the form are given as following:

Y − Yes; N − No;

EB − Eastbound; WB − Westbound;

NB − Northbound; SB − Southbound;

EW − East-West; NS − North-South;

NA − Not Available;

For lane design at unsignalized intersection:

L − Left; T − Through; R − Right;

LT − Left-Through shared; RT − Right-Through shared;

LR − Left-Right shared; LTR − Left-Through-Right shared.

Measurement units

Volume − veh/h Signal Cycle − s

ID	403749		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	4	0	52	0
PHV	0.1		TH	0	0	384	640
BC	2.01		RT	52	0	0	8
Effective	Y						
	BEFORE						
Unsignalized			Control Type:				U
			Major Direction:				NS
			Flared?	N	N		
			Flare Storage				
			Channelized?	N	N	N	N
			Median?				N
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	NA	NA	LT	NA
			TH	LR	NA	NA	NA
			RT	NA	NA	NA	TR
	AFTER						
Unsignalized			Control Type:				U
			Major Direction:				NS
			Flared?	N	N		
			Flare Storage				
			Channelized?	N	N	N	N
			Median?				N
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	NA	NA	L	NA
			TH	LR	NA	T	NA
			RT	NA	NA	NA	TR

ID	406557		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	20	172	128	16
PHV	0.1		TH	1152	1524	1228	48
BC	18.63		RT	120	28	184	56
Effective	Y						
BEFORE							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	0	1	1	1
			TH	2	2	1	1
			RT	0	0	0	0
AFTER							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	1	1	1	1
			TH	2	1	1	1
			RT	0	1	0	0

ID	403748		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	36	36	28	8
PHV	0.1		TH	56	32	696	436
BC	5.08		RT	4	28	4	8
Effective	Y						
	BEFORE						
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	0	0	0	0
			TH	1	1	1	1
			RT	0	0	0	0
	AFTER						
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	0	0	1	1
			TH	1	1	1	1
			RT	0	0	0	0

ID	403748		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	0	152	0	40
PHV	0.1		TH	0	0	184	284
BC	5.08		RT	0	0	264	0
Effective	Y						
BEFORE							
Unsignalized			Control Type:				U
			Major Direction:				NS
			Flared?	N	N	N	N
			Flare Storage	0	0	0	0
			Channelized?	N	N	Y	N
			Median?		N		N
			Median Type		N		N
			Median Storage		0		0
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	NA	NA	NA	LT
			TH	NA	LR	T	NA
			RT	NA	NA	R	NA
AFTER							
Unsignalized			Control Type:				U
			Major Direction:				NS
			Flared?	N	N	N	N
			Flare Storage	0	0	0	0
			Channelized?	N	N	N	N
			Median?		N		N
			Median Type		N		N
			Median Storage		0		0
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	NA	NA	NA	LT
			TH	NA	LR	T	NA
			RT	NA	NA	R	NA

ID	411201		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	0	131	0	317
PHV	0.1		TH	796	488	0	0
BC	11.57		RT	55	0	0	368
Effective	Y						
BEFORE							
Unsignalized			Control Type:				U
			Major Direction:				EW
			Flared?	N	N	N	N
			Flare Storage	0	0	0	0
			Channelized?	Y	N	N	Y
			Median?		Y		
			Median Type		RM		
			Median Storage		2		
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	T	L	NA	NA
			TH	T	T	NA	LR
			RT	R	T	NA	NA
AFTER							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	0	1	0	1
			TH	2	2	0	0
			RT	1	0	0	1

ID	255837		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	0	131	317	0
PHV	0.1		TH	796	488	0	0
BC	30.7		RT	55	0	368	0
Effective	Y						
BEFORE							
Unsignalized			Control Type:				U
			Major Direction:				EW
			Flared?	N	N	N	N
			Flare Storage	0	0	0	0
			Channelized?	Y	N	N	Y
			Median?		Y		
			Median Type		RM		
			Median Storage		2		
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	T	L	L	NA
			TH	T	T	NA	NA
			RT	R	T	R	NA
AFTER							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	0	1	1	0
			TH	2	2	0	0
			RT	1	0	1	0

ID	255871		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	24	0	0	12
PHV	0.1		TH	372	308	0	0
BC	6.35		RT	0	8	0	32
Effective	Y						
BEFORE							
Unsignalized			Control Type:				U
			Major Direction:				EW
			Flared?	N	N	N	N
			Flare Storage	0	0	0	0
			Channelized?	N	N	N	N
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	LT	NA	NA	NA
			TH	NA	NA	NA	LR
			RT	NA	TR	NA	NA
AFTER							
Unsignalized			Control Type:				U
			Major Direction:				EW
			Flared?	N	N	N	N
			Flare Storage	0	0	0	0
			Channelized?	N	N	N	N
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	L	NA	NA	NA
			TH	T	NA	NA	LR
			RT	NA	TR	NA	NA

ID	255771		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	88	32	100	52
PHV	0.1		TH	652	752	68	56
BC	5.9		RT	16	40	140	104
Effective	Y						
BEFORE							
Unsignalized			Control Type:				U
			Major Direction:				EW
			Flared?	N	N	N	N
			Flare Storage				
			Channelized?	N	N	N	N
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	L	L	L	NA
			TH	T	T	NA	LTR
			RT	TR	TR	TR	NA
AFTER							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	1	1	0	0
			TH	2	2	1	1
			RT	1	1	1	0

ID	255791		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	335	0	0	176
PHV	0.1		TH	820	1764	0	0
BC	3.8		RT	0	277	0	336
Effective	Y						
BEFORE							
Unsignalized			Control Type:				U
			Major Direction:				EW
			Flared?	N	N	N	N
			Flare Storage				
			Channelized?	N	N	N	N
			Median?		Y		
			Median Type		RM		
			Median Storage		2		
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	L	T	NA	NA
			TH	T	T	NA	LR
			RT	T	R	NA	NA
AFTER							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	1	0	0	1
			TH	2	2	0	0
			RT	0	1	0	1

ID	255679		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	220	184	135	227
PHV	0.1		TH	562	451	3108	1981
BC	2.47		RT	65	158	256	119
Effective	Y						
BEFORE							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	1	1	2	2
			TH	2	2	3	3
			RT	0	0	0	0
AFTER							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	2	2	2	2
			TH	2	2	3	3
			RT	0	0	0	0

ID	255839		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	228	137	695	274
PHV	0.1		TH	187	353	1371	922
BC	2.14		RT	193	76	218	103
Effective	Y						
BEFORE							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	1	0	1	1
			TH	1	1	2	2
			RT	1	0	1	1
AFTER							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	1	0	2	1
			TH	1	1	2	2
			RT	1	0	1	1

ID	256345		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	234	0	0	13
PHV	0.1		TH	1166	927	0	0
BC	6.36		RT	0	37	0	245
Effective	Y						
BEFORE							
Unsignalized			Control Type:				U
			Major Direction:				EW
			Flared?	N	N	N	N
			Flare Storage	0	0	0	0
			Channelized?	N	N	N	N
			Median?		N		N
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	LT	NA	NA	NA
			TH	NA	NA	NA	LR
			RT	NA	TR	NA	NA
AFTER							
Unsignalized			Control Type:				U
			Major Direction:				EW
			Flared?	N	N	N	N
			Flare Storage	0	0	0	0
			Channelized?	N	N	N	N
			Median?		N		N
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	L	NA	NA	NA
			TH	T	NA	NA	LR
			RT	NA	TR	NA	NA

ID	256359		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	263	0	0	50
PHV	0.1		TH	901	673	0	0
BC	4.25		RT	0	37	0	142
Effective	Y						
BEFORE							
Unsignalized			Control Type:				U
			Major Direction:				EW
			Flared?	N	N	N	N
			Flare Storage	0	0	0	0
			Channelized?	N	N	N	N
			Median?		Y		
			Median Type		TWLT		
			Median Storage		1		
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	LT	NA	NA	NA
			TH	NA	NA	NA	LR
			RT	NA	TR	NA	NA
AFTER							
Unsignalized			Control Type:				U
			Major Direction:				EW
			Flared?	N	N	N	N
			Flare Storage	0	0	0	0
			Channelized?	N	N	N	N
			Median?		Y		
			Median Type		TWLT		
			Median Storage		1		
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	L	NA	NA	NA
			TH	T	NA	NA	LR
			RT	NA	TR	NA	NA

ID	257107		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	64	224	360	420
PHV	0.1		TH	1344	624	836	724
BC	2		RT	96	420	416	84
Effective	Y						
BEFORE							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	1	1	1	1
			TH	3	2	2	2
			RT	0	1	1	0
AFTER							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	1	1	2	2
			TH	3	2	3	3
			RT	0	1	1	0

ID	256982		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	16	28	48	56
PHV	0.1		TH	580	648	96	64
BC	4.48		RT	44	56	40	32
Effective	Y						
	BEFORE						
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	0	0	0	0
			TH	2	2	1	1
			RT	0	0	0	0
	AFTER						
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	1	1	1	1
			TH	2	2	1	1
			RT	0	0	0	0

ID	257140		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	24	44	16	16
PHV	0.1		TH	4	8	572	492
BC	3.73		RT	16	4	52	28
Effective	Y						
BEFORE							
Unsignalized			Control Type:				U
			Major Direction:				EW
			Flared?	N	N	N	N
			Flare Storage	0	0	0	0
			Channelized?	N	N	N	N
			Median?		N		
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	NA	NA	NA	NA
			TH	LTR	LTR	LTR	LTR
			RT	NA	NA	NA	NA
AFTER							
Unsignalized			Control Type:				U
			Major Direction:				EW
			Flared?	N	N	N	N
			Flare Storage	0	0	0	0
			Channelized?	N	N	N	N
			Median?		N		
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	L	L	L	L
			TH	NA	NA	NA	NA
			RT	TR	TR	TR	TR

ID	256923		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	0	32	160	0
PHV	0.1		TH	1052	444	0	0
BC	2.8		RT	12	0	140	0
Effective	Y						
BEFORE							
Unsignalized			Control Type:				U
			Major Direction:				EW
			Flared?	N	N	N	N
			Flare Storage				
			Channelized?	N	N	N	N
			Median?		N		
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	T	L	L	NA
			TH	T	T	NA	NA
			RT	R	T	R	NA
AFTER							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	0	1	1	0
			TH	2	2	1	0
			RT	1	0	0	0

ID	255859		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	197	282	287	510
PHV	0.1		TH	1368	2186	582	554
BC	6.14		RT	118	361	173	188
Effective	Y						
BEFORE							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	1	1	0	2
			TH	2	3	2	2
			RT	1	0	1	0
AFTER							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	0	0	0	2
			TH	2	3	2	2
			RT	1	0	1	0

ID	256420		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	0	321	0	53
PHV	0.1		TH	408	833	0	0
BC	6.54		RT	228	0	0	89
Effective	Y						
	BEFORE						
Unsignalized			Control Type:				U
			Major Direction:				EW
			Flared?	N	N	N	N
			Flare Storage				
			Channelized?	N	N	N	N
			Median?		N		
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT	NA	L	NA	NA
			TH	T	T	NA	LR
			RT	R	NA	NA	NA
	AFTER						
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	0	1	0	1
			TH	1	1	0	0
			RT	1	0	0	1

ID	403859		Volume (veh/h)	EB	WB	NB	SB
PHF	1		LT	412	702	501	417
PHV	0.1		TH	760	1200	2200	974
BC	2.01		RT	290	425	334	276
Effective	Y						
BEFORE							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	1	2	2	2
			TH	2	2	3	3
			RT	0	0	1	1
AFTER							
Unsignalized			Control Type:				S
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				N
			Parking				N
			Cycle min				60
			Cycle max				120
Lane Design							
			LT	2	2	2	2
			TH	2	2	3	3
			RT	1	1	1	1

ID	406222		Volume (veh/h)	EB	WB	NB	SB
PHF			LT				
PHV			TH				
BC	4.35		RT				
Effective	N						
BEFORE							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				
AFTER							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				

ID	255887		Volume (veh/h)	EB	WB	NB	SB
PHF			LT				
PHV			TH				
BC	4.71		RT				
Effective	N						
BEFORE							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				
AFTER							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				

ID	255694		Volume (veh/h)	EB	WB	NB	SB
PHF			LT				
PHV			TH				
BC	1.6		RT				
Effective	N						
BEFORE							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				
AFTER							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				

ID	255875		Volume (veh/h)	EB	WB	NB	SB
PHF			LT				
PHV			TH				
BC	7.5		RT				
Effective	N						
	BEFORE						
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				
	AFTER						
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				

ID	**255831**		**Volume (veh/h)**	**EB**	**WB**	**NB**	**SB**
PHF			**LT**				
PHV			**TH**				
BC	**4.6**		**RT**				
Effective	**N**						
	BEFORE						
Unsignalized			**Control Type:**				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			**CBD**				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				
	AFTER						
Unsignalized			**Control Type:**				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			**CBD**				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				

ID	255836		Volume (veh/h)	EB	WB	NB	SB
PHF			LT				
PHV			TH				
BC	4.08		RT				
Effective	N						
BEFORE							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				
AFTER							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				

ID	255838		Volume (veh/h)	EB	WB	NB	SB
PHF			LT				
PHV			TH				
BC	4.25		RT				
Effective	N						
BEFORE							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				
AFTER							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				

ID	255727		Volume (veh/h)	EB	WB	NB	SB
PHF			LT				
PHV			TH				
BC	2.41		RT				
Effective	N						
	BEFORE						
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				
	AFTER						
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				

ID	255695		Volume (veh/h)	EB	WB	NB	SB
PHF			LT				
PHV			TH				
BC	2.41		RT				
Effective	N						
	BEFORE						
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				
	AFTER						
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				

ID	255779		Volume (veh/h)	EB	WB	NB	SB
PHF			LT				
PHV			TH				
BC	3.4		RT				
Effective	N						
BEFORE							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				
AFTER							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				

ID	255724		Volume (veh/h)	EB	WB	NB	SB	
PHF			LT					
PHV			TH					
BC	2.4		RT					
Effective	N							
BEFORE								
Unsignalized			Control Type:					
			Major Direction:					
			Flared?					
			Flare Storage					
			Channelized?					
			Median?					
			Median Type					
			Median Storage					
Signalized			CBD					
			Parking					
			Cycle min					
			Cycle max					
Lane Design								
			LT					
			TH					
			RT					
AFTER								
Unsignalized			Control Type:					
			Major Direction:					
			Flared?					
			Flare Storage					
			Channelized?					
			Median?					
			Median Type					
			Median Storage					
Signalized			CBD					
			Parking					
			Cycle min					
			Cycle max					
Lane Design								
			LT					
			TH					
			RT					

ID	257006		Volume (veh/h)	EB	WB	NB	SB
PHF			LT				
PHV			TH				
BC	2.4		RT				
Effective	N						
BEFORE							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				
AFTER							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				

ID	257144		Volume (veh/h)	EB	WB	NB	SB
PHF			LT				
PHV			TH				
BC	2.8		RT				
Effective	N						
BEFORE							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				
AFTER							
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				

ID	257102		Volume (veh/h)	EB	WB	NB	SB
PHF			LT				
PHV			TH				
BC	3.59		RT				
Effective	N						
	BEFORE						
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				
	AFTER						
Unsignalized			Control Type:				
			Major Direction:				
			Flared?				
			Flare Storage				
			Channelized?				
			Median?				
			Median Type				
			Median Storage				
Signalized			CBD				
			Parking				
			Cycle min				
			Cycle max				
Lane Design							
			LT				
			TH				
			RT				