ASSESMENT OF TRAFFIC IMPACT STUDIES ON OAHU

BETWEEN 1976 AND 2002

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# ABSTRACT

Traffic forecasting is an essential part of project development. The impact that forecast traffic has on infrastructure planning and design is essential for project approval. Since population, employment and tourism are projected to grow by 17%-25% on Oahu over the next 25 years, the need for further development is clear. So the key question is: Can decision makers rely on project traffic forecasts?

Previous studies showed large inaccuracy in traffic forecasting, 50% of all megaprojects have inaccuracies larger than ±20%, and 25% of all megaprojects have inaccuracies larger than ±40%. In a U.S. study of roadways the inaccuracies were not as large, 72.4% of all road segments analyzed were within ±0.5% accuracy; the remaining 27.8%% were either over- or underestimated. These studies showed major problems with forecasting accuracy.

The analysis herein compared forecasted traffic levels from Traffic Impact Analysis Reports, available through the Hawaii Department of Health, to actual traffic volumes recorded by the Hawaii Department of Transportation to assess traffic forecasting accuracy on Oahu between 1976 and 2002. Information extracted from the EIS and TIAR included: year of EIS, consultant, type of project, location, movement, forecast horizon, forecasted traffic volumes and forecasting method.

This study focused on road and residential developments on Oahu and attempted to answer questions such as: Do forecasts show an accurate picture of future traffic demand, both related directly to a specific project and the affected region? Do forecasts provide a “picture perfect” view of future conditions in order to get the projects approved? Is traffic forecasting on Oahu conservative or optimistic? Do

forecasts vary by type of development? What is the effect of the forecast horizon? What is the effect of background growth extrapolations?

The analysis is split into three components: Illustrative analysis, quantitative analysis, and a three-way comparison among (1) Flyvbjerg's study of more than 200 megaprojects across the world, (2) a study conducted in Minnesota by Parthasarathi and Levinson on post-construction evaluation of traffic forecast accuracy, (3) and the results of this analysis.

The analysis of Oahu data shows a tendency towards overestimation of traffic forecasts. The average overestimation is 35% or more than one third of the forecast volume. Fourteen out of the 37 cases, or 38%, were underestimated: nine cases with an error of greater than -20%, two cases with an error of greater than -40% and three cases within the -60% to -40% range. The findings of this study differ greatly from the two studies it is compared to. The study of mega-projects world-wide shows a tendency towards overestimation, the study of traffic accuracy in Minnesota shows very accurate forecasting volumes.

There are several reasons for inaccuracy in traffic forecasting, such as inappropriate forecasting models, the assumptions and growth rates used as input into the models, the large uncertainties associated with green field developments, bias for or against projects and lack of an evaluation and adjustment process.

# ABBREVIATIONS

| | |
|---|---|
| EA | Environmental Assessment |
| EIS | Environmental Impact Study |
| HDOT | Hawai‘i Department of Transportation |
| NEPA | National Environmental Policy Act |
| TIAR | Traffic Impact Analysis Report |

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# CHAPTER 1 - INTRODUCTION & PROBLEM STATEMENT

## *1.1 Introduction*

Traffic demand forecasting is an important process for project development. The forecast traffic impact on existing infrastructure is essential to project approval. Accurate traffic forecasts are essential for decision makers. Previous studies, both in the U.S. and internationally, show varying accuracy in traffic forecasts: 50% of all megaprojects, defined as major infrastructure projects that cost more than $1 billion or projects that have a significant cost and attract a high level of attention from the public and political interest due to large impacts on the environment, budgets and community [1], have inaccuracies larger than ±20%, and 25% of all megaprojects have inaccuracies larger than ±40% [2]. In a U.S. study of roadways the inaccuracies were not as large, 72.4% of all road segments analyzed were within ±0.5% accuracy; the remaining 27.8%% were either over- or underestimated [3]. These studies show major problems with forecasting accuracy.

Part of the reason may be that in the current system, there is no follow-up procedure after project approval and construction. This means that there may be no evaluation of forecasting accuracy and subsequently no improvement in techniques over time. Another reason for high traffic forecasting inaccuracy may be the lack of a holistic approach to traffic forecasting. In other words, high forecasting accuracy of the proposed project is important, but it is not enough. The surrounding projects in the region should also be considered when addressing future traffic conditions. A single project may not have a large impact on future traffic conditions, but an aggregation of the traffic from several projects can have a very large effect on future traffic conditions.

A holistic view of the region provides a more accurate estimate of future traffic conditions. This, in turn, provides decision makers with comprehensive information to make qualified decisions, such as approval of projects or approval of sufficient infrastructure in due time and where it is most necessary. Public resources are scarce and every time those resources are used, the decision should be based on reliable data. In this way, the public not only gets the most for its money, but also the public knows what effect different projects will have on traffic conditions.

The value of this endeavor may be explained using Oahu as a test case that can be generalized to any other metro areas. On Oahu, like many other metro areas in the U.S., population is expected to grow; its population between 2007 and 2035 is expected to increase by 23%; its employment is expected to grow by 25%, and tourism is expected to grow by 17% [4]. An expansion of the infrastructure is likely needed to accommodate this growth. To avoid bottlenecks and severe traffic congestion, accurate traffic demand forecasts are needed to get an accurate picture of future traffic conditions on Oahu. A study of historical data is important to evaluate and optimize the current process. This thesis assesses accuracy in traffic forecasting on Oahu between 1980 and 2002. Based on the U.S. Census, population on Oahu grew by 25% between 1980 and 2010 [5].

### *1.2 Problem Statement*

Since population, employment and tourism are projected to grow by 17%-25% on Oahu over the next 25 years, the need for further development is clear. The necessary development includes, among others: residential developments, employment centers, new infrastructure and expansion of existing infrastructure. Accurate traffic forecasts are needed in order to analyze and accommodate the impact the developments will have on future traffic conditions; however, there has not been a study to determine how accurate traffic forecasts on Oahu have been. This study focuses on road and residential developments on Oahu and attempts to answer questions such as:

- Do forecasts show an accurate picture of future traffic demand, both related directly to a specific project and the affected region?
- Do forecasts provide a "picture perfect" view of future conditions in order to get the projects approved?
- Is traffic forecasting on Oahu conservative or optimistic?
- Do forecasts vary by type of development?
- What is the effect of the forecast horizon?
- What is the effect of background growth extrapolations?

The impact that forecast traffic has on existing infrastructure is essential for project approval, so the key question is: Can decision makers rely on project traffic forecasts? It is important to answer all of these questions, and in order to do so an evaluation and analysis of historic traffic forecasting must be conducted. This study intends to determine how accurate traffic forecasting on Oahu has been, and investigate what variables may have an effect on forecasting accuracy. This study has a focus on localized forecasts and impacts because TIARs do not provide a regional view. The study also compares the results of the analysis to the limited number of similar studies on traffic forecasting accuracy.

### *1.3 Objectives*

The goal for this study is to assess accuracy in traffic forecasting on Oahu between 1980 and 2002, along with an analysis of which variables affect forecasting accuracy. To achieve this goal the following objectives are carried out:

- Determine what data are needed for the study and the collection thereof.
- Prepare the data to ensure that the variables and cases are useful for the study and can be compared and used for further analysis.
- Assess the commonalities and patterns in traffic forecast accuracy on Oahu.
- Develop basic models that analyze accuracy in traffic forecasting and explore which variables affect accuracy.
- Conduct a comparison among the results of this study, a study of international megaprojects and a study of Minnesota roadway projects.

### *1.4 Thesis Structure*

This report is organized as follows: Chapter 2 presents previous literature on traffic forecasting and a recent review of best practices for Traffic Impact Analysis Reports for Hawaii. Chapter 3 outlines the methodology used in the study. The methodology includes descriptions of the data collection and preparation as well as the analysis techniques applied in this study. Chapter 4 consists of a detailed description of the projects analyzed in this study. The chapter is divided into two sections covering road projects and residential developments, respectively. The description of the projects includes location, consultant, project characteristics, forecasting method and year of EIS. Chapter 5 presents the results from data analysis, models and comparisons between studies. Chapter 6 discusses the outcomes of the analysis and presents the conclusions of the study.

# CHAPTER 2 – LITERATURE REVIEW

Transportation infrastructure is a vital social and economic feature; decisions on infrastructure have impacts that last for decades. A high number of public resources go towards transportation infrastructure, but unfortunately not much research on the accuracy of traffic demand forecasting has been conducted [2]. In this chapter, an overview of findings from other studies on traffic forecasting is conducted; this is followed by an in-depth overview of two particular studies on traffic forecasting accuracy. Then a brief review of best practices for Traffic Impact Analysis Reports for Hawaii is provided, followed by evaluation and a summary.

## *2.1 Forecasting Models and Inputs*

Forecasting errors occur when forecast and actual traffic volumes do not coincide. Traffic forecasts are used to design transportation infrastructure; when forecast errors occur the design either does not meet the actual transportation need, making facilities over or undersized in regard to the actual traffic volumes. Previous studies on accuracy in traffic forecasting have suggested several reasons for forecasting error. One of the reasons suggested is the forecasting model and the inputs used. Closed static models are often used to analyze the impact a proposed project will have on the traffic network. However urban settings are open and dynamic with overlaps between transportation and other urban functions. Also the relationship between variables in the model may change over time, which creates uncertainty in the model [6].

Many traffic forecasting models are based on a variety of assumptions, such as future travel patterns, population and employment estimations, household size and activity, spatial development and government policy outcomes.  These assumptions are based on forecasted estimates. Statistical models produce both mean and variance estimates.

However only the mean estimate is carried forward in the models and the variance information is lost. In omitting the variance in the outcomes, the final result is limited to mean estimates as well, but the correct result would be a range instead of a point estimate. Many inputs in the model are based on assumptions; these assumptions can change over time. This can be due to shifts in lifestyle or impacts from a range of policies.

Even simple projections are based on several variables, and would yield a range of combinations of future conditions, unless some of the variables are constrained by assumptions. Assumptions are often based on historical facts. But as mentioned above, trends do change over time, hence the assumptions should follow. However, sometimes old assumptions are still used, even after they have been proven wrong. This is partly due to the fact that it is easier to incorporate old assumptions into a forecast than it is to anticipate a new one [6, 7, 8].

Another uncertainty is the size of the network analyzed. It is difficult to obtain accurate estimates of traffic flow when a simple network with only a few origin-destination pairs are included, compared to a comprehensive network with multiple alternative routes. However, smaller areas, such as corridors are often analyzed over full-scale networks, which increase forecasting error. This is usually done to decrease costs [9].

Niles and Nelson [6] divided uncertainty in forecasting into three categories: <u>Unknowables</u>, where future events cannot be imagined. <u>Structural uncertainties</u>, an understanding that new events can occur but there is not enough experience to judge the likelihood of the event. <u>Risk with historical precedence</u>, the probability of it occurring again can be estimated. Although the first two: unknowables and structural uncertainties cannot be forecast, history shows that they do occur. Uncertainty can be greatly minimized by looking at trends that have shaped and are shaping society and by recognizing technical developments as well as life style changes in the horizon [6].

For large projects or developments, models are estimated sequentially, with the outcomes of one model used as inputs in the next model. In most cases only the mean estimate and not the variance is passed on to the subsequent models, limiting the outcomes of the final model to mean estimates as well, making comparisons between different plans or alternatives incorrect. In reality overlaps between different plans or alternatives may occur, however they are not visible or accounted for [8].

When outputs from one model are used as inputs into another model the error or uncertainty is passed on and multiplied. Also forecasting error is compounded through the four stages of the multi-stage model. Mispredictions in the early stages, amplifies across later stages. The conclusion of the study is that overall predictions from many traffic forecasting models may be highly uncertain due to the uncertainties of the inputs. Forecasters should recognize and estimate uncertainties [8].

Another issue with models is the circularity of forecasts. The future is made by people and is not out of our control, so when a certain outcome is predicted and the necessary facilities provided, there is no way of knowing what would have happened had the facilities not been provided [7].

### *2.2 Bias*

The technical complexity of forecasting combined with political preferences and pressure can create an ethical dilemma for forecasters. Forecasts which support a certain course of action are often demanded by the entity or client requiring the forecast. Forecasting is based upon many assumptions and judgments; and it is almost always possible to adjust these assumptions to a degree so the forecast will meet the demands, either by choosing particular data or mathematical forms [7]. Even though forecasters often view themselves as neutral technical experts, it is their responsibility to provide work that meets their client's best interest, they also have to serve the public's best interest [10]. But it can be difficult for forecasters to remain neutral and unbiased when there is a lot of pressure to produce a certain outcome [7].

According to Flyvbjerg sometimes forecasts can be used to promote certain politics or ideologies, forecasts can be used as political tools to get projects approved and to show voters that things are being done about the problems. Flyvbjerg goes one step further and states that sometimes forecasts are altered intentionally to promote a certain policy. For example, if politicians want to promote a new bus system, the benefits can get inflated and costs deflated to ensure public support [2].

### *2.3 Public planning of mega-projects: overestimation of demand and underestimation of costs*

The study on traffic and cost forecasting accuracy by Flyvbjerg consists of 210 transportation infrastructure projects worldwide. The projects are located in 14 countries on five continents and include urban rail, high-speed rail, conventional rail, fixed links such as bridges and tunnels, highways and freeways. For the three-way comparison, between the Flyvbjerg study, the Post-construction evaluation of traffic forecast accuracy in Minnesota and the assessment of forecasting accuracy on Oahu, conducted in the analysis, only the results from the road projects are used. The projects were completed between 1969 and 1998, and are approximately worth $62 billion in actual costs [2].

The study shows that the risk of road project forecasts being inaccurate is high; more than 50% of all road projects have a forecasting error greater than ±20%. The forecasting error is balanced, meaning that the chance of overestimation compared to underestimation is very little, with 21.3% of projects being underestimated by -20% or more and 28.4% of projects being overestimated by +20% or more. The study also investigates if traffic forecasting has become more accurate over time, and concludes that it has not. Road project forecasts have become more inaccurate over the 30 year time period examined [2].

In summary, the study by Flyvbjerg showed a tendency towards an underestimation of - 8.7% on average. Flyvbjerg identified several reasons for inaccuracy in road traffic forecasting, the two main causes were: Change in land use and trip generation. Trip generation is based on traffic counts, demographics and geographic data; often these data are outdated and incomplete. The other cause for forecasting inaccuracy is change in land use: The land use plan that is actually implemented may be quite different from the plan used in the analyses [11].

Flyvbjerg et al. also suggested that inaccuracy in traffic forecasting can be biased by politics. For example in areas where traffic growth is considered undesirable, forecasts may be underestimated, and vice-versa. The desire to minimize traffic growth can come from an environmental point of view or a NIMBY – not in my backyard consideration, where people do not want big infrastructure developments close to home [12].

### *2.4 Post-construction evaluation of traffic forecast accuracy*

This study by Parthasarathi and Levinson analyzed traffic forecasting accuracy in the Twin City metropolitan area, by comparing actual traffic volumes obtained after completion to the forecasted traffic volumes of each highway project. The study consists of 2984 roadway segments from 108 different projects. All projects had a forecast horizon year of 2010 or earlier, they were prepared between 1904 and 1991 [3].

This study of post-construction accuracy shows that for most cases the traffic forecasting accuracy is very good with 72.4% of all projects being within a ±0.5% error range. Of the remaining cases 9.5% are underestimated by more than -0.5%. The degree of underestimation is not provided, 18% are overestimated between 0.5% and 6% and 0.2% of the cases are overestimated by more than 6%.

The authors suggest several reasons for the inaccuracies in traffic forecasting. A primary reason is errors in the inputs that go into the forecasting model. In the study most forecasts were based on the Regional Travel Demand Model, which was modified by ground counts and turning movements. The analysis also shows that socio-economic and demographic inputs are important reasons for forecasting inaccuracy [3]. These inputs are based on assumptions and forecasts, thus, they are uncertain as well. The outcomes from statistical models are both a mean estimate as well as estimates of variance. However, only the mean estimate is used in the travel demand models. Models based on mean estimates constrain the results into mean estimates as well, thus, the variance information is lost [8]. More sophisticated models could be used to take account of variability.

It is suggested that inaccuracy is not only due to poor input into the regional model, but the problem can also be with the regional model itself. The regional model is based on a Travel Behavior Inventory survey conducted by the Metropolitan Council and Minnesota DOT about every 10 years. The data from this survey is used to update the regional model. However, because the survey is conducted every 10 years, traffic forecasts can be based on fairly old data [3].

### *2.5 Best Practices in Hawaii*

HDOT has developed a Best Practices document to provide guidance for preparing TIARs. TIARs ensure that transportation infrastructure can accommodate proposed changes in land use. The document provides a recommended process for both preparers and reviewers, and informs about the process [13]. The document is divided into several sections: The process and terms of TIARs, the roles of people involved and elements of the TIAR. The Best Practices document also provides a number of checklists to ensure that the final TIAR includes all necessary information so decision makers can make informed decisions.

The process for developing a TIAR in Hawaii is a five step plan. First step is “Plan” the TIAR which ensures that the final document will meet the needs of the reviewing agencies. The second step is “Do” which is basically the study phase, where the analysis is conducted. The third step is “Check” which determines if the document meets all the requirements and if the analysis is sufficient. Next step is “Refine” in which adjustments are done before the project. Mitigations are implemented in the final step, “Act”. The process is circular meaning that there is a continuing need to evaluate impacts throughout the process [13].

The document does not provide any information about recommended growth rates. It recommends the use of ITE Trip Generation as forecasting method, but other alternatives can be considered if specific trip generators are not provided or not covered well [13].

### *2.6 Evaluation*

In order to optimize traffic forecasting it is good to start with a historical overview. What has been done and what lessons can we learn from previous projects? Sometimes planning can be politicized and there may be little transparency in the preparation and decision making process. A post construction study of projects is necessary to improve forecasting accuracy [14]. This is also noted by Wee who suggests peer review of forecasts after the fact, just as in academic journals, making this review public and apply legal and professional sanctions when manipulation in forecasts is found [15].

When looking at the overall accuracy of traffic forecasting in the Twin Cities metro area, 72.4% of the cases are within ±0.5%, which is by far the best forecasting accuracy in the comparison. However the forecasting accuracy was not always this good. In the 1980s Minnesota DOT conducted a study of accuracy in traffic forecasting. That study showed a mean absolute percent error of 19.5% and about 62% of all cases were underestimated. Since then forecasters in Minnesota have improved forecasting accuracy significantly [3]. This indicates that an evaluation of practices can be very useful and helps optimize the forecasting process.

### *2.7 Summary*

Traffic forecasting is an essential part of project development. Studies show that there is an issue with traffic forecasting accuracy, but not a lot of analysis on this matter has been conducted. The literature suggests several reasons for the inaccuracy. The main reasons are: The forecasting models, input assumptions, bias in favor of the project, and lack of evaluation of historical data.

# CHAPTER 3 – METHODOLOGY

Three major components comprise the analysis: project selection and data collection; data analysis; and a three-way comparison between this study and two others on traffic demand forecasting. In step one a number of promising EIS reports are selected for further study, the basis for the initial project selection is a list of criteria to eliminate projects that are not usable in this study. After the project selection is completed data collection can begin. The data is collected from two sources, EIS reports and the Hawaii Department of Transportation (HDOT). A number of data are needed for this study: from project specific information found in the EIS and TIAR to the corresponding actual traffic volume found from HDOT sources. The next step is data preparation, which is done in a spreadsheet in order to make the data compatible to conduct further analysis. All of this information provides the basis for analyzing the commonalities, patterns and trends in traffic demand forecasting.

The analysis is split into three components: illustrative and quantitative analysis and a three-way comparison between this study and two others about traffic demand forecasting: Bent Flyvbjerg's study of 200+ megaprojects *Public planning of mega-projects: overestimation of demand and underestimation of costs* [2] and *Post-construction evaluation of traffic forecast accuracy* [3] by Parthasarathi, P. and Levinson, D. After the analysis is completed, findings and lessons will be drawn from the study. *Figure 3.1* provides a complete methodology flow diagram and an in-depth description of the components of the study is explained in the following sections**.**

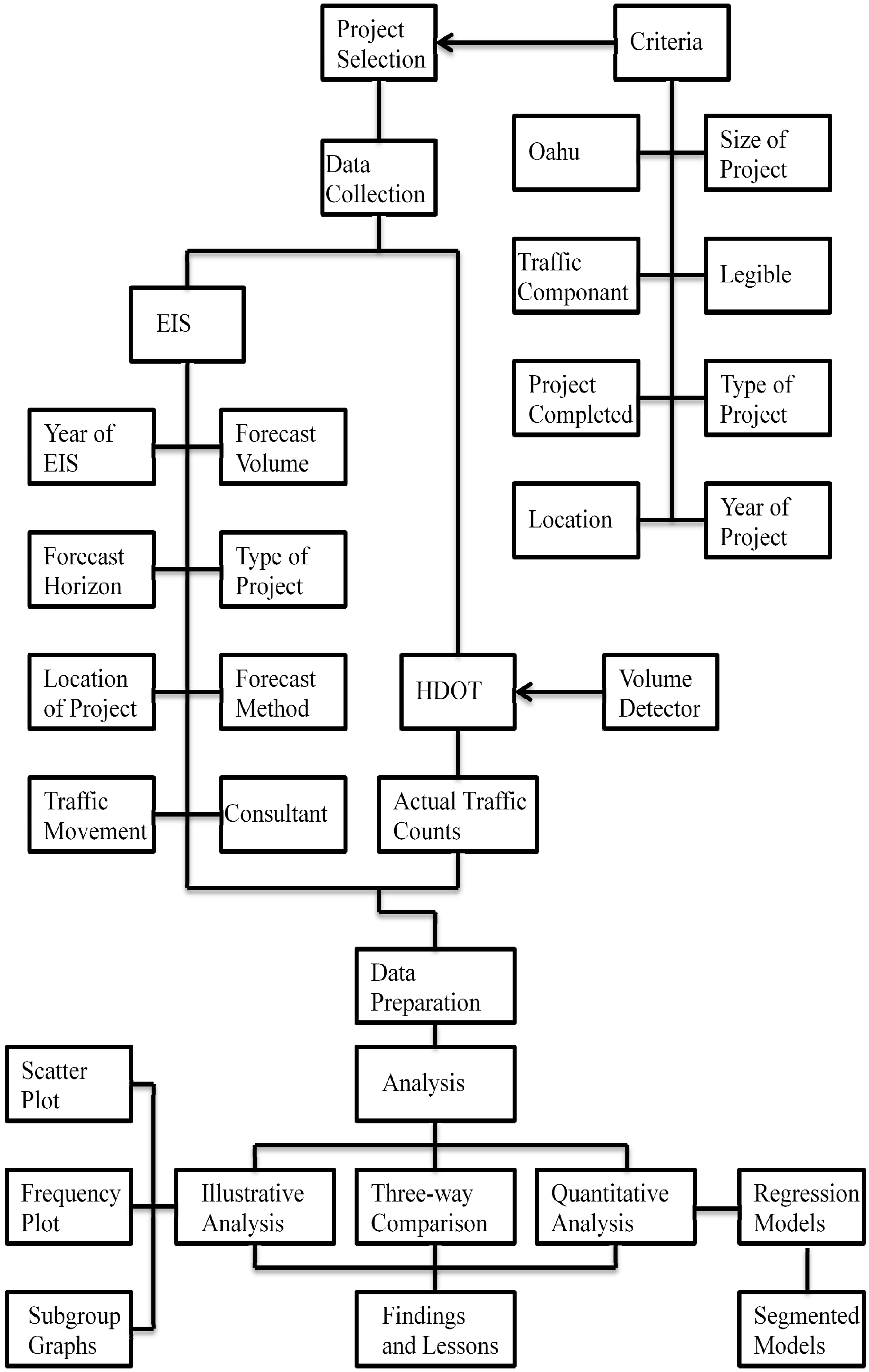


**Figure 3.1 - Methodology Flow Diagram**

### *3.1 Data Collection*

The first component in the data collection is to select a number of EIS reports for further investigation. The criteria for the initial selection of projects are as follows:

- Project location on Oahu
- Does the EIS have a traffic component?
- Is the EIS legible?
- Is it a residential development or road project?
- Is the project proposed and built between 1980 and 2010?
- Is the project fully completed?
- Proximity to state roads.
- Forecast horizon before 2010.
- No military projects.

Projects that meet these initial requirements undergo further investigation. This expanded investigation examines the location and type of project and how closely it resembles the originally proposed project. Local knowledge and Google Maps provided the answers to these questions. If the project is determined to be suitable for this study, then the project-specific information that is needed for the analysis is collected. The information required from the EIS and TIAR are: year of EIS, consultant, type of project, location, movement, forecast horizon, forecasted traffic volumes and forecasting method. These variables are chosen because they are easily assessable and are expected to have an impact on traffic demand forecasting accuracy.

Year of EIS and forecasting method is included in the analysis to measure if any progress and improvement has been made over time in forecasting accuracy. Forecasting method is mainly various editions of the ITE Trip Generation; however some projects do not state which forecasting method was used. In this study they are included as do not know (DNK). The more recent the project is, the higher the ITE Trip Generation edition. Seven different consultants prepared the TIARs used in this study; they are given a number from 1 to 7 in order to distinguish them from each other. The consultants are not identified in the analysis; they are only mentioned by number. In the study two types of projects are used, they are: road projects and residential developments. The location of the project is also examined to see if it has any impact on the forecast accuracy. Oahu is divided into five areas: Honolulu, Ewa, Central Oahu, North Shore and Windward side. The variable "Movement" distinguishes between through and turning movements. Turning movements are primarily project generated traffic, and through movements are project generated and projected background traffic in the area. Forecast horizon is the number of years between forecast year and year of TIAR and lastly there is forecast volume. Forecast volume is the traffic volume projected in the TIAR, the volume includes both traffic generated by the project and the background traffic volumes. Forecast volume is reported in vehicles per hour (vph) during the AM and PM peak hours.

**Environmental Impact Statement**

An Environmental Impact Statement (EIS) is a document required by law under the National Environmental Policy Act (NEPA) for projects or actions that significantly impact the quality of human life in an area. Not all projects require an EIS; if a project is not likely to cause a significant impact on the environment, then a more basic, less comprehensive document called an Environmental Assessment (EA) can be prepared.

The findings in the EA determine whether an EIS is required. If the EA finds that an action will not cause a significant impact on the environment, then an EIS is not necessary. The EIS is a tool for decision making; it describes both the positive and negative actions of a proposed project and it usually lists one or more alternatives that may be chosen instead of the proposed action.

An EIS consists of four sections:

- An introduction, including a statement of purpose and need for the proposed action.
- A description of the affected environment.
- A range of alternatives to the proposed action.
- An analysis of the environmental impacts of each alternative.

The Traffic Impact Analysis Report (TIAR) is found in the analysis of the environmental impacts. This part of the EIS analyzes the impact of the proposed project on the traffic conditions in that particular area. The report includes a study of the existing conditions as well as the future conditions with and without the proposed action. It also provides recommendations to mitigate the impact the proposed project will have on the traffic conditions [16].

**Forecasting Tools**

Most TIARs analyzed in this study used the ITE Trip Generation to forecast future traffic volumes. Different editions of the ITE Trip Generation method were used depending on the year of project preparation. The ITE Trip Generation method is based on the four-step traffic demand forecasting process, which consists of the following four major components:

1. Trip Generation
2. Trip distribution
3. Mode choice
4. Trip assignment

The four-step modeling process uses sequential demand forecasting, where the outputs of one step becomes the input in the following step. The four step modeling process also requires relevant input such as: network description, land use plans and socio-economic factors.

**Trip Generation**

The objective of trip generation is to forecast the number of person trips a project will generate. The person trips are divided into two groups: trips that start at the proposed project and trips that end at the proposed project. Both residential and nonresidential land uses are analyzed to estimate the trips generated by a proposed project.

**Trip distribution**

The second step estimates the number of trips between different zones. The number of trips generated by one zone, found in step one, are distributed between the trip receiving zones. The number of trips a receiving zone attracts depends on the relative attractiveness compared to other receiving zones. The most common method to distribute trips is the gravity model, which is based on Newton’s law of gravitation.

**Mode Choice**

Trip makers can choose between several different travel modes to conduct a trip. The purpose of the third step in the forecasting process is to estimate what mode trip makers will use to conduct their trip. The trip maker can choose from a range of different modes: car, carpool, public transit, walking and biking. There are three factors that affect choice of mode: the characteristics of the trip maker, the characteristics of the trip and the attributes of the travel modes.

**Trip assignment**

The final step in the traffic forecasting model is trip assignment. This step is concerned with the trip maker's choice of path between trip generating and trip receiving zones by mode and the resulting traffic volumes on the roadway network. Trip assignment estimate future traffic flows in order to analyze future traffic conditions [16].

**Actual Traffic Volumes**

The next step in the data collection is to find the relevant actual traffic counts. The data is acquired through a remote access to the HDOT network where historical traffic counts, obtained by field equipment such as pneumatic tubes, for state roads are stored.

The Hawaii Department of Transportation does not record continuous traffic data; usually the available data is a collection of samples taken over a two day period. The traffic counts are based on 24-hour recording reported in 15 minute intervals. The HDOT calculates the AM and PM peak hour volumes along with directional peaks, these are both measured in vph.

One of the criteria for selecting projects for this study is proximity to state roads. This helps find actual traffic counts that are consistent with the location of the forecasted traffic volumes. When the relevant traffic counts are found, the traffic volumes from the year closest to the forecasted year are used. Since traffic counts are recorded over a two day or longer period, the traffic volume used in the analysis is an average of the counts.

A few issues surfaced during the collection of actual traffic volumes. This included inconsistency in traffic direction, inaccurate traffic counts and the inability to find traffic counts that were recorded close to the forecasted years. To account for the traffic direction component, all volumes were double-checked to ensure that the directional peak was consistent with general knowledge of traffic flow on Oahu. For example, the “heavy” direction in the AM peak hour on Fort Weaver Road should be north bound. It should be south bound from Mililani developments. If this was not the case then the counts were either omitted or the directions reversed. HDOT was consulted before action was taken.

Inconsistencies in the magnitude of traffic counts were compensated for by taking an average of the two or three day survey. Traffic counts that had a large variance of volumes were omitted. For example, if two traffic counts in a specific location were in the 550 vph range and a third count was only 300 vph, then the deviant traffic count was omitted. If it was impossible to find traffic counts that corresponded with the locations of the forecasted traffic volumes, then the projects were excluded from the analysis.

Lastly, if the year of the actual traffic count and the year of the forecasted traffic volumes did not coincide, the traffic count closest to the year of the forecasted traffic volumes was selected. And then the forecasted traffic volume was updated to fit the actual traffic count. This updating is explained in *Data Preparation*.

The collection of data was slow and tedious; some of the EIS and TIARs were very difficult to read, the forecast traffic volumes had to be double checked, and corresponding traffic counts had to be found.

### *3.2 Data Analysis*

Once the data collection was completed, the data were consolidated in a spreadsheet where it was organized by using columns for variables and rows for project data, as shown in *Figure 3.2*. The dataset consists of 37 cases covering a total of ten different projects, four road projects and seven residential developments. The data collected from EISs, TIARs and HDOT provides two dependent variables, absolute and percent error, and eight independent variables: location, type of project, year of TIAR, forecast horizon, forecast method, consultant and peak hour traffic.

Before any further analysis can be conducted, the type of analysis to be completed must be considered. The compiled datasheet provides a range of variables that can be analyzed, and in order to best analyze the data, both an illustrative and quantitative analysis are conducted.

In order to create a dataset large enough for analysis, it was decided to include several traffic volumes from the same project. The number of cases per project varies from one to ten. This was done to investigate if certain movements had an influence on traffic forecasting accuracy. When the data was collected and reviewed it was noticed that the inaccuracy in traffic forecasting varied a lot even between cases from the same projects, indicating that the cases were independent even though they came from the same project. Therefore it was decided to continue the analysis with the same number of cases.

**Data Preparation**

The first step in data preparation is to ensure that the variables and cases can, in fact, be compared. A major obstacle in this particular study is the difference between the year of the traffic count and the year of the traffic forecast. This could be anywhere from minus five years to plus eleven years. The traffic volumes from the TIAR are updated to compensate for this. The regional growth rates for Oahu provided from the Hali 2005 Regional Transportation Plan [17] are used in conjunction with the simple growth model:

$$x_t = x_0 \times (1 + t \times r) \qquad (1)$$

Where $x_t$ is the updated traffic volume, $x_0$ is the traffic volume at time 0, $t$ is the number of years between the forecast year and year of the traffic count, and $r$ is the annual growth rate. The growth rates are differentiated according to the project location, see *Table 3.1*. This is done because different annual growth rates are expected in certain areas of Oahu. For example North Shore and the Ewa region are expected to have the highest growth rates of 2.6% and 2.7% respectively, and Honolulu and the Windward area are expected to have low growth rates of 0.6% and 0.2%.

**Table 3.1 - Annual Growth Rates by Location [17]**

| Location | Annual Growth Rates |
|---|---|
| **North Shore** | 2.7% |
| **Ewa** | 2.1% |
| **Honolulu** | 0.6% |
| **Central Oahu** | 1.1% |
| **Windward** | 0.2% |

After the forecasted traffic volumes are updated, the percent error and absolute error in volume are found. The equation to establish the percent error between actual and forecasted traffic volumes is as follows:

$$\%\, error = \frac{Updated\ TIAR\ volume - Actual\ traffic\ volume}{Actual\ traffic\ volume} \times 100 \tag{2}$$

$$Absolute\ error = Updated\ TIAR\ volume - Actual\ traffic\ volume \tag{3}$$

Where *% error* is the percent difference between forecasted and actual traffic volumes, *Absolute* error is the absolute difference between forecasted and actual traffic volumes, Updated *TIAR volume* is the forecasted traffic volume updated to fit with the year of the HDOT traffic count, and *Actual traffic volume* is the traffic volume from the HDOT traffic counts. A positive percent error indicates an overestimation, e.g., the forecasted traffic volumes are higher than the actual traffic volumes recorded by HDOT. A negative percent error shows an underestimation, e.g., forecasted traffic volumes are lower than the actual traffic counts.

The absolute difference in volumes is the difference between the number of vehicles in the forecasted and actual traffic volumes. A positive difference shows an overestimation in traffic demand forecasting and a negative value shows an underestimation.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Project | Station no. | EIS yr. | TIAR Prepared by | Type of project | Land Use Code | Location | Movement | Movement | ADT/vph | AM/PM | Forecast Year | Horizon | Forecast Traffic | Forecast Method | Peak hour in+out | Standard Error | HDOT Count Year |
| 2 | Haleiwa Bypass | B72-117 | 1981 | 5 | Road | | North Shore | NB | TH | vph | AM | 2001 | 20 | 500 | DNK | 1250 | | 2005 |
| 3 | Haleiwa Bypass | B72-117 | 1981 | 5 | Road | | North Shore | HNL-B | TH | vph | AM | 2001 | 20 | 750 | DNK | 1250 | | 2005 |
| 4 | Sand Island Access Road Widening and Improvement | 202 | 1982 | 4 | Road | | Honolulu | WB | TH | vph | AM | 2000 | 18 | 1800 | DNK | 2228 | | 1999 |
| 5 | Sand Island Access Road Widening and Improvement | 202 | 1982 | 4 | Road | | Honolulu | EB | TH | vph | AM | 2000 | 18 | 2976 | DNK | 2228 | | 1999 |
| 6 | Sand Island Access Road Widening and Improvement | 202 | 1982 | 4 | Road | | Honolulu | NB | TR | vph | AM | 2000 | 18 | 617 | DNK | 2228 | | 1999 |
| 7 | Sand Island Access Road Widening and Improvement | 202 | 1982 | 4 | Road | | Honolulu | SB | TR | vph | AM | 2000 | 18 | 1611 | DNK | 2228 | | 1999 |
| 8 | H3 | B72 | 1976 | 7 | Road | | Central | HNL-B | TH | Vph | AM | 2008 | 32 | 3050 | DNK | 3050 | | 2010 |
| 9 | Kahekili Hwy | 31-K | 1990 | 7 | Road | | Windward | HNL-B | TH | Vph | AM | 2008 | 18 | 3195 | DNK | 2898 | | 2003 |
| 10 | Kahekili Hwy | 31-K | 1990 | 7 | Road | | Windward | HNL-B | RT | Vph | AM | 2008 | 18 | 2055 | DNK | 2898 | | 2003 |
| 11 | Kahekili Hwy | 31-K | 1990 | 7 | Road | | Windward | EB | TH | Vph | AM | 2008 | 18 | 869 | DNK | 2898 | | 2003 |
| 12 | Kahekili Hwy | 31-K | 1990 | 7 | Road | | Windward | NB | LT | Vph | AM | 2008 | 18 | 843 | DNK | 2898 | | 2003 |
| 13 | | | | | | | | | | | | | | | | | | |
| 14 | West Loch Estates North | 10-K | 1987 | 1 | Residential development | | Ewa | SB | TH | vph | PM | 1991 | 4 | 2698 | ITE 3rd Edition | 1388 | | 1993 |
| 15 | West Loch Estates North | 10-K | 1987 | 1 | Residential development | | Ewa | NB | TH | vph | PM | 1991 | 4 | 2103 | ITE 3rd Edition | 1388 | | 1993 |
| 16 | West Loch Estates North | 10-K | 1987 | 1 | Residential development | | Ewa | EB | TR | vph | PM | 1991 | 4 | 405 | ITE 3rd Edition | 1388 | | 2002 |
| 17 | West Loch Estates South | 10-G | 1987 | 1 | Residential development | | Ewa | SB | TH | vph | PM | 1991 | 4 | 2416 | ITE 3rd Edition | 1388 | | 1993 |
| 18 | West Loch Estates South | 10-G | 1987 | 1 | Residential development | | Ewa | NB | TH | vph | PM | 1991 | 4 | 1478 | ITE 3rd Edition | 1388 | | 1993 |
| 19 | West Loch Estates South | 10-G | 1987 | 1 | Residential development | | Ewa | EB | TR | vph | PM | 1991 | 4 | 722 | ITE 3rd Edition | 1388 | | 2002 |
| 20 | Gentry Ewa Makai | 219 | 2002 | 2 | Residential development | | Ewa | NB | TH | vph | AM | 2010 | 8 | 1792 | ITE 6th Edition | 1687 | | 2009 |
| 21 | Gentry Ewa Makai | 219 | 2002 | 2 | Residential development | | Ewa | SB | TH | vph | AM | 2010 | 8 | 1476 | ITE 6th Edition | 1687 | | 2007 |
| 22 | | | | | | | | | | | | | | | | | | |
| 23 | Ewa Gentry | 10W | 1988 | 2 | Residential development | | Ewa | SB | TH | vph | AM | 1995 | 7 | 2020 | ITE 3rd Edition | 4420 | | 1995 |
| 24 | Ewa Gentry | 10W | 1988 | 2 | Residential development | | Ewa | NB | TH | vph | AM | 1995 | 7 | 4769 | ITE 3rd Edition | 4420 | | 1995 |

**Figure 3.2 – Part of the data organized in a spreadsheet.**

**Illustrative Analysis**

The first step in the analysis is an illustrative analysis; during this step the numeric results of the initial analysis, percent error and absolute difference in volume, are graphed to illustrate various 2-dimensional relationships or lack thereof. The result of the graphs provides a visual component to the analysis, which gives a better initial understanding of the data. However, this type of data representation may not provide strong statistical conclusions and is strictly for comparative purposes.

The two-dimensional graphs include a scatter plot of the actual traffic volumes to the updated TIAR traffic volumes as well as a frequency plot of the percent error. Graphs that show the relationship between size of project and percent error are also developed. These graphs provide an initial idea of the trends and patterns in traffic demand forecasting on Oahu, Hawaii. The final step in the illustrative analysis is to create graphs that split the cases into subgroups to examine whether the overall trends and patterns are the same in the subgroups. These split of the cases are based on the percent error for each case, and are as follows: +/- 20%, +/- 21-99% and greater than 100%. The reasoning behind this division is to examine cases with large percent errors captured in the subgroup with percent errors greater than 100%, the subgroup covering the cases with a percent error of +/- 21-99% examines cases with a substantial forecasting inaccuracy and the subgroup that includes the cases in the +/- 20% range examines traffic demand forecasting when the error is fairly evenly distributed around 0% inaccuracy.

**Quantitative Analysis**

When the illustrative analysis is complete, a quantitative analysis must be conducted. This is a statistical analysis where several variables are tested to examine their impact on the dependent variables. These are percent error, absolute difference in volume, and the relationship between the independent variables is also examined. The statistical program SPSS 17.0 was used for this part of the analysis. In SPSS data are entered into a data editor and a range of statistical analyses can be applied to reach different conclusions.

The variables tested in this part of the analysis are the variables collected from the EIS and TIAR. Again an analysis is conducted with all cases and with varying subgroups.

## *3.3 Analysis Methods*

The following sections describe the three methods selected and used in this study: Basic Statistics, Regression Analysis and Three-way Comparison.

**Basic Statistics**

One method of analysis assesses data through basic statistics such as mean, variance and two-dimensional relationships. Using Microsoft Excel – a program used to organize and analyze data – several tables and graphs were developed for the initial illustrative analysis which aimed at providing an initial understanding of the data.

**Regression Analysis**

Basic Statistics revealed various strong and weak relationships, but one-at-a-time. Variables are often interrelated in more than paired relationships. Regression analysis is a statistical tool for modeling and investigating the relationship between the variables [18]. In multiple regression analysis more than one variable is used to predict the value of the dependent variable and to investigate the interrelationship between the independent variables. The equation is:

$$\hat{Y} = \alpha + \beta_1 \times x_1 + \beta_2 \times x_2 + \beta_3 \times x_3 + \cdots + \beta_i \times x_i \tag{3}$$

Where $Y$ is the dependent variable, $x_i$'s are the independent variables, $a$ is the intercept and each $\beta_i$ is a regression coefficient that shows how the predicted value of the dependent variable changes in the context of the other independent variables for each unit change of the independent variable $i$. Although the model is linear and needs to be linear in order to be processed with the Ordinary Least Squares method, several variables may be included in a transformed form, e.g. $x_3=ln(z)$. To estimate the regression coefficients the method of least squares is applied. This method results in a line that minimizes the sum of squared deviation of predicted to actual values of the dependent variable [19].

The power of each variable is expressed in the β-values. The sign of the parameter estimate - positive or negative - shows whether the variable has a positive or negative relationship with the dependent variable. The magnitude of the beta parameters does not necessarily imply the corresponding variables are more significant when predicting the value of the dependent variable. Rather, the magnitude of a regression coefficient is affected by the correlation of the corresponding independent variable with all other variables in the equation and the units used to measure the corresponding variable. For all variables in the model the t-statistic is calculated along with the significance of the variable. The better the probability level the more significant effect the corresponding independent variable has on the dependent variable. The $R^2$ value is the strength of the linear relationship; it expresses the proportion of the dependent variable that is explained by the weighted combination of independent variables specified in the regression model [19].

Regression models are susceptible to an undesirable condition called multicolinearity. Multicolinearity is when two or more strongly correlated variables are included in a regression model. One measure of multicolinearity is tolerance; this is the proportion of variation the independent variable does not have in common with other independent variables in the regression model. As a rule of thumb, multicolinearity is a problem when the tolerance of an independent variable is less than 0.10, meaning that 10% of the variance of the independent variable is not explained by the other independent variables in the regression model [19].

Stepwise regression is a conjugational process that optimizes the selection of the independent variables that should be included in the regression model while rejecting those variables that are too weak or correlated to other independent variables. Stepwise regression first includes the independent variable that correlates most highly with the dependent variable. The next step is to include a variable that, when added, produces the highest change in $R^2$ as long as it meets the significance criterion. In this case that criterion is less than 0.05. Then the other variables in the model are examined for removal. The variable that produces the smallest $R^2$ is removed, but only if that change is significantly small. The process is repeated until no more variables are suited for entry or removal [19] SPSS handless all these tasks automatically.

The location variables are coded as binary numbers, for example the variable "Location Honolulu" is coded as 1, if the case is located in Honolulu and 0 if it is not located in Honolulu. The variable "Movement" is coded as 1 if it is a turning movement and 0 if it is a through movement. The variable "Type of Project" is coded as 1 for road projects and 0 for residential developments. The variable "Year of TIAR" is coded as the actual year the TIAR was prepared, for example if a case was prepared in 1986 it is coded as 1986. The variable "Forecast Horizon" is coded as the actual number of years the forecast horizon is. For example, a case with a forecast horizon of 20 years is coded as 20. The forecasting method variables are coded as binary numbers, for example the variable "Do not know" is coded as 1, if the case is forecasted using an unknown forecasting method and 0 if not. Similar binary variables were created for each applicable version of the ITE Trip Generation edition. The consultant variables are coded as binary numbers, for example the variable "Consultant 1" is coded as 1 if a case is prepared by Consultant 1, and 0 if not. The variable "Peak Hour Volume" is coded as the actual peak hour volume. The coding for the segmented models is similar. No changes to the variables were made in the segmented models.

**Three-way Comparison**

The last step in the analysis is a three-way comparison among (1) Flyvbjerg's study of more than 200 megaprojects across the world, (2) a study conducted in Minnesota by Parthasarathi and Levinson on post-construction evaluation of traffic forecast accuracy, (3) and the results of this analysis on Oahu.

This comparison reveals whether there are similar tendencies in traffic demand forecasting in Hawaii, Minnesota and world-wide. All three studies provide outcomes expressed in percent errors as well as frequency histograms. These outcomes are compared in order to investigate if there are any commonalities and patterns between the three studies.

### *3.4 Summary*

The methodology is divided into three major components to best assess the traffic demand forecast accuracy on Oahu, Hawaii. First the data needed for the analysis are collected. The data collection can be conducted online through the Hawaii Department of Health and the HDOT. Next the data are prepared and analyzed. The data preparation ensures that the data can be compared, and in this study the main issues were inaccuracy in direction and magnitude of traffic counts as well as availability of traffic counts from the same year as the forecast year. The analysis consists of an illustrative, quantitative and comparative analysis. The illustrative analysis is important to visualize the trends and patterns in forecasting accuracy; the quantitative analysis is used to investigate the effect that the independent variables have on the dependent variables. A three-way comparison is conducted in order to examine whether the outcomes of the three studies of traffic demand accuracy are similar.

# CHAPTER 4 - DESCRIPTION OF PROJECTS

The analysis is based on 37 cases derived from ten different projects. The ten projects cover four road projects and six residential developments. Depending on the size of the project and availability of actual traffic counts, the number of cases per project varies from one to ten. In the following paragraphs the ten projects are described. All the information on the projects is found in the project EIS's, which are made public through the State of Hawaii Department of Health [20]. *Table 4.2* provides a list of projects and their year of preparation.

**Table 4.2 – List of Projects and Year of TIAR**

| **Road Projects** | **Residential Development Projects** |
|---|---|
| Haleiwa Bypass (1981) | West Loch Estates North and South (1987) |
| Sand Island Access Road Widening and Improvement (1982) | Ewa by Gentry (1988) |
| H3 (1976) | Gentry Ewa - Makai Development (2002) |
| Kahekili Highway (1990) | 476 Acre Development at Mililani Town (1983) |
| | Mililani Mauka Residential Community (1984) |
| | Waikele Development (1986) |

## *4.1 Road Projects*

### Haleiwa Bypass


**Figure 4.3 - Location of Haleiwa Bypass**


**Figure 4.4 - Haleiwa Bypass**

Haleiwa Bypass, also known as Joseph P. Leong Highway, is a highway around the town of Haleiwa on the North Shore of Oahu, Hawai'i. The highway begins at the Weed Junction Traffic Circle and meets Kamehameha Highway at Haleiwa Beach Park. The alignment is approximately 2.3 miles long and consists of two 12 ft. traffic lanes and 10 ft. paved shoulders.

The TIAR was prepared by Fujinaka & Fujinaka Engineers and reviewed at state and federal levels by the US Department of Transportation, Federal Highway Administration and State of Hawai'i Department of Transportation, Highway Division. The final EIS was completed in 1981 and had an anticipated project completion in 1986.

The final EIS does not specify which method was used to derive the forecasted traffic volumes. It was expected that 60% of the traffic would use the Bypass alignment and 40% would continue to go through Haleiwa town on Kamehameha Highway.

From this project two cases were chosen, the north bound through movement and the south bound through movement on Haleiwa Bypass.

## Sand Island Access Road Widening and Improvement

Figure 4.5 - Location of Sand Island Access Road


Figure 4.6 - Sand Island Access Road

The project is located in Honolulu on the island of Oahu, Hawai'i. The alignment starts at the intersection of Nimitz Highway and Sand Island Access Road and continues on to Sand Island Parkway to the east end of Sand Island and the entrance of the Sand Island State Park. The project intended to improve the existing Sand Island Access Road as well as widen it. The project was necessary due to the rapid growth in the area.

The TIAR was prepared by Wilson Okamoto & Associates and reviewed at state and federal levels by the US Department of Transportation, Federal Highway Administration and State of Hawai'i Department of Transportation, Highway Division. The final EIS was completed in 1982.

The EIS does not specify which method was used to forecast future traffic levels. It does, however, provide traffic volumes throughout the alignment. This study used the traffic volumes at the intersection of Nimitz Highway and Sand Island Access Road for our assessment.

From this project four cases were chosen, the east bound through and west bound through movements on Nimitz Highway. Since the traffic counts from HDOT did not provide the actual right and left turning movements from Nimitz Highway the south and north bound volumes located immediately after the intersection on Sand Island Access Road were used instead.

## H-3 Freeway


**Figure 4.7 - Location of H-3 Freeway**

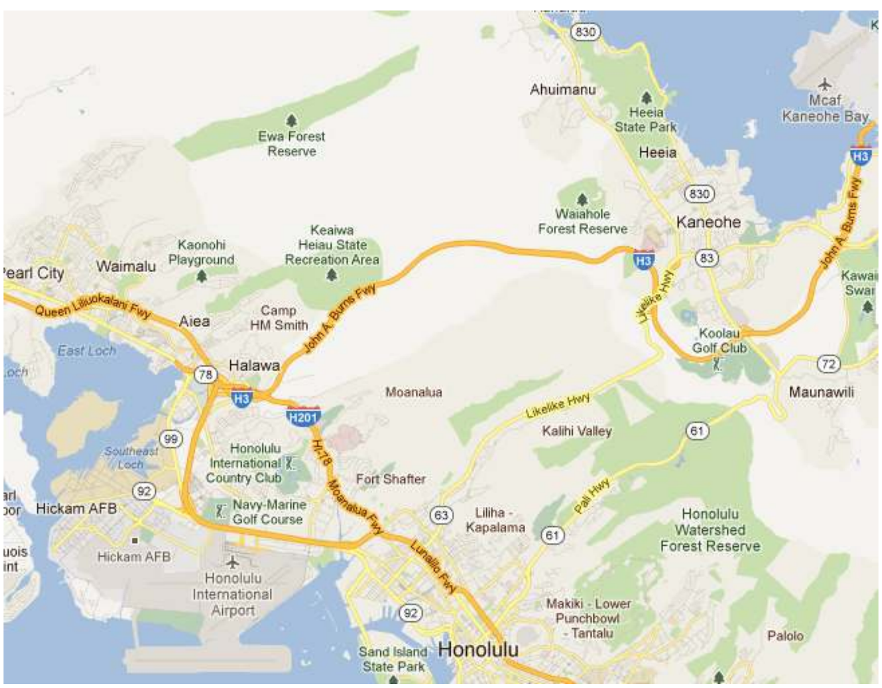


**Figure 4.8 – H-3 Freeway**

H-3 Freeway, also known as John A. Burns Freeway is the third Trans Koolau route connecting Honolulu with Oahu's Windward side. H-3 Fwy. is a four-lane, 10.7 mile long highway. It begins at the Halawa Interchange on H-1 Freeway and continues through North Halawa Valley as an at-grade and elevated highway. The highway has two bored 5,100-foot long tunnels (the Tetsuo Harano Tunnels) through the Koolau Range. The highway emerges in the Haiku Valley and continues east through the Hospital Rock Tunnels. H-3 Fwy. ends at the Marine Corps Base Hawai'i in Kaneohe.

The TIAR was prepared by the State of Hawai'i Department of Transportation, Highway Division. There has been significant controversy about the project and several supplements were made since the first EIS published in 1972. The last supplement was published in 1987 and the H-3 Fwy. opened in 1997.

The EIS does not specify which method was used to forecast traffic volumes. The H-3 Freeway does not have any entrances or exits from Halawa to the Likelike Highway; therefore, interchange traffic counts were taken close to the Halawa Viaduct. Only one case from this project was chosen, it was the south bound movement on H3 Fwy.

## Kahekili Highway Widening


**Figure 4.9 - Location of Kahekili Highway**

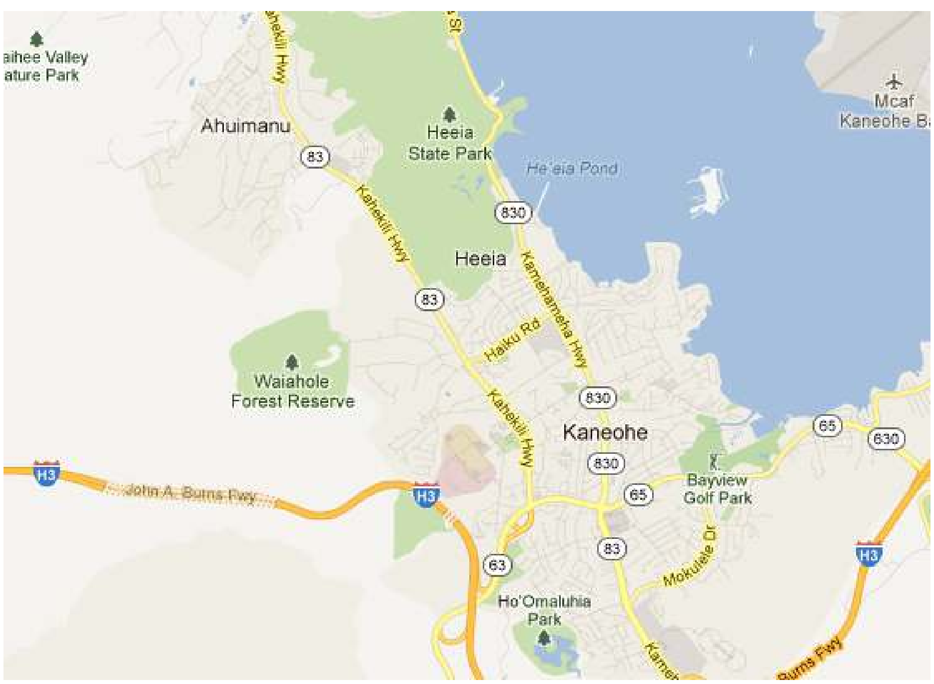


**Figure 4.10 - Kahekili Highway**

The project is located on the Windward side of Oahu, Hawai'i. The highway is connected to Likelike Highway in the south and to Kamehameha Highway in Kahaluu. It was constructed in 1966 as a two-lane highway and is a 4.4 mile major arterial road with varying widths between 24 and 43 ft. and paved shoulders with a varying width of 4 to10 ft. The project widened the highway from two to six lanes between Likelike Highway and Haiku Road, and from two to four lanes between Haiku Road and Kamehameha Highway. The project also included construction of an interchange at the Kahekili and Likelike intersection.

The TIAR was prepared by the State of Hawai'i Department of Transportation, Highway Division, and was published in 1990. The EIS was reviewed by the Federal Highway Administration.

The EIS does not specify which method was used to forecast the traffic volumes. The volumes used in this study are from the intersection of Kahekili Highway and Likelike Highway.

From this project four cases were chosen: Honolulu bound through movement on Likelike Highway, Kaneohe bound through movement on Likelike highway, north-west bound movement on Kahekili Highway and a south-east bound movement on Kahekili Highway.

## *4.2 Residential Developments*

### West Loch Estates North and South


**Figure 4.11 - Location of West Loch Estates North and South**

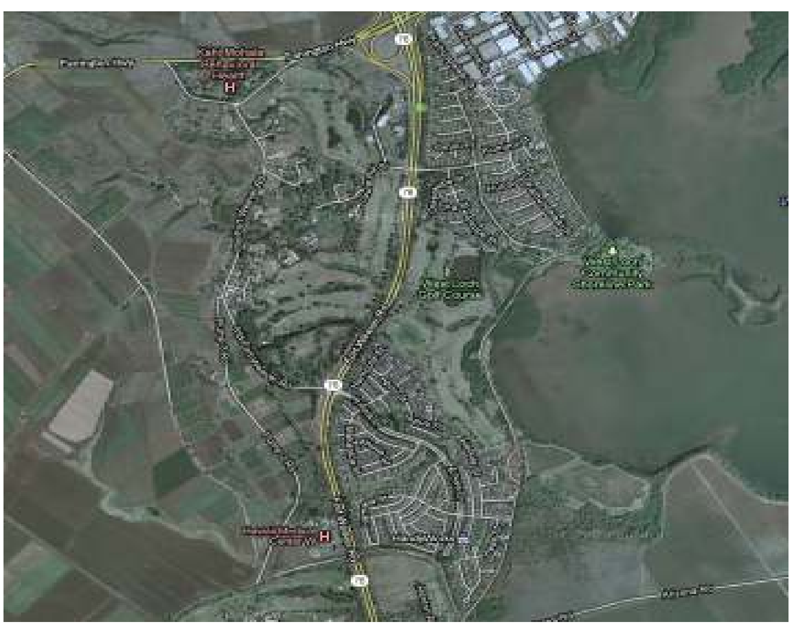

**Figure 4.12 - West Loch Estates North and South**

The project is located along Fort Weaver Road in Ewa, on the south shore of Oahu, Hawai'i. The project comprises two phases; in this study they are called West Loch Estates North and West Loch Estates South. The project was proposed by the Department of Housing and Community Development of the City and County of Honolulu.

The project consists of 1,500 residential single-family housing units, 150 elderly housing units, an 18-hole golf course, multiple parks, a commercial business district, a park-and-ride facility, an elementary school site and a child care facility.

The EIS was completed in 1987; the TIAR was prepared by Pacific Planning & Engineering. ITE Trip Generation 3rd Edition was the method used to forecast future traffic volumes.

From this project three cases were chosen from West Loch Estates North and South, respectively. For West Loch Estates North it was north and south bound through movements north of the development on Fort Weaver Road and an east bound movement on Laulaunui Street. For West Loch Estates South it was a northbound movement south of the development, a southbound movement between the two intersections and an eastbound movement on A'awa Drive.

## Ewa by Gentry


**Figure 4.13 - Location of Ewa by Gentry**

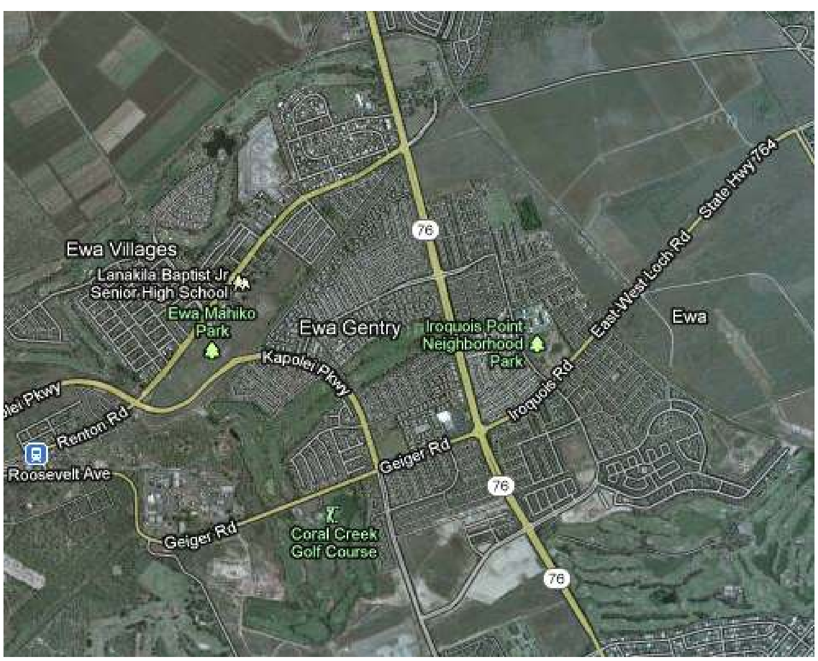


**Figure 4.14 - Ewa by Gentry and Gentry Ewa – Makai Development**

The project is located on both sides of Fort Weaver Road in Ewa, Oahu, Hawai'i between the Ewa Village and Ewa Beach communities. Gentry Investment Properties, Honolulu, Hawai'i owned and developed the project.

The 930 acre project consists of 7,000 dwelling units. Approximately half are single-family residential units; the other half are multi-family residential units. A school site, park site and 18-hole golf course were also provided within the project.

The EIS was finished in 1988; Parsons Brinckerhoff Quade & Douglas, Inc., prepared the TIAR. ITE Trip Generation 3rd Edition was used to forecast future traffic volumes. It was not possible to find forecasted or actual traffic counts for any turning movements in this development. Only two cases - north and south bound through movements on Fort Weaver Road were available and applied.

**Gentry Ewa – Makai Development**


**Figure 4.15 - Location of Gentry Ewa - Makai Development**

This project is also located in Ewa, Oahu, Hawai'i and serves as an extension of the Ewa by Gentry project. The project is owned and developed by Gentry Investment Properties, Honolulu, Hawai'i. In order to build this project lands had to be re-categorized and transferred from agricultural to urban use.

The project consists of 550 single-family and 1,329 multi-family residential units, approximately 30 acres of light industrial use, a community recreational center, a new middle school site, two church sites and two neighborhood sites. This project shares the Holomua Elementary School and the Coral Creek Golf Course, which are already built at the Gentry by Ewa Development.

The EIS was completed in December 2002; the TIAR was prepared by Parsons Brinckerhoff Quade & Douglas, Inc. ITE Trip Generation 6th Edition was used to forecast future traffic volumes. Since no actual traffic counts could be found for any turning movements, only two cases, north and south bound through movements, on Fort Weaver Road were used in the analysis.

## 476 Acre Development at Mililani Town


**Figure 4.16 - Location of 474 Acre Development at Mililani Town**

**Figure 4.17 - 476 Acre Development at Mililani Town**

The project is an increment of a 3,500 acre master planned community located in Mililani, Central Oahu, Hawai'i. Mililani Town, Inc. developed the project.

The project is a 476 acre residential development; it has 1,245 single-family and 845 multi-family residential units. The project also includes a 45 acre regional shopping center, 130 acres of recreational areas and parks, and 66 acres to be allocated to community facilities and amenities.

The EIS was finished in 1983; VTN Pacific prepared the TIAR. It is not stated what method was used to forecast the future traffic volumes. From this project two cases were used, the north and south bound on-ramps to H-2 Fwy. from Meheula Parkway. Actual traffic counts from the inside the development were not recorded by HDOT.

## Mililani Mauka Residential Community

**Figure 4.18 - Location of Mililani Mauka Residential Community**

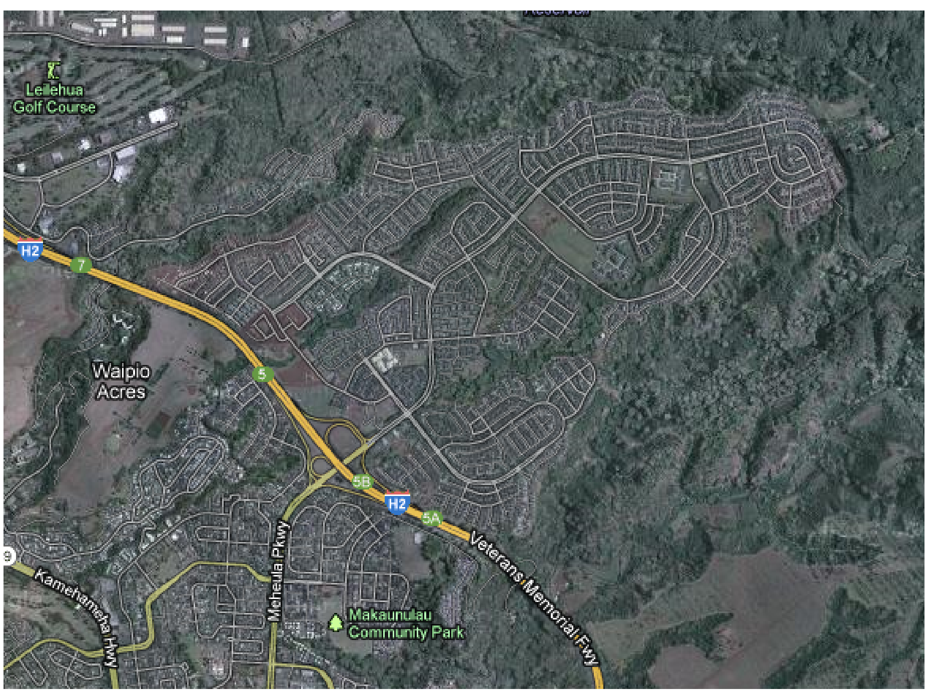


**Figure 4.19 - Mililani Mauka Residential Community**

The project is the completion of the master planned community Mililani Town, Oahu, Hawai'i. This part of Mililani Town is located east of the H-2 Fwy. in Central Oahu and covers 1,200 acres of land. Mililani Town, Inc. developed the project.

The project consists of 5,630 residential units, 1,010 low-density apartment units, two elementary school sites, a middle school site, church sites and recreational and open space.

The EIS was finished in 1987, Parsons Brinckerhoff Quade & Douglas, Inc. developed the TIAR in 1984. ITE Trip Generation 2nd Edition was used to forecast future traffic volumes. From this project four cases were used, the two on-ramps and the two off-ramps from H-2 Fwy.to Meheula Parkway. Actual traffic counts from the inside the development were not recorded by HDOT.

## Waikele Development


**Figure 4.20 - Location of Waikele Development**

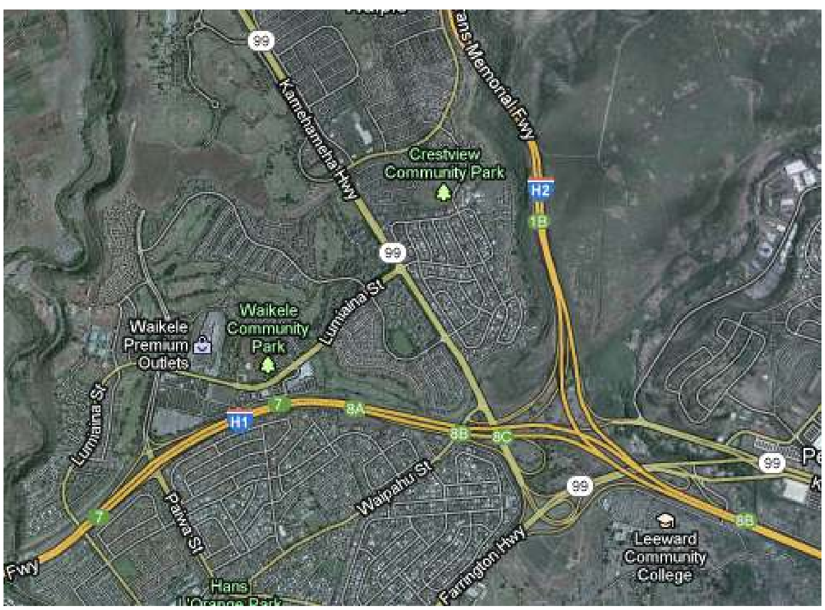


**Figure 4.21 - Waikele Development**

The project is located in Waikele, central Oahu, Hawai'i. Amfac Property Development Corp. owned and developed it. It is located north of the H-1 Fwy. and between Kamehmeha Highway and the Waikele Stream/Kipapa Gulch.

The development is a master planned community that is divided into three areas: East Waikele, West Waikele and Central Waikele. The core of the project is a commercial/ community Village Center surrounded by an 18-hole golf course. The project provides for a 150,000 sq. ft. shopping center and a 42.6 acre office park. The project also provides a wide range of residential dwelling types, including single-family units, townhouses and garden apartments.

The EIS was finished in 1985. Austin, Tsutsumi & Associates prepared the TIAR and ITE Trip Generation 3rd Edition was used to forecast future traffic volumes. Waikele is located close to both the H-1 Fwy. and Kamehameha Highway, and both forecasted and actual traffic volumes were available from both highways. From H-1 Fwy. six cases were used, the two on-ramps, the two off-ramps between H-1Fwy. and Paiwa Street and the east and west bound movements on H-1 Fwy. From Kamehameha Highway the north, south, east and west bound movements from the Kamehameha Highway and Lumiana Street intersection were used.

### *4.3 Summary*

The analysis was based on 37 cases derived from ten projects. The projects cover both road projects and residential developments. *Table 4.3* provides a summary of the 37 cases used in the analysis. From here on the consultant will not be mentioned by name, but by number.

The number assigned to the consultant does correspond to the case numbers.

**Table 4.3 – List of Cases**

| No. | TIAR Title | Prepared by | Prepared for | Year |
|---|---|---|---|---|
| **1-2** | Haleiwa Bypass | Fujinaka & Fujinaka Engineers | State of Hawaii | 1981 |
| **3-6** | Sand Island Access Road Widening and Improvement | Wilson Okamoto & Associates | State of Hawaii | 1982 |
| **7** | H3 | HDOT | State of Hawaii | 1976 |
| **8-11** | Kahekili Hwy | HDOT | State of Hawaii | 1990 |
| **12-14** | West Loch Estates North | Pacific Planning & Engineering | Department of Housing and Community Development | 1987 |
| **15-17** | West Loch Estates South | Pacific Planning & Engineering | Department of Housing and Community Development | 1987 |
| **18-19** | Gentry Ewa Makai | Parsons Brinckerhoff Quade & Douglas, Inc | The Gentry Companies | 2002 |
| **20-21** | Ewa Gentry | Parsons Brinckerhoff Quade & Douglas, Inc | The Gentry Companies | 1988 |
| **22-23** | 476 acre development at Mililani Town | VTN Pacific | The Gentry Companies | 1983 |
| **24-37** | Mililani Mauka Residential Community | Parsons Brinckerhoff Quade & Douglas, Inc | Mililani Town, Inc. | 1984 |
| **28-37** | Waikele Development | Austin, Tsutsumi & Associates | Amfac Property Development CORP | 1986 |

# CHAPTER 5 – STATISTICAL ANALYSIS & RESULTS

The analysis was conducted to determine the accuracy of traffic demand forecasting, comparing forecasted traffic volumes to the actual traffic volumes on Oahu. The analysis consists of an illustrative analysis, quantitative analysis and a three-way comparison. The illustrative analysis illustrates the two-dimensional relationship between forecast error and traffic volumes. The quantitative analysis provides a statistical analysis of the dataset, in order to test the impact of a number of independent variables on the two dependent variables: percent error and absolute error. Lastly, a three-way comparison of outcomes among this study, a study from Minnesota and a worldwide study of forecasting accuracy is conducted.

## *5.1 Illustrative Analysis*

The purpose of the illustrative analysis is to get an overview of the accuracy in traffic demand forecasting on Oahu, Hawaii for TIARs conducted between 1980 and 2002. The analysis uses scatterplot visualization along with a frequency analysis to determine trends, if any. The scatterplot compares the updated traffic volumes from all 37 cases to the actual traffic volumes. Recall that the TIAR forecasted volumes were updated using OMPO growth rates to match the year of HDOT's actual traffic volume. For eight cases no update was needed, 27 cases needed a 1-5 year adjustment and 2 cases needed a 6-11 year adjustment.

The target line shows the ideal condition, where forecast and actual traffic volumes are identical. *Figure 5.22* demonstrates that most cases are above the target line. This indicates that for most projects, the actual traffic volume does not reach the forecast traffic volume, in other words, most forecast volumes were overestimated. The scatter plot also shows that cases with small traffic volumes are fairly close to the target line; as volumes increase the cases have a wider distribution.

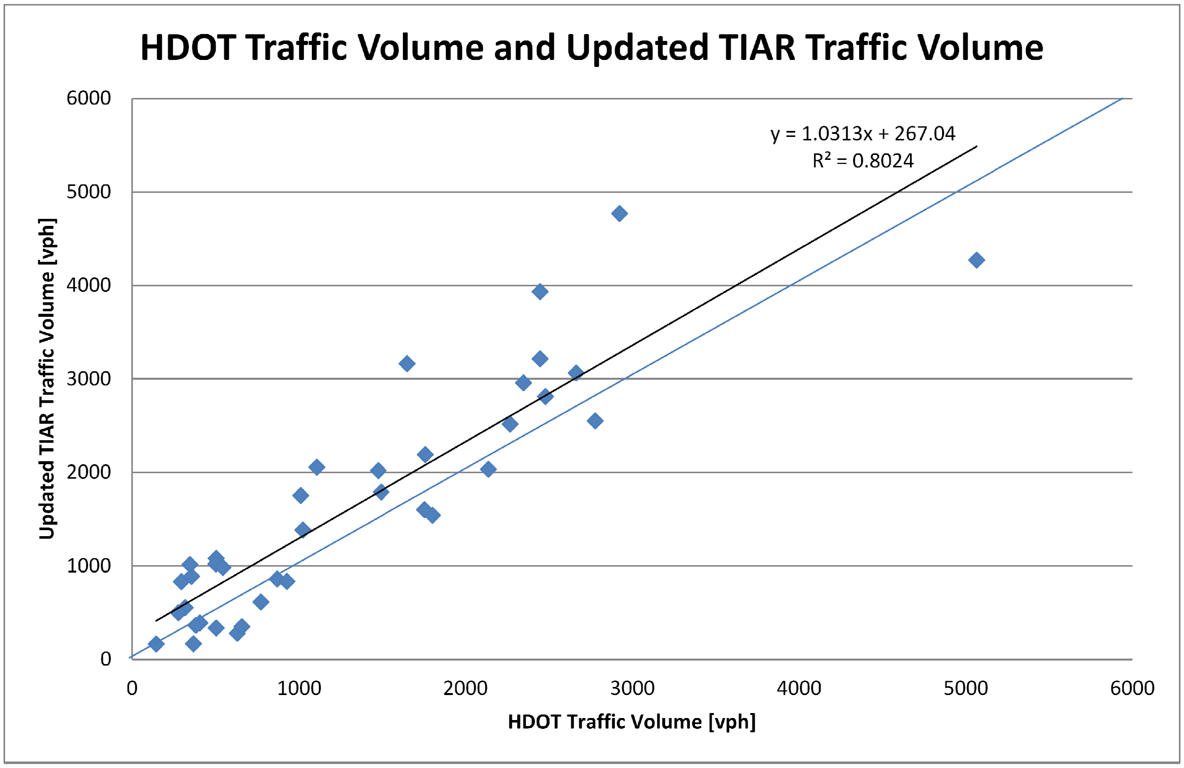


**Figure 5.22 – Scatter plot of HDOT traffic volume and updated TIAR volume.**

As explained in the methodology chapter, an updated TIAR volume is used in the analysis. This is done to correct for the eventual difference in year of the traffic forecast and the year of the traffic count. In *Figure 5.23* the impact of updating the forecasted traffic volume is examined, this graph shows the HDOT, original forecast and updated forecast volumes. The traffic volumes were on average overestimated by 30% before they were updated, meaning that the update increased overestimation by 5% to 35%. The update increased inaccuracy for 19 cases, decreased inaccuracy for ten cases and for eight cases there was no change.

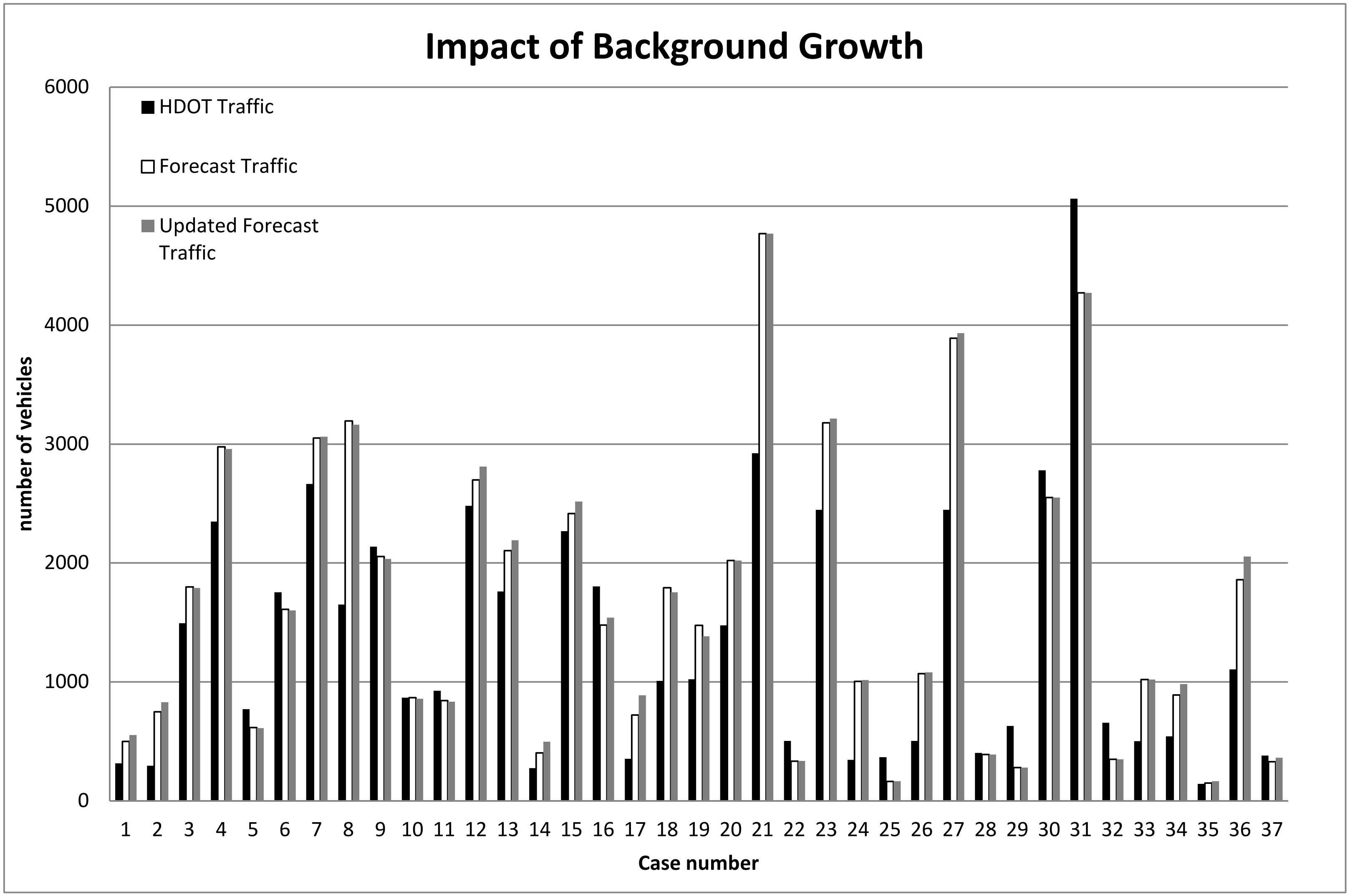


**Figure 5.23 - Impact of background growth.**

The frequency plot in

*Figure* 5.24**,** confirms this outcome; by showing the distribution of accuracy in traffic demand forecasting. The accuracy is measured in percent error, which is the difference between updated and actual traffic volumes over actual traffic volume, see equation (2) page 21.

Where *% error* is the percent difference between forecasted and actual traffic volumes, *Updated TIAR volume* is the forecasted traffic volume updated to fit with the year of the HDOT traffic count, and *Actual traffic volume* is the traffic volume from the HDOT traffic counts.

A positive error occurs when the forecast traffic volumes are higher than the actual traffic volumes; e.g. when there is an overestimation in traffic demand. A negative error occurs when forecast traffic volumes are lower than the actual traffic volumes; e.g. when there is an underestimation in traffic demand.

In the frequency plot the forecasting errors are divided into bins, each bin covers an interval within which the data points are counted. In this analysis a bin interval of 20 units was chosen. A data point is included in a particular bin if the number is greater than the lowest bound and equal to or less than the greatest bound for the data bin. For example, in the bin of 40 the cases with a forecasting error of 20% to 40% are included. The bin of -40 includes cases with a forecasting error of -60% to -40%.

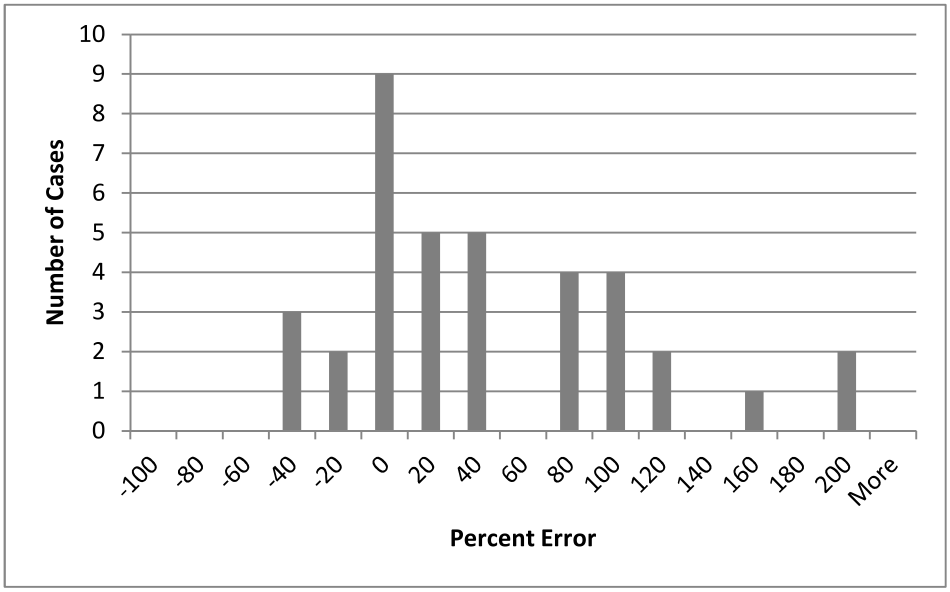


**Figure 5.24 - Frequency plot of inaccuracies in traffic demand forecasting.**

Based on the analysis, 14 out of the 37 cases are underestimated. Nine cases with an error of less than 20%, two cases with an error of less than 40% and three cases within the -60% to -40% range. The frequency plot also shows that 14 of the 37 cases are within ±20% error, a total of 21 of the 37 cases are within a ±40% error range. Considering the relatively simple tools used to forecast traffic demand in the TIARs and the high growth rates on Oahu this could be considered a “good” result.

Both the scatter plot and frequency plot show that there is a general tendency towards overestimation in traffic demand forecasting, with 23 of 37 cases being overestimated, five of these are within the 20%, 13 cases within the 20% to 100% range and five cases more than 100% overestimated. This tendency towards overestimation shows that consultants are conservative in their traffic demand forecasting. This is desirable compared to underestimation, because an underestimation of traffic volumes can cause severe unforeseen traffic conditions such as poor LOS and congestion.

Out of 37 cases 16 are overestimated by ±40% or more. These 16 cases are divided among seven projects – two road projects and five residential developments. The TIARs were prepared by 5 of the 7 consultants covered in this study. Most of the cases were prepared before 1990 with one exception – a case prepared in 2002. These cases cover both turning and through movements and are located throughout the island. All four types of forecasting method: 2$^{nd}$, 3$^{rd}$ and 6$^{th}$ edition of ITE Trip Generation and unknown (DNK) are represented in the 16 cases, and the forecast horizon varies from four to 18 years. Two projects – Haleiwa Bypass and Mililani Mauka Residential Community have all cases (two of two and four of four) represented in the 16 cases that are overestimated by more than ±40%. This suggests that traffic demand forecasting for these two projects was inaccurate. There does not seem to be any similarities or patterns between independent variables for the cases with an overestimation above ±40%.

The next step in the initial analysis requires the development of graphs to examine whether there are any patterns between TIAR volume error and the size of projects, measured by their forecast traffic volumes. Forecast traffic volumes are a proxy for the size of the project.

*Figure 5.25* includes all 37 cases and shows the same tendency as Figures *5.1* and *5.2***:** 13 cases, 35%, are within ± 20% error. *Figure 5.25* combines the two previous graphs by examining the relationship between the size of the project and percent error. The distribution of the cases indicates that: cases in the ±20% error range have a random error between percent error and size of project, because the cases are evenly distributed, there appears to be somewhat of a relationship between size of project and percent error for cases with a percent error greater than 40% with error being smaller for smaller projects.

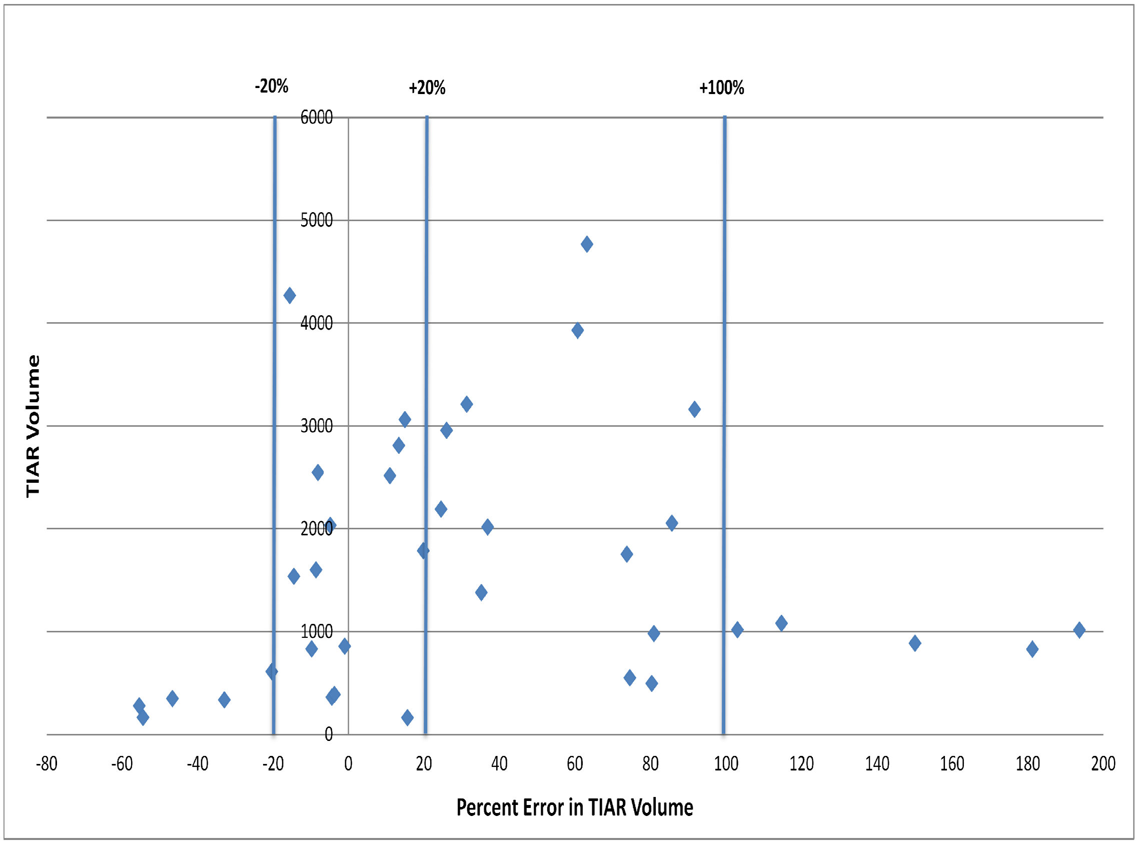


**Figure 5.25 - Relationship between percent error and size of project.**

The cases were divided into three groups based on their percent error in order to examine the previous findings more thoroughly. The first group covers cases that are in the ± 20% error range; the second group includes cases with ±21 – 99% error margin; the last group comprises the cases with a percent error greater than 100%.

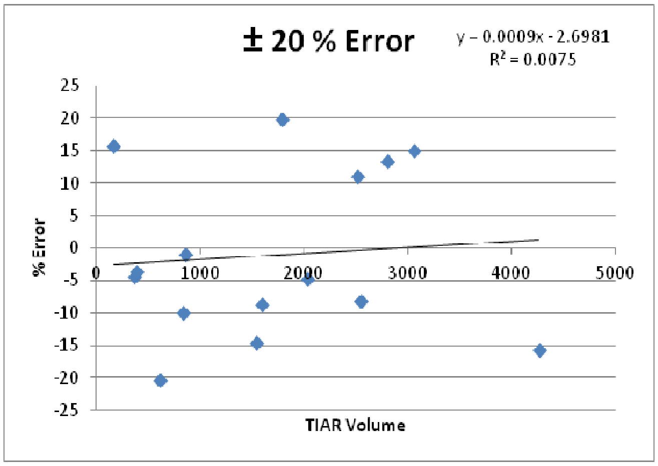


**Figure 5.26 - Project size and volume error for projects with ± 20 % error.**

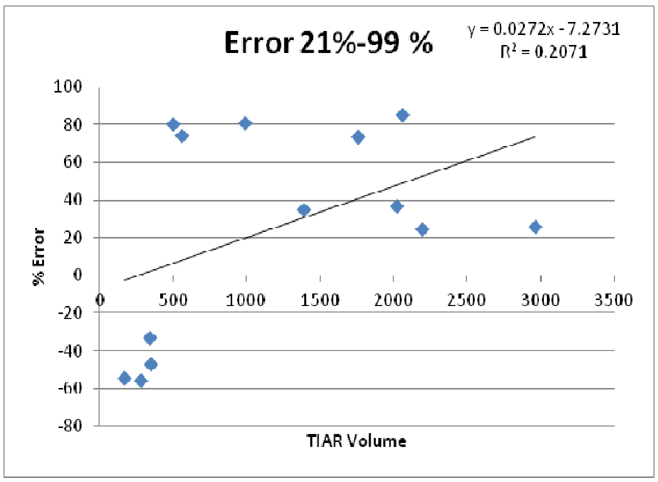


**Figure 5.27 - Project size and volume error for projects with ±21%-99% error.**

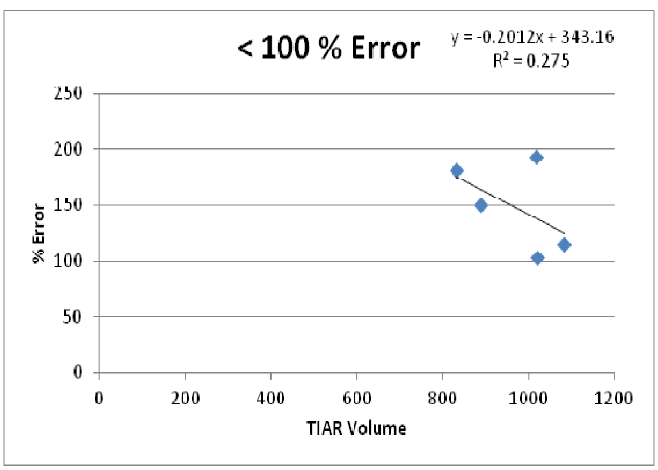


**Figure 5.28 - Project size and volume error for projects with >100% error.**

*Figure 5.26* shows that there is no correlation between the percent error and the forecast traffic volumes. Only 0.75% of the variation in percent error is explained by the size of the project in this error range.

*Figure 5.27* shows that the bigger the forecast traffic volumes, the bigger the percent error for projects with error in the ±21% to 99% range. A simple regression shows that about 21% of the variation in percent error is explained by the size of the project.

For cases with errors greater than 100%, *Figure 5.28* shows that the error decreases as the size of the project increases. A simple regression analysis shows that about 28% of the variation in percent error is explained by the size of project. It is important to note that this group consists of only five cases.

This initial analysis shows that there is a tendency towards overestimation in traffic demand forecasting on Oahu. Specifically, most cases are over- or underestimated within a ±40% range. There are no large underestimations for any of the projects examined. The illustrative analysis further suggests, based on visual investigation, that there is a random error in traffic demand forecasting for cases with a percent error within a ±20% range, and that the percent error increases as the size of the projects increase for cases in the 21-99% error range.

### *5.2 Quantitative Analysis*

The purpose of the quantitative analysis is to further study the data to determine which variables affect accuracy in traffic demand forecasting. As a part of the quantitative analysis several models were developed formulating traffic demand forecasting accuracy as a function of certain relevant variables. Traffic demand forecasting accuracy is measured both as percent and absolute error. The quantitative analysis uses the same data set as the illustrative analysis.

The basic functional form of the regression model estimated is

$$A = f(L, LTR, T, Y, H, M, C, PHV)$$

Where $A$ is the forecasting accuracy measured in either percent error or absolute error, $L$ is the project location, $LTR$ is the turning movement, $T$ is the type of project, $Y$ is the year of TIAR, $H$ is the forecast horizon, $M$ is the forecast method, $C$ is the consultant and $PHV$ is the size of project measured in peak hour volume.

Several regression models were developed; some of the models covered the entire dataset while other models were segmented and analyzed a homogenous portion of the cases. The segmented models use the same variables as the models covering the entire data set but separate an independent variable into intervals in order to further examine the data. Segmented models are created for a number of variables; however, not all of these models are included in the analysis because they were found to be statistically insignificant. The following independent variables are separated into categories or intervals for this analysis:

- Type of project (*T*)
  - Road projects
  - Residential developments
- Horizon year (*H*)
  - Forecast horizon more than 10 years
  - Forecast horizon less than 10 years
- Year of TIAR (*Y*)
  - Before 1990
  - After 1990
- Movement (*LTR*)
  - Through movements
  - Turning movements

Some of the models run in SPSS did not provide an outcome, and the segmented models that were based on a small number of cases, were omitted. The following sections describe the models which best explain the dependent variables "percent error in volume" and "absolute error in volume", defined by equations *(2)* and *(3)*.

Models 1, 5 and 6 cover the entire dataset; models 7 and 8 cover cases with the dependent variable absolute error of more or less than 300 respectively; models 2 and 9 cover road projects; model 10 covers residential developments; models 3 and 11 cover TIARs prepared before 1990; model 4 covers through movements; model 12 covers turning movements; and model 13 covers projects with a forecast horizon of less than 10 years.

First a Pearson's correlation between the two dependent variables and the independent variables is estimated to determine whether there is any dependency between the dependent and independent variables. The outcome of this correlation shows that there is no or very little correlation between the two dependent variables and the independent variables or between the independent variables. This means that there is no multi collinearity between the variables, which will result in more accurate β-values; the β-value of the individual independent variable is more reliable in this model, than in a model with high correlation between the independent variables.

**Forecast Volume: "Percent Error" is the Dependent Variable**

Four different models were created to analyze the accuracy in volume forecasts measured in percent error, to identify variables that affect forecasting accuracy, and the magnitude of their effect. Common for all four models in *Table 5.4* is that the intercepts are positive in the 12%-31% range, which means that the traffic forecast usually starts from an overestimated position. For independent variables included by SPSS' stepwise function, all β-values that are statistically significant at the 95% level are in bold and the β-values that are statistically significant at the 90% level are in italic. In all four models the variable Location North Shore is included and is significant at the 98-100% level. Location North Shore is overestimated by 107% on average; however, it is based on one project with two cases. This error may have been caused by “background growth rates” which were relatively high, but the “Keep the Country Country” movement apparently kept traffic growth in the North Shore to a minimum.

The models show that consultants have a tendency to be conservative in their analysis, and Consultant 2 is a repeat variable that explains the overestimation in traffic demand forecasting on Oahu. All the models are shown in *Table 5.4*.

Model 1 covers the entire data set, a total of 37 cases. This model shows that the percent error is affected by Location North Shore and Consultant 2. These two variables both explain a part of the overestimation of the percent error. As mentioned above, the variable Location North Shore is overestimated in all the models with percent error as the dependent variable. The independent variable Consultant 2 on average overestimates forecasting accuracy by a margin of 45.1%. The intercept also shows a tendency towards forecast overestimation. In this model, 18.7% of the variation in the model is explained by these two independent variables.

For the segmented models only three include statistically significant independent variables. The three models cover either road projects, projects forecasted before 1990 or the through movements. The models covering residential developments, forecasting horizons of less and more than ten years, projects forecasted after 1990, and turning movements either did not have an outcome or were based on very few cases and therefore omitted.

Model 2 analyzes only the cases that are classified as road projects. Here the only independent variable that SPSS allowed in the model is Location North Shore. This location is overestimated by 115.9% compared to other road projects, which on average have an overestimation of 12%, expressed in the intercept. In this model the independent variable Location North Shore is strongly statistically significant. It is based on 11 cases and 55.4% of the variation is explained by the model.

Model 3 covers the cases that are forecasted before 1990. This model is very similar to Model 1, with an intercept of 19.4, indicating a starting position of overestimation. Consultant 2 on average overestimates traffic demand forecasting by 49.7% and Location North Shore is on average overestimated by 108.5%. This model is based on 31 cases and 15.5% of the variation in the model is explained by the independent variables. The fact that this model is so similar to Model 2 indicates that forecasters have not improved forecasting accuracy in the cases forecasted after 1990.

Model 4 covers the cases with through movements. This model is based on 29 cases and 35.6% of the variation in the model is explained by the independent variable. Again the intercept shows that traffic demand forecasting accuracy starts from an overestimation position; in this model the accuracy is on average overestimated by 31.6% from the starting position. The independent variable Location North Shore accounts for an overestimation of 96.2% on average.

**Table 5.4 - Models with percent error in forecasted volume.**

| | All Projects | | Type of Project | | Year of TIAR | | Movement | |
|---|---|---|---|---|---|---|---|---|
| | Model 1 | | Model 2 | | Model 3 | | Model 4 | |
| | All cases | | Road | | Before 1990 | | Through | |
| | $R^2 = 0.187$ | | $R^2 = 0.554$ | | $R^2 = 0.115$ | | $R^2 = 0.356$ | |
| | N = 37 | | N = 11 | | N = 31 | | N = 19 | |
| Variable | $b_i$ | *p* % | $b_i$ | *p* % | $b_i$ | *p* % | $b_i$ | *p* % |
| Intercept | 19.3 | *92%* | 12.0 | 60% | 19.4 | 88% | 31.6 | **100%** |
| Location NS | 108.5 | **99%** | 115.9 | **100%** | 108.5 | **98%** | 96.2 | **100%** |
| Consultant 2 | 45.1 | **95%** | | | 49.7 | *93%* | | |

## Forecast Volume: "Absolute Error" is the Dependent Variable

Nine different models were developed to analyze the traffic demand forecasting accuracy measured in absolute error as shown in *Table 5.5.* All β-values that are statistically significant at the 95% level are in bold and the β-values that are statistically significant at the 90% level are in italics. All the models have a positive intercept. This means that the forecast volumes start at a position of overestimation. There are two repeat independent variables in the models where absolute error is the dependent variable: Consultant 2 and the size of the project measured in peak hour traffic volumes. Consultant 2 prepared 8 out of 37 cases or about 22%. Consultant 2 is included in four of the ten models and size of project is included in three of them. Consultant 2 overestimates forecasting volumes in the range of 567-766 vehicles, for the independent variable size of project, the bigger the project, the greater the overestimation. The overestimation is in the 14-27% range, meaning that for every 100 vehicles added to the forecast; the traffic demand forecast will be overestimated by 14-17 vehicles.

Models 5 and 6 both cover all 37 cases. Model 5 starts from an overestimating position of 177 vehicles, shown in a positive intercept. This model also includes movement, forecasting method TG-2e[1] and size of traffic. The variable movement indicates that turning movements lower the absolute error by 363 vehicles compared to through movements. The independent variable forecasting method TG-2e will lower the absolute error by 310 vehicles on average. The model also indicates that the bigger the project the greater the absolute error, expressed by the variable peak hour traffic. As peak hour traffic increases the absolute error increases by 11%. The model is based on 37 cases and 18% of the variance is explained by the model.

Model 6 covers all cases and the only independent variable included in this model is Consultant 2 (Note that there were seven consultants in the dataset). In this model the intercept is positive which means that the forecast starts from an overestimated position of 186 vehicles. The variable Consultant 2 will increase inaccuracy by 567 vehicles on average. Both the independent variable and the intercept are statistically significant at the 99% and 95% level respectively. The model explains 16.3% of the variation.

Two models were created to segment the dependent variable into models with an absolute error less than 300 vehicles and one with an absolute error greater than 300 vehicles. Model 7 covers the cases with an absolute error less than 300 vehicles. In this model the intercept is 23, meaning that the forecast starting position is an overestimation of 23 vehicles. The intercept is much smaller than that for the models covering all cases. This is expected because the absolute error in this model is lower than the other models. Location Central Oahu is the independent variable included in this model, the β-value is negative. This means that the absolute error for Location Central Oahu on average is

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[1] ITE Trip Generation 2nd Edition, 1979

lower by 251 vehicles. This model is based on 19 cases and 20.8% of the variation is explained by the model. This outcome may reflect reasonable background growth rates for the expanding Central Oahu population and residential developments.

Model 8 covers the cases with an absolute error greater than 300 vehicles. The intercept is greater than that in model 9, at 332 vehicles. The independent variable in this model is the size of project measured in peak hour volume. The β-value for the variable is 0.151, meaning that for every 100 vehicles added to the forecast volume the absolute error exceeds the mean by 15 vehicles. Model 8 is based on 18 cases, 16.1% of the variation is explained by the model. This follows the results of the illustrative analysis: the bigger the project, the greater the forecasting error.

Models 9 and 10 split the cases into road and residential development projects. The intercept in model 9 is 511, meaning that model 9 starts from an overestimate position of 511 vehicles. The independent variable movement is included in this model. For turning movements the error is 638 vehicles below the mean. Model 9 is based on 11 cases and 35.7% of the variation is explained by the model.

In model 10, which covers residential developments, the intercept is 129 vehicles also starting the model from an overestimation position. In this model, Consultant 2 on average overestimates the forecast for residential developments by 624 vehicles. Model 10 is based on 26 cases and 22.7% of the variation is explained by the model.

Model 11 covers cases that were forecasted before 1990. Again the intercept is positive and starts the forecast with an overestimation of 164 vehicles. For projects before 1990, Consultant 2 on average overestimates traffic volumes by 657 vehicles. In model 6 (all projects before and after 1990), the average overestimation by Consultant 2 was nearly 100 vehicles less. This indicates that Consultant 2 improved traffic volume forecasting accuracy in forecasts made after 1990. This model is based on 31 cases and 21.2% of the variation is explained by the model.

Model 12 analyzes the variable movement and covers the cases with turning movements. This model includes TG-2e as an independent variable; on average this variable overestimated turning movements by 559 vehicles. This likely indicates that early editions, such as TG-2e, tend to overestimate project generated traffic. ITE Trip Generation is currently in its 8th Edition. The intercept is positive, meaning that the forecast starts at an overestimate position of 75 vehicles. This model is based on 16 cases and 19.4% of the variation is explained by the model.

The final model, model 13, tests the independent variable forecast horizon. The cases are divided into forecast horizon of over or under ten years; a model is developed that covers only the cases with a forecast horizon of less than ten years. Model 13 also has a positive intercept; it estimates the starting overestimation to be 108 vehicles. The independent vehicle included in this model is Consultant 2; this variable overestimates forecasts on average by 766 vehicles. This model is based on 20 cases and it explains 27.2% of the variation in the data.

**Table 5.5 - Models with absolute error in forecasted volume.**

| | All Projects | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model 5 | | Model 6 | | Model 7 | | Model 8 | |
| | All cases 1 | | All cases 2 | | Abs. Error < 300 | | Abs. Error > 300 | |
| | $R^2 = 0.229$ | | $R^2 = 0.163$ | | $R^2 = 0.208$ | | $R^2 = 0.161$ | |
| | N = 37 | | N = 37 | | N = 19 | | N = 18 | |
| | $b_i$ | *p* % | $b_i$ | *p* % | $b_i$ | *p* % | $b_i$ | *p* % |
| Intercept | 177 | 47% | 186 | **95%** | 23 | 24% | 332 | 85% |
| Location Central Oahu | | | | | -251 | **97%** | | |
| Movement | -363 | **95%** | | | | | | |
| Method 2ed | 310 | 56% | | | | | | |
| Consultant 2 | | | 567 | **99%** | | | | |
| PH Traffic | 0.111 | 69% | | | | | 0.151 | **95%** |

| | Type of Project | | | | Year of TIAR | | Movement | | Horizon | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Model 9 | | Model 10 | | Model 11 | | Model 12 | | Model 13 | |
| | Road | | Res. Dev. | | Before 1990 | | Turn | | Less than 10 years | |
| | $R^2 = 0.357$ | | $R^2 = 0.227$ | | $R^2 = 0.212$ | | $R^2 = 0.194$ | | $R^2 = 0.272$ | |
| | N = 11 | | N = 26 | | N = 31 | | N = 16 | | N = 20 | |
| | $b_i$ | *p* % | $b_i$ | *p* % | $b_i$ | *p* % | $b_i$ | *p* % | $b_i$ | *p* % |
| Intercept | 511 | **99%** | 129 | 71% | 164 | *90%* | 75 | 43% | 108 | 62% |
| Location Central Oahu | | | | | | | | | | |
| Movement | -638 | **97%** | | | | | | | | |
| Method 2ed | | | | | | | 559 | **95%** | | |
| Consultant 2 | | | 624 | **99%** | 657 | **100%** | | | 766 | **99%** |
| PH Traffic | | | | | | | | | | |

### *5.3 Three-way Comparison*

Flyvbjerg conducted a study of 210+ transportation infrastructure megaprojects; the projects are located in 14 countries on five continents and were worth approximately $59 billion in actual costs in 2006 prices. The projects were completed between 1969 and 1998 [2]. His study includes urban rail, high speed rail, conventional rail, bridges, tunnels, highways and freeways. Another study from Minnesota by Levinson and Parthasarathi [3], analyzed projects with a horizon forecast year of 2010 or earlier located in the Twin Cities metro area (Minneapolis-Saint Paul, Minnesota). The analysis included 2984 roadway segments.

Only the findings regarding road projects (183 projects) from the study conducted by Flyvbjerg are included in the three-way comparison. This enables comparison between the findings from the worldwide study, the findings on Oahu and those in Minnesota. Demand forecasting for rail and road/residential development projects, respectively, is very different, and where demand forecasting for road and residential developments is very common, rail project forecasting is not.

In the analysis of worldwide road projects it is found that there is an average underestimation in traffic forecasting of 8.7%, resulting in actual traffic volumes higher than the forecasted traffic volumes. *Fig. 5.29* shows that one-half of the road projects have a forecasting error of more than ±20% and one-quarter of more than ±40%. There is no significant difference between the frequency of overestimated and underestimated forecasts with 21.3% of the projects being underestimated by more than -20%, and 28.4% overestimated by more than 20%.

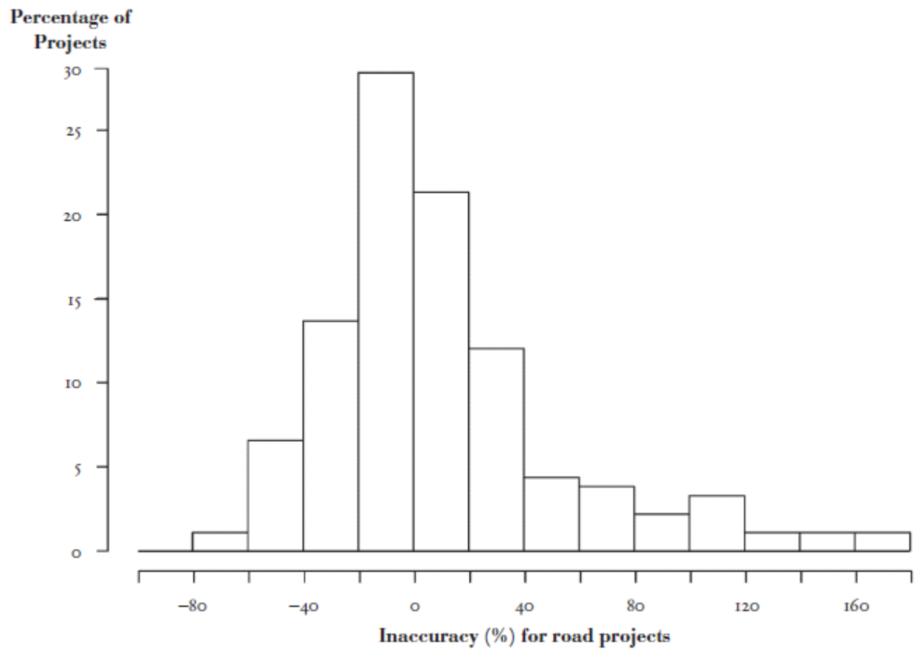


**Figure 5.29 - Frequency plot of inaccuaries in travel demand forecasting for road projects only [2].**

This study also investigated whether traffic demand forecasting has become more accurate over the 30-year time period analyzed. The conclusion was that is not the case. On the contrary, forecasting became more inaccurate, with larger traffic underestimations towards the end of the period.

In the Levinson and Parthasarathi study, there is a trend of underestimation in roadway forecasts as well. This means that actual traffic volumes were often higher than the forecasted traffic volumes. *Figure 5.30* shows that 56% of the cases in the database are underestimated and 44% of the cases are overestimated. However in this study the distribution of forecasting errors is not great, 46% of the cases are in the range of a −0.5% to 0.0% difference between forecasted and actual traffic volumes. Only 9.5% are underestimated by more than -0.5% and 0.2% of the cases are overestimated by more than 6%.

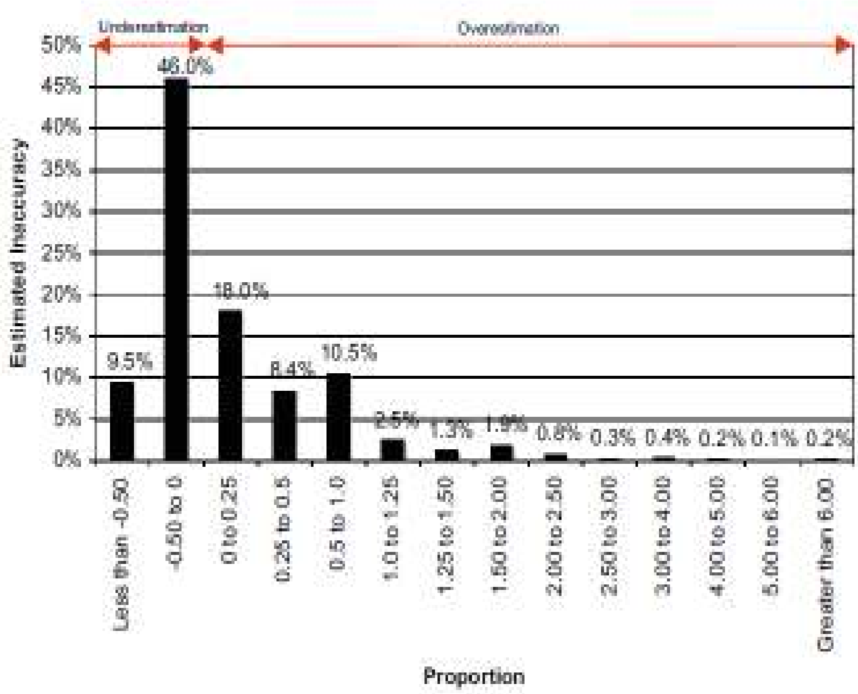


**Figure 5.30 - Frequency plot of inaccuracies in travel demand forecasting for Minnesota [3].**

This study also developed models to examine which factors affect traffic demand forecasting accuracy. Independent variables such as the number of years between report year and forecast year, roadway type, functional classification, project size measured in VKT, direction, decade of report preparation and roadway status. Four models were developed and the analysis showed that the number of years between report and forecast year is statistically significant in all models, with a negative β-value, indicating that the longer the forecast horizon, the smaller the forecasting error. Also the variables location and roadway type were repeat variables that were statistically significant in the four models. Project size was only significant at the 90% level in one model and had a negative β-value. For all models the intercept is positive and is statistically significant in three of four models.

In the analysis of traffic demand forecasting accuracy on Oahu it was shown that the forecast traffic volumes are higher than the actual ones recorded by HDOT, on average the cases are overestimated by 35% for both road projects and residential developments. For road projects only the average overestimation is 33%.

The study of mega-projects covers projects constructed between 1969 and 1998; it does not provide a forecast horizon. However since the study only covers mega-projects it is reasonable to assume a forecast horizon of 20 years to 50 years. The study of Minnesota roadway segments cover projects prepared and built between 1963 and 1991, they have a forecast horizon between 3 years and 25 years with one outliner of 86 years. The average forecast horizon is 17.5 years, four projects had a forecast horizon between three and four years, zero projects had a forecast horizon between 6 and 10 years, 31 projects had a forecast horizon between 11 and 15 years, 32 projects had a forecast horizon between 16 and 20 years, 38 projects had a forecast horizon between 21 and 25 years and one project had a forecast horizon of 86 years.. The study of forecasting accuracy on Oahu covers projects prepared and built between 1976 and 2002; the projects have a forecast horizon between 4 years and 32 years with an average forecasting horizon of 11.5 years. The frequency in forecasting horizon for the Oahu study of forecasting accuracy is shown in *Figure 5.31.*

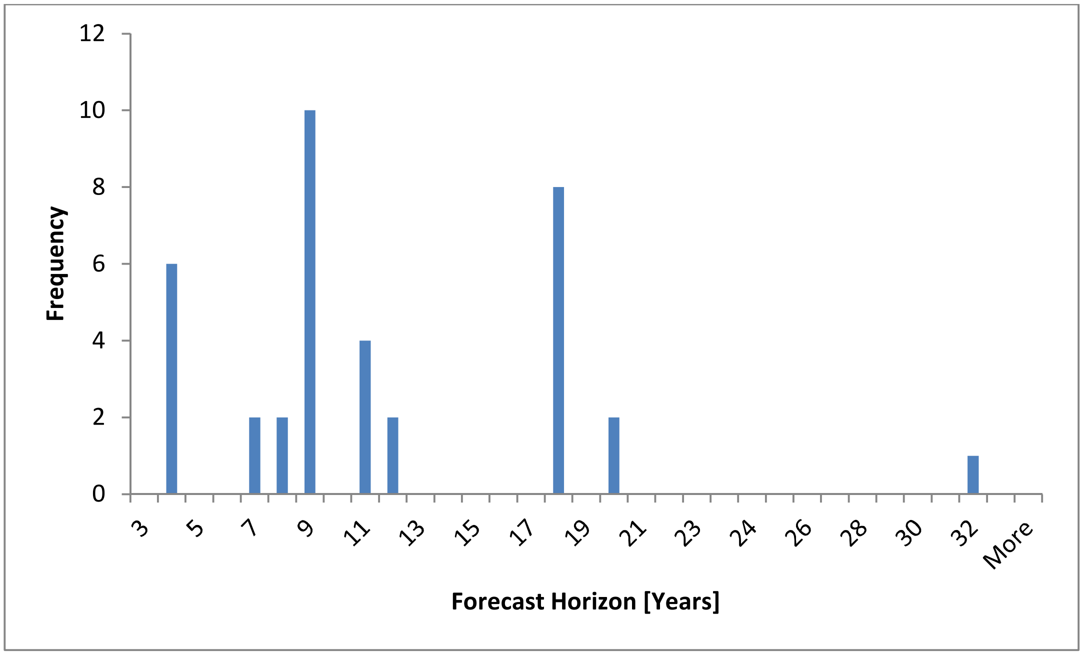


**Figure 5.31 – Forecast Horizon Frequency**

The time period and forecast horizons for all three studies are in the same range, with the Flyvbjerg study and the study by Levinson and Parthasarathi both covering projects prepared between the 1960s and 1990s, the study on Oahu covering projects prepared ten years later. The study from Minnesota cover projects with an average forecast horizon of 17.5 years, on Oahu the average forecast horizon is 11.5 years and the study of mega-projects does not provide forecast horizons.

The study by Flyvbjerg, and the study by Levinson and Parthasarathi show a tendency towards underestimation, but this underestimation is not large. For the Flyvbjerg study the average underestimation is 8.7%. The study by Levinson and Parthasarathi does not provide an average over- or underestimation; however 46% of all the cases are within the -0.5-0% range, only 9.5% are underestimated more than -0.5% and only 0.2% are overestimated by more than 6%, indicating a fairly small underestimation in traffic demand forecasting accuracy in Minnesota. The analysis for Oahu shows an average forecasting overestimation for road projects of 33%, which is very different from the findings in the other two studies.

In the quantitative analysis different variables are tested in the Oahu study and Minnesota study. Both studies found that forecasting started from an overestimation position; both studies also included location in the models.

# CHAPTER 6 – SUMMARY AND CONCLUSION

This chapter contains a summary of the analysis results and a discussion of the findings for the illustrative and quantitative analysis as well as for the three-way comparison. The discussion includes comparisons of models where relevant, and commonalities and patterns in the findings. Recommendations and lessons learned are in the conclusions.

## *6.1 Summary*

The graphs created in Excel and the stepwise regression models created in SPSS show the same trend: a tendency towards overestimation of traffic forecasts on Oahu between 1980 and 2002. The average overestimation is 35% or more than one third of the forecast volume. Fourteen out of the 37 cases, or 38%, were underestimated: nine cases with an error of less than -20%, two cases with an error of less than -40% and three cases within the -60% to -40% range. The frequency plot also shows that 14 of the 37, or 38%, of the cases are within the ±20% error range, and that a total of 21 of the 37 of the cases, or 57%, are within the ±40% error range. Compared to the two other studies the inaccuracy on Oahu is larger, again showing that traffic forecasting on Oahu is highly inaccurate and could be conducted better. When a metropolitan area such as the Twin Cities can conduct traffic forecasting with accurate results, it should be possible for Oahu to improve traffic forecasting accuracy as well.

About 43% of the Oahu traffic forecasts are over- or underestimated by more than 40%. In the illustrative analysis, the cases with a forecasting error greater than 40% are compared, to see if there are any patterns or commonalities which could account for this large inaccuracy. The comparison showed that there are no commonalities in the variables that would explain the inaccuracy: most of the consultants (5 of 7) are represented, all forecasting methods, and a forecasting horizon of four to 18 years are included, the location of the cases is across the entire island (except for urban Honolulu), and both turning and through movements are represented.

The only variable that offers some explanation is forecast year. All but one case were forecast before 1990; however, this idea is rejected when analyzed with quantitative analysis. Models 1, 3, 6 and 11 cover all cases and cases forecasted before 1990. All the models included the same variables and the magnitudes of the β-value are very similar; this indicates that forecasting accuracy has not improved since 1990.

The study by Flyvbjerg also investigated whether forecasting has become more accurate over time. Their conclusion is actually the opposite. Forecasting has become more inaccurate over the years. This is not the case for Oahu, where forecasting accuracy has remained at the same poor level throughout the years. This means that traffic forecasting has been conducted the same way as usual for a long time, without any evaluation of performance and improvement.

For two projects, the Haleiwa Bypass and the Mililani Mauka Residential Community, all the traffic demand estimations are outside the ±40% error range, meaning that traffic demand forecasting for these two projects was inaccurate by a large margin. However, when the six estimates from these two projects are omitted there is still no pattern in the variables that explains inaccuracies in the remainder of the cases.

The four residential development projects with inaccuracies larger than ±40% that are located in Central Oahu had their TIAR done in the early to mid 1980s. They all had a large distribution of forecasting accuracy, varying from a -55% underestimation to a

194% overestimation within the same project. This means that there was no pattern in forecasting accuracy and the forecasted volumes had very little credibility. In the late 1980s TIARs for three residential development projects located in the Kapolei area were prepared. This time the distribution of the forecasting inaccuracy was smaller, with one outlier of 150%. Including the outlier, the distribution of inaccuracy decreased from an average spread between lowest estimate and highest estimate of 140% to 84%. In the TIAR for a residential development prepared in 2002 the spread is relatively small at 39%.

The illustrative and quantitative analysis showed that there has not been improvement in traffic forecasting accuracy over the years. Hence this finding shows that even though the distribution of inaccuracy has improved, the overall traffic forecasting has not. Instead of the large over- and underestimations in the early to mid 1980s, traffic forecasting became more one-sided, with a tendency to only overestimate traffic volumes in the projects prepared later. A reason why forecasting accuracy became more one sided with a strong tendency towards overestimation is that the expected growth on Oahu did not occur or it happened in other areas than expected.

There has been improvement in traffic forecasting when it comes to underestimation; projects prepared in the early to mid-1980s had forecast volumes underestimated with as much as -56%, leading to severe traffic congestion because the road infrastructure was not designed to carry this amount of traffic. In the late 1980s the low estimate was no longer a large underestimation; in many cases the low estimate for a project was either a small over- or underestimation instead. However the tendency to greatly overestimate traffic volumes continued, preventing the overall inaccuracy in traffic demand forecasting to improve. This tendency must be altered, because when traffic volumes are overestimated roadways will be oversized, which is a waste of scarce public funds. *Table 6.6* shows the forecasting error range.

**Table 6.6 - Range of forecasting accuracy**

| TIAR Title | Location | Project Type | Year | Lowest Estimate | Highest Estimate | Error Range |
|---|---|---|---|---|---|---|
| **H3** | Central Oahu | Road | 1976 | - | 15 | - |
| **Haleiwa Bypass** | North Shore | Road | 1981 | 74 | 181 | 107 |
| **Sand Island Access Road Widening and Improvement** | Honolulu | Road | 1982 | -20 | 26 | 46 |
| **476 acre development at Mililani Town** | Central Oahu | Residential Development | 1983 | -33 | 31 | 64 |
| **Mililani Mauka Residential Community** | Central Oahu | Residential Development | 1984 | -55 | 194 | 249 |
| **Waikele Development** | Central Oahu | Residential Development | 1986 | -56 | 103 | 159 |
| **Waikele Development** | Central Oahu | Residential Development | 1986 | -4 | 86 | 90 |
| **West Loch Estates North** | Ewa | Residential development | 1987 | 13 | 80 | 67 |
| **West Loch Estates South** | Ewa | Residential development | 1987 | -15 | 150 | 165 |
| **Ewa Gentry** | Ewa | Residential development | 1988 | 37 | 63 | 26 |
| **Kahekili Hwy** | Windward | Road | 1990 | -10 | 92 | 102 |
| **Gentry Ewa Makai** | Ewa | Residential development | 2002 | 35 | 74 | 39 |

Both the illustrative and quantitative analysis showed that the larger the project, the larger the forecasting error. The result shows that consultants on Oahu are better at forecasting traffic volumes for smaller projects than they are for large projects. This could be because the ITE tools are more suitable for forecasting traffic demand for smaller projects compared to large ones, or consultants are better at forecasting traffic volumes for small projects compared to large projects.

The quantitative analysis shows a trend towards starting the traffic demand forecast from an overestimation position; this is proven through a positive intercept. Even though a wide range of variables were included in the regression analysis, not many had an impact on forecasting accuracy that was statistically significant, and thus they were not included in the models. This means that there are variables not included in the regression analysis that could explain forecasting inaccuracy. The variables included in the analysis are variables that were fairly easy to identify and collect, indicating that the forecasting error lies in assumptions not explicitly mentioned and described in the EISs and TIARs. They include the ITE Trip Generation models and the OMPO, HDOT, City or Consultant assumptions about background growth. The finding that inaccuracy in traffic forecasting on Oahu is not explained by the variables tested in the analysis, but rather affected by the assumptions included in the forecasting models follows the previous literature on the subject, stating assumptions included in forecasting models are one of the main reasons for forecasting inaccuracy.

The Flyvbjerg study [2] and Levinson and Parthasarathi [3] study suggest that inputs such as demographic, geographic and socio-economic factors are important for forecasting accuracy. The projects analyzed for this study did not incorporate demographic, geographic and socio-economic inputs.

The regression analysis revealed that only a few variables correlate to forecasting error. A few variables that emerged in the regression analysis are Consultant 2, Location North Shore and accuracy improvement over the years – or lack thereof.

The analysis also includes a three-way comparison which shows that the traffic demand forecasting trend on Oahu differs a lot from two other studies that investigated traffic forecasts vs. actual traffic volumes. On Oahu there is a strong trend towards forecasting overestimation, the studies by Flyvbjerg, and Levinson and Parthasarathi show a trend towards underestimation; also the distribution of forecasting accuracy is smaller for the other two studies compared to the Oahu study. Compared to the study of mega projects across the world, the forecasts on Oahu are four times worse. In Minnesota a study of forecasting accuracy was conducted in the 1980s, back then the percent error was close to 20%. Obviously the results of that study lead to changes, because now more than 70% of the cases are within ±0.5% accuracy. A comprehensive evaluation of traffic forecasting on Oahu is very much needed to improve the process and improve forecasting accuracy.

There are several possible explanations for the large overestimation on Oahu, and one of the most significant is the large variance in circumstances under which traffic forecasting is conducted. On Oahu most development has been green field and in high growth areas. In Minnesota, however, high growth rates are not an issue, with a 6.1% growth in population from 2000 to 2010 [21].

Another source for forecasting inaccuracy is the modal split. When comparing the modal split on Oahu to the United States it is observed that the percentage of people using automobiles is about the same for Hawaii and the United States. However on Oahu

46.2% carpool when commuting to work, for the United States that percentage is only 10%. The percentage of people using transit is about the same at 5%, on Oahu the percentage of people biking is about twice as high as for the United States and the percentage of people walking is more than three times higher for Oahu compared to the rest of the country [22, 23]. *Table 6.7* shows the modal split.

**Table 6.7 - Modal split in the United States and Oahu**

| | | Oahu | The United States |
|---|---|---|---|
| Automobile | Total | 84.2 | 86.1 |
| | Drive alone | 38 | 76.1 |
| | Carpool | 46.2 | 10 |
| Transit | | 5.2 | 5 |
| Bicycle | | 1.1 | 0.6 |
| Pedestrian | | 9.6 | 2.9 |

In the ITE Trip Generation it is assumed that 100% of the generated trips are by cars with an average occupancy of 1.2 people per vehicle. That is not the case for Oahu; here 46.2% of all trips are carpools with an average of 2.4 people per vehicle. Also on Oahu the percentages of biking and walking are higher compared to the mainland. When taking carpooling into account the average vehicle occupancy is 1.8 people per vehicle, which is 50% higher than the average occupancy of 1.2 people per vehicle assumed by ITE Trip Generation. This shows that the standard modal split provided in ITE is inappropriate for Oahu.

Finally the study of international mega-projects is special. Megaprojects will never become routine and experiences from one project cannot easily be transferred to another.

The only mega-project included in the Oahu study is the H-3 Freeway. The final EIS for this project was prepared in 1976 and had a 32 year forecasting horizon to 2008. The forecasting error for this project is an overestimation of 15% or close to 400 vehicles in the am peak hour. The overestimation for this project is less than half the average overestimation on Oahu. However, it differs significantly from the average forecasting error of -8.7% found in the Flyvbjerg study [2]. This single data point hints that traffic forecasting on Oahu may be more accurate for a road mega-project compared to other projects.

Historically there has been a tendency towards large traffic forecasting errors on Oahu; there are several possible reasons for that. Oahu's population is expected to grow by 23% from 2007 to 2035; in order to accommodate previous growth there has been a tendency for mostly green field developments such as Mililani Town and Kapolei. It is more difficult to predict travel patterns for green field developments compared to brown field or infill developments. Green field developments occur in areas that are undeveloped such as farmland, forests or fields located close to urban areas. Brown field development is development or redevelopment in areas that might be compromised by the presence of environmental contamination [24]. Infill development is redevelopment or development of areas that have remained vacant, or is underutilized compared to the surrounding land use activities [25]. The uncertainty for green field development is higher, leading to greater inaccuracy in traffic forecasting. Some reasons why there is a higher uncertainty in traffic forecasting for green field developments are: uncertain growth rates in the area, uncertainty in the future land use for surrounding projects, uncertainty in future transportation improvements and higher sensitivity to economic shocks.

The analysis so far showed large problems with traffic forecasting accuracy on Oahu between 1976 and 2002. Three brief analyses were conducted to investigate this forecasting inaccuracy further. The first is an interisland comparison of road project traffic forecasting accuracy among the Hawaiian Islands. The second is an analysis into the impact of diurnal patterns (day of the week and month) on forecasting error. The third is an investigation into ITE Trip Generation forecasting models.

**Interisland Comparison**

In 2005 the Statistics Unit of HDOT's Planning Section conducted an internal analysis of traffic forecasting accuracy throughout the Hawaiian Islands. The Statistics Unit processed 116 traffic forecasts prepared in 1995. Cases that did not include the construction of H-3 Freeway in the TIAR were omitted from this analysis because H-3 Freeway was completed and opened to traffic in 1998. The final dataset comparing forecasting accuracy between the islands consisted of 108 cases, 29 cases from Oahu, 9 cases from Molokai, 31 cases from Maui, 21 cases from Kauai, 14 cases from Hawaii and 4 cases from Lanai, respectively. Actual daily traffic data were collected in 2005 and these traffic volumes were compared to the project forecast volumes.

*Table* 6.8 shows the maximum, minimum and average error in both percent and absolute error for all the islands.

**Table 6.8 - Interisland Comparison of Forecasting Accuracy**

| | | Percent Error | | | Absolute Error | | |
|---|---|---|---|---|---|---|---|
| **Island** | **No. of Projects** | **Max Error** | **Min Error** | **Avg. Error** | **Max Error** | **Min Error** | **Avg. Error** |
| **Oahu** | 29 | 122 | -23 | 34 | 79693 | -10685 | 17106 |
| **Molokai** | 9 | 355 | 30 | 82 | 4432 | 444 | 1899 |
| **Maui** | 31 | 90 | -23 | 15 | 25926 | -4535 | 3169 |
| **Kauai** | 21 | 63 | -11 | 15 | 10593 | -948 | 2440 |
| **Hawaii** | 14 | 43 | -4 | 13 | 8770 | -281 | 1507 |
| **Lanai** | 4 | 13 | -46 | -4 | 350 | -918 | -90 |

The internal analysis of project forecasts by HDOT shows that Molokai has the largest percent error among the islands, with an average forecasting error of 82%. Molokai is followed by Oahu with an average forecasting error of 34%. When looking at the absolute error, Oahu has the largest forecasting error of 17,106 vehicles daily of volume overestimation. This is followed by Maui with an average overestimation of 3,169 vehicles daily.

The analysis shows that projects on all the islands, except Lanai, tend to have overestimated traffic volumes. Lanai on average had underestimated traffic forecasts by 4%. However, only four cases from Lanai were analyzed. The comparison between the islands also confirm the trend from Oahu, that traffic forecasts are mostly overestimated, and in some cases the low estimate is still an overestimation in traffic forecasting. *Figure 6.32* and *Figure 6.33* illustrate these comparisons.

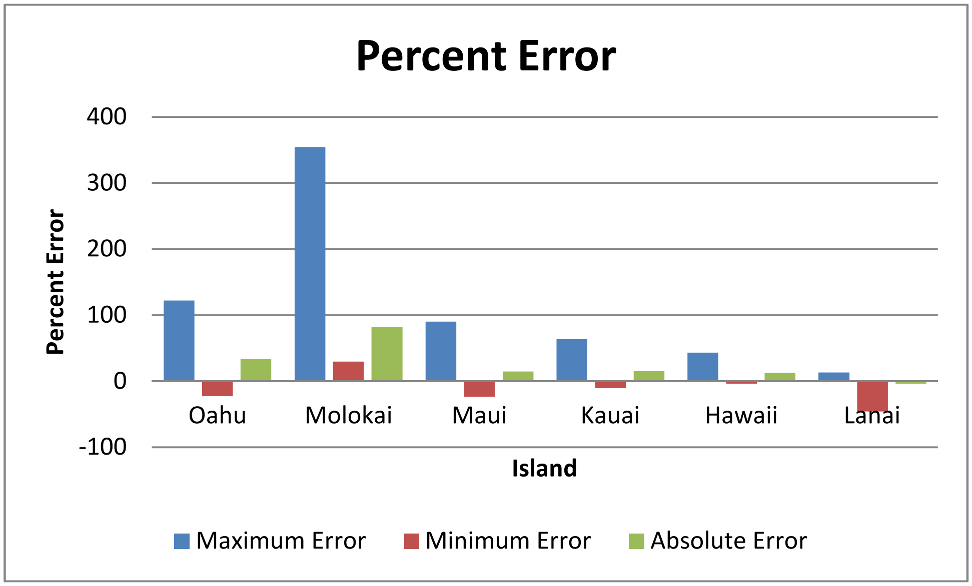


**Figure 6.32- Interisland Comparison: Percent Error**

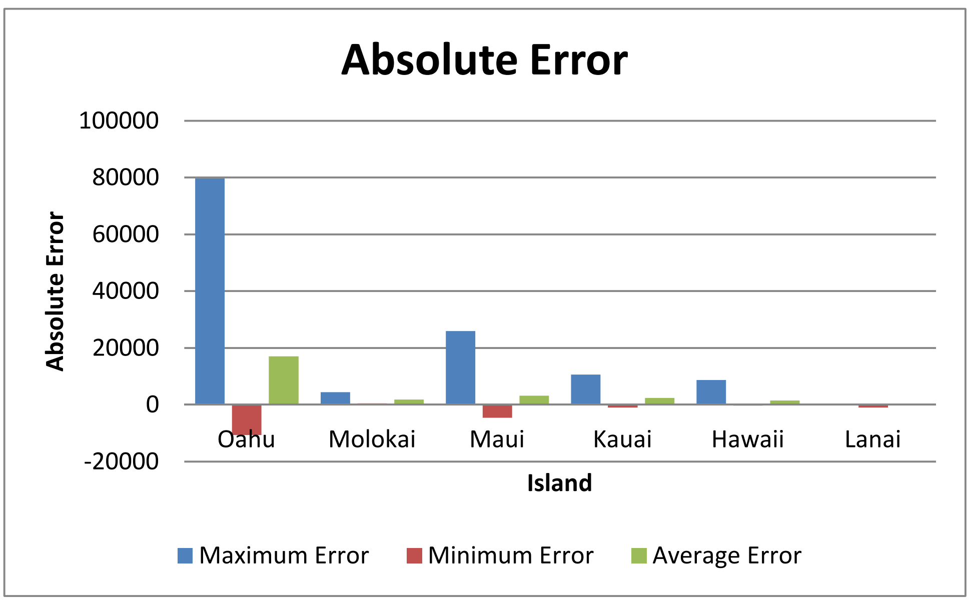


**Figure 6.33 - Interisland Comparison: Absolute Error**

### Monthly Variation: Haleiwa Bypass

The analysis showed that Haleiwa Bypass has very large forecasting errors, with an average overestimation of almost 130%. HDOT uses International Road Dynamics (IRD) data stations to record real-time traffic volumes at specific locations throughout the islands. One of the locations is the Haleiwa Bypass, making it possible to create a monthly profile of traffic forecasting error. This is done to analyze if month-to-month has an impact on traffic forecasting error. Actual am peak hour traffic counts were taken on one Tuesday and one Wednesday for every month in 2011. The analysis showed that there was no big difference between traffic volumes recorded on Tuesdays compared to Wednesdays, indicating that day of recording does not have an effect on traffic forecasting error. Tuesday data were used to create the monthly forecasting error profile.

The TIAR forecast year is 2001, so the forecast traffic volume was updated to 2011 using the annual growth rate for the North Shore provided in *Table 3.1*. *Figure 6.34* shows the monthly error variation.

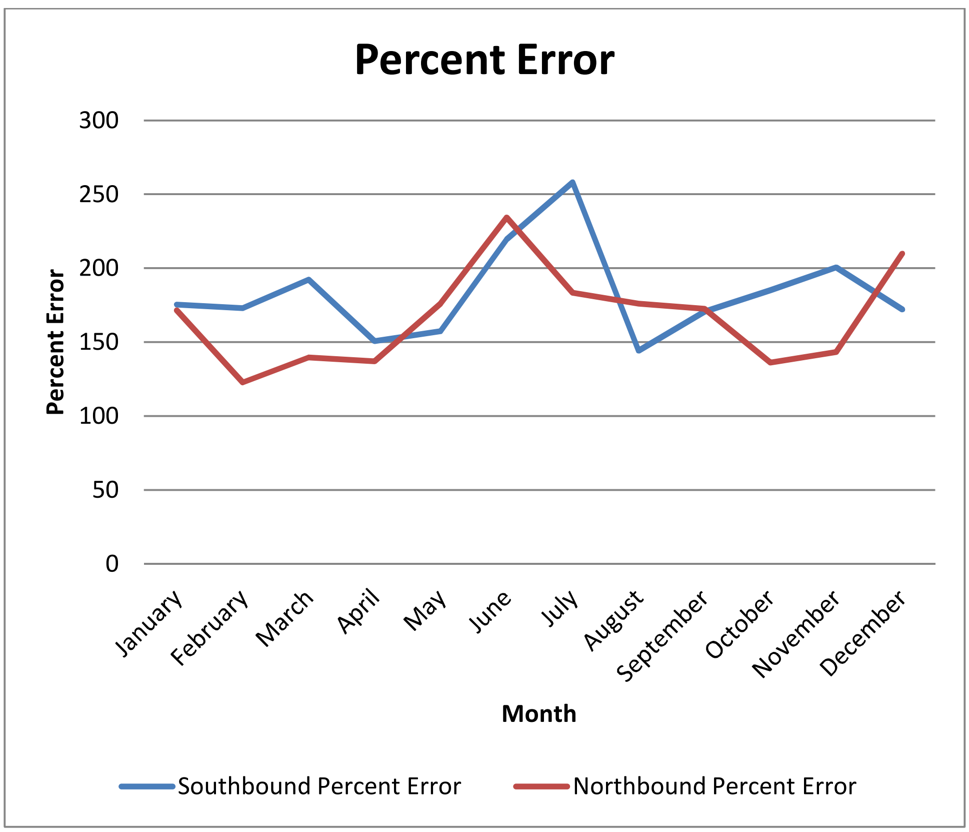


**Figure 6.34 - Monthly Variation: Haleiwa Bypass**

The data collected throughout 2011 show an average forecasting error of 163% and 180% for Northbound and Southbound traffic respectively, with a minimum error of 123% recorded in February Northbound direction, and a maximum error of 258% recorded in July Southbound direction. The analysis shows that there is a variation in forecasting error throughout the duration of a year, with the biggest forecasting errors in the summer. This indicates that month of actual traffic recording has an effect on forecasting error. During the summer months, traffic volumes decrease on weekdays, making the forecasting error greater.

During the busiest tourism month of August weekend traffic was analyzed as well. This was done to investigate if tourism has a significant impact on forecasting accuracy. Actual am peak hour traffic volumes from each Saturday during August in 2011 were selected and compared to the forecasted traffic volumes. The TIAR 2001 traffic volumes were updated to 2011 using the annual growth rate provided in *Table 3.1*. *Table 6.9* shows the percent error on weekends during the month of August.

**Table 6.9 – Percent Forecasting Error during Peak Tourism Month by Direction and Weekday or Weekend**

| | | **Average Error August** | **Avg. Yearly Error** |
|---|---|---|---|
| **Northbound AM Peak Hour** | Tuesday | 176 | 163 |
| | Saturday | 105 | |
| **Southbound AM Peak Hour** | Tuesday | 144 | 180 |
| | Saturday | 335 | |

The analysis of tourism's impact on traffic forecasting accuracy shows that during summer months weekday traffic decreases, making the forecasting error for the Haleiwa

Bypass project even greater compared to the 2011 average error. During weekends traffic volumes increase making the forecasting error smaller than the 2011 average error. The forecasting error for Northbound is decreased by 58% and the Southbound forecasting error is increased 155% during the summer. Tourism related traffic impacts traffic conditions differently than regular traffic. In this analysis the “heavy” movement changes direction and more traffic is Northbound compared to Southbound, which is the opposite of the forecasted trend that assumed 60% of the traffic would be southbound. In areas with high levels of tourism, the impact of tourism related traffic should always be taken into account. Forecasters should be aware of the possibility that tourism related traffic behaves differently than traffic generated by employment and households, and that this traffic could generate the critical traffic flows.

**ITE Trip Generation Models**

Most projects included in the analysis were based on the ITE Trip Generation Method. In the statistical quantitative analysis ITE Trip Generation 2$^{nd}$ Edition was included in several models, as a variable that affected forecasting accuracy. In this section Trip Generation rates from several ITE Trip Generation Editions are compared to investigate if there has been an improvement in the trip generation rates over time. The data that are compared in this analysis is the data for Single-Family Detached Housing (210) on weekdays. The trip generation rates from four editions are compared, they are the 4$^{th}$ from 1987, 5$^{th}$ from 1991, 7$^{th}$ from 2003 and 8$^{th}$ edition from 2008. The 2$^{nd}$ Edition of the ITE Trip Generation Method from 1979 could not be found for this analysis. It is fair to assume that the average generation rate, standard deviation and number of cases the study is based on is the same or at or poorer level than the 4$^{th}$ Edition. The summarized data can be found in *Table 6.10 - Trip Generation Rates* and the complete data sheets can be found in *APPENDIX B: ITE DATA SHEET.*

The analysis shows that there has been an improvement over time in the ITE Trip Generation Editions. However, there has not been a change between the 7$^{th}$ and 8$^{th}$ Edition, except that the 8$^{th}$ edition is based on an extra case. This indicates that ITE regards the data to be representative and accurate and that there is no need to improve the trip generation rates for single-family detached housing. The trip generation rate has decreased a little which would result in lower forecast levels; the standard deviation has also decreased over time making the trip generation estimate more accurate and the number of studies the rates are based on has increased over time. If it is assumed that the same trend happened in the earlier editions as well, then the average trip rate in the 2$^{nd}$ Edition should be higher – increasing forecasted traffic levels, the standard deviation should be greater – increasing the inaccuracy of the estimate and it should be based on fewer studies. The brief analysis shows that forecasting methods have improved over time, and that the forecasted estimate has become more accurate in newer editions of the ITE Trip Generation Method.

**Table 6.10 - Trip Generation Rates**

| ITE Trip Generation Edition | Average Trip Rate | Standard Deviation | Number of Studies |
|---|---|---|---|
| **4$^{th}$** | 10.062 | 4.36 | 320 |
| **5$^{th}$** | 9.55 | 3.66 | 348 |
| **7$^{th}$** | 9.57 | 3.69 | 350 |
| **8$^{th}$** | 9.57 | 3.69 | 351 |

### *6.2 Conclusion*

The study revealed several patterns in traffic forecasting, as well as possible reasons for inaccuracy in traffic forecasting on Oahu. They are listed below:

- Forecasting model: Different models are appropriate in certain situations; the choice of an inappropriate model can affect traffic forecasting accuracy. In this analysis ITE Trip Generation 2$^{nd}$ Edition was a variable in several models.
- High growth rates: On Oahu there is high growth in population, employment and tourism. These high growth rates makes forecasting difficult compared to situations or areas with modest growth.
- Green field developments: It is more difficult to predict travel patterns for green field developments compared to brown field or infill developments.
- Bias for projects: It is almost always possible to adjust the assumptions to meet the demands of client. Forecasters tend to view themselves as neutral technical experts whose responsibility is to provide work that meets their client's best interest. They also have to serve the public's best interest which may be distorted by the perception of political decision makers.
- Lack of evaluation: On Oahu the average forecasting error is much higher compared to the other two studies analyzed. In Minnesota a study of forecasting accuracy displayed large forecasting errors. After that time improvements and changes must have been made to the forecasting process, because now more than 70% of the cases are within ±0.5% accuracy.
- No improvement in traffic forecasting over time: Forecasting accuracy on Oahu has remained at the same poor level throughout the years.

- No pattern in forecasting accuracy: There was no pattern in forecasting accuracy on Oahu, and the forecasted volumes had very little credibility. Forecasts from the same projects had both large over- and underestimations.
- One-sided inaccuracy: In the early 1980s forecasts were both largely over- and underestimated, traffic forecasting in the late 1980s became more one-sided, with a tendency to only overestimate traffic volumes. This is confirmed by the project from 2002, which only have forecasting overestimations. However, only one project prepared after 2000, was included in the study. A reason why forecasting accuracy became more one sided with a strong tendency towards overestimation is that the expected growth on Oahu did not occur or it happened in other areas than expected.
- Size of project: The larger the project is, the larger the forecasting error will be.
- Forecasting on Oahu compared to other studies: Traffic demand forecasting on Oahu differs a lot from two other studies that investigated traffic forecasts vs. actual traffic volumes. On Oahu there is a strong trend towards overestimation, the studies by Flyvbjerg, and Levinson and Parthasarathi show a trend towards underestimation.

This study began by raising a number of questions. It now concludes by answering these questions.

**Do forecasts show an accurate picture of future traffic demand, both related directly to a specific project and the affected region?** No the forecasts on Oahu do not show an accurate picture of future traffic demand. Traffic forecasts are on average overestimated by 35%. Both through movements and turning movements had large inaccuracies indicating that project specific traffic, turning movements, and background traffic, through movements, were highly inaccurate.

**Do forecasts provide a "picture perfect" view of future conditions in order to get the projects approved?** No, on the contrary, traffic forecasts were overestimated, thus they showed a worse picture of future conditions than what actually occurred.

**Is traffic forecasting on Oahu conservative or optimistic?** Traffic forecasting on Oahu is very conservative, there is a strong tendency to overestimate traffic forecasts by more than one-third.

**Do forecasts vary by type of development?** No there are no indications that forecasting accuracy varies with project type. However, size of project has an effect on accuracy.

**What is the effect of the forecast horizon?** The variable forecast horizon is not included in any of the regression models, meaning that this variable had no statistically significant effect on forecasting accuracy.

**What is the effect of background growth extrapolations?** Background growth was not a variable examined in regression analysis. Previous literature on the subject suggests that assumptions in models, such as growth rates, have a large impact on traffic forecasting accuracy.

**The final question is this: Have consultants and decision makers on Oahu learned anything from previous projects?** No. Many of the residential developments proposed on Oahu are large green field developments in areas such as Koa Ridge, Ho'opili and

Kalaeloa [4]. Nothing found in our investigation suggests that anything has changed to improve forecasting accuracy.

**Recommendations**

Overall the study confirms that there is a need for traffic forecasting improvement on Oahu and by extension to the State of Hawaii, because the average forecasting error is 35%. Several methods to improve forecasting accuracy are listed below:

- A comprehensive evaluation of forecasting accuracy on Oahu to confirm the findings of this study.
- A review of forecasting models: Are the models used for traffic forecasting on Oahu appropriate? Is ITE Trip Generation appropriate for the islands?
- Validate if ITE Trip Generation rates are appropriate for Oahu.
- Investigation into the effects that assumptions, projections and growth rates have on forecasting accuracy.
- Are OMPO-model-based growth rates appropriate and representative?

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# APPENDIX A: TIAR DATA

| Project | Station no. | EIS yr. | TIAR Prepared by | Type of project | Location | Movement | Movement | ADT/vph |
|---|---|---|---|---|---|---|---|---|
| Haleiwa Bypass | B72-117 | 1981 | 5 | Road | North Shore | NB | TH | vph |
| Haleiwa Bypass | B72-117 | 1981 | 5 | Road | North Shore | HNL-B | TH | vph |
| Sand Island Access Road Widening and Improvement | 202 | 1982 | 4 | Road | Honolulu | WB | TH | vph |
| Sand Island Access Road Widening and Improvement | 202 | 1982 | 4 | Road | Honolulu | EB | TH | vph |
| Sand Island Access Road Widening and Improvement | 202 | 1982 | 4 | Road | Honolulu | NB | TR | vph |
| Sand Island Access Road Widening and Improvement | 202 | 1982 | 4 | Road | Honolulu | SB | TR | vph |
| H3 | B72 | 1976 | 7 | Road | Central Oahu | HNL-B | TH | Vph |
| Kahekili Hwy | 31-K | 1990 | 7 | Road | Windward | HNL-B | TH | Vph |
| Kahekili Hwy | 31-K | 1990 | 7 | Road | Windward | HNL-B | RT | Vph |
| Kahekili Hwy | 31-K | 1990 | 7 | Road | Windward | EB | TH | Vph |
| Kahekili Hwy | 31-K | 1990 | 7 | Road | Windward | NB | LT | Vph |
| | | | | | | | | |
| West Loch Estates North | 10-K | 1987 | 1 | Residential development | Ewa | SB | TH | vph |
| West Loch Estates North | 10-K | 1987 | 1 | Residential development | Ewa | NB | TH | vph |
| West Loch Estates North | 10-K | 1987 | 1 | Residential development | Ewa | EB | TR | vph |
| West Loch Estates South | 10-G | 1987 | 1 | Residential development | Ewa | SB | TH | vph |
| West Loch Estates South | 10-G | 1987 | 1 | Residential development | Ewa | NB | TH | vph |
| West Loch Estates South | 10-G | 1987 | 1 | Residential development | Ewa | EB | TR | vph |
| Gentry Ewa Makai | 219 | 2002 | 2 | Residential development | Ewa | NB | TH | vph |
| Gentry Ewa Makai | 219 | 2002 | 2 | Residential development | Ewa | SB | TH | vph |
| | | | | | | | | |
| Ewa Gentry | 10W | 1988 | 2 | Residential development | Ewa | SB | TH | vph |

| Project | Station no. | EIS yr. | TIAR Prepared by | Type of project | Location | Movement | Movement | ADT/vph |
|---|---|---|---|---|---|---|---|---|
| Ewa Gent y | 10W | 1988 | 2 | Residential development | Ewa | NB | TH | vph |
| | | | | | | | | |
| 476 acre deve opment at M lilani Town | | 1983 | 3 | Residential Deve opment | Centra Oahu | H-2 On Ramp NB | TR | vph |
| 476 acre deve opment at M lilani Town | | 1983 | 3 | Residential Deve opment | Centra Oahu | H-2 On Ramp SB | TR | vph |
| | | | | | | | | |
| M l lani Mauka Residential Community | | 1984 | 2 | Residential Deve opment | Centra Oahu | H-2 Off Ramp NB | TR | vph |
| M l lani Mauka Residential Community | | 1984 | 2 | Residential Deve opment | Centra Oahu | H-2 Off Ramp SB | TR | vph |
| M l lani Mauka Residential Community | | 1984 | 2 | Residential Deve opment | Centra Oahu | H-2 On Ramp NB | TR | vph |
| M l lani Mauka Residential Community | | 1984 | 2 | Residential Deve opment | Centra Oahu | H-2 On Ramp SB | TR | vph |
| | | | | | | | | |
| Waike e Deve opment | | 1985 | 6 | Residential Deve opment | Centra Oahu | H-1 Off Ramp WB | TR | vph |
| Waike e Deve opment | | 1985 | 6 | Residential Deve opment | Centra Oahu | H-1 Off Ramp EB | TR | vph |
| Waike e Deve opment | | 1985 | 6 | Residential Deve opment | Centra Oahu | H-1 WB | TH | vph |
| Waike e Deve opment | | 1985 | 6 | Residential Deve opment | Centra Oahu | H-1 EB | TH | vph |

| Project | Station no. | EIS yr. | TIAR Prepared by | Type of project | Location | Movement | Movement | ADT/vph |
|---|---|---|---|---|---|---|---|---|
| Waike e Deve opment | | 1985 | 6 | Residential Deve opment | Centra Oahu | H-1 On Ramp WB | TR | vph |
| Waike e Deve opment | | 1985 | 6 | Residential Deve opment | Centra Oahu | H-1 On Ramp EB | TR | vph |
| | | | | | | | | |
| Waike e Deve opment | | 1985 | 6 | Residential Deve opment | Centra Oahu | Kam. Hwy NB | TH | vph |
| Waike e Deve opment | | 1985 | 6 | Residential Deve opment | Centra Oahu | Kam.Hwy WB | TR | vph |
| Waike e Deve opment | | 1985 | 6 | Residential Deve opment | Centra Oahu | Kam. Hwy SB | TH | vph |
| Waike e Deve opment | | 1985 | 6 | Residential Deve opment | Centra Oahu | Kam. Hwy EB | TR | vph |

| Project | AM/PM | Forecast Year | Horizon | Forecast Traffic | Forecast Method | Peak hour in+out | HDOT Count Year | HDOT Count Date | HDOT Traffic |
|---|---|---|---|---|---|---|---|---|---|
| Haleiwa Bypass | AM | 2001 | 20 | 500 | DNK | 1250 | 2005 | avg | 318 |
| Haleiwa Bypass | AM | 2001 | 20 | 750 | DNK | 1250 | 2005 | avg | 296 |
| Sand Island Access Road Widening and Improvement | AM | 2000 | 18 | 1800 | DNK | 2228 | 1999 | 08-09 | 1493 |
| Sand Island Access Road Widening and Improvement | AM | 2000 | 18 | 2976 | DNK | 2228 | 1999 | 08-09 | 2348 |
| Sand Island Access Road Widening and Improvement | AM | 2000 | 18 | 617 | DNK | 2228 | 1999 | 08-09 | 771 |
| Sand Island Access Road Widening and Improvement | AM | 2000 | 18 | 1611 | DNK | 2228 | 1999 | 08-09 | 1734 |
| H3 | AM | 2008 | 32 | 3050 | DNK | 3050 | 2010 | avg | 2664 |
| Kahekili Hwy | AM | 2008 | 18 | 3195 | DNK | 2898 | 2003 | avg | 1651 |
| Kahekili Hwy | AM | 2008 | 18 | 2055 | DNK | 2898 | 2003 | avg | 2138 |
| Kahekili Hwy | AM | 2008 | 18 | 869 | DNK | 2898 | 2003 | avg | 869 |
| Kahekili Hwy | AM | 2008 | 18 | 843 | DNK | 2898 | 2003 | avg | 926 |
| | | | | | | | | | |
| West Loch Estates North | PM | 1991 | 4 | 2603 | ITE 3rd Edition | 1388 | 1993 | 08-18 | 2480 |
| West Loch Estates North | PM | 1991 | 4 | 2103 | ITE 3rd Edition | 1388 | 1993 | 08-19 | 1760 |
| West Loch Estates North | PM | 1991 | 4 | 405 | ITE 3rd Edition | 1388 | 2002 | avg | 277 |
| West Loch Estates South | PM | 1991 | 4 | 2416 | ITE 3rd Edition | 1388 | 1993 | 03-11 | 2268 |
| West Loch Estates South | PM | 1991 | 4 | 1473 | ITE 3rd Edition | 1388 | 1993 | 03-11 | 1803 |
| West Loch Estates South | PM | 1991 | 4 | 722 | ITE 3rd Edition | 1388 | 2002 | avg | 355.5 |
| Gentry Ewa Makai | AM | 2010 | 8 | 1792 | ITE 6th Edition | 1687 | 2009 | avg | 1010 |
| Gentry Ewa Makai | AM | 2010 | 8 | 1476 | ITE 6th Edition | 1687 | 2007 | avg | 1023 |
| | | | | | | | | | |
| Ewa Gentry | AM | 1995 | 7 | 2020 | ITE 3rd Edition | 4420 | 1995 | 01-23 | 1476 |

| Project | AM/PM | Forecast Year | Horizon | Forecast Traffic | Forecast Method | Peak hour in+out | HDOT Count Year | HDOT Count Date | HDOT Traffic |
|---|---|---|---|---|---|---|---|---|---|
| Ewa Gentry | AM | 1995 | 7 | 4769 | ITE 3rd Edition | 4420 | 1995 | 01-23 | 2923 |
| | | | | | | | | | |
| 476 acre development at Mililani Town | AM | 1995 | 12 | 334 | DNK | 883 | 1996 | 02/08 | 504 |
| 476 acre development at Mililani Town | AM | 1995 | 12 | 3179 | DNK | 883 | 1996 | 02/09 | 2447 |
| | | | | | | | | | |
| Mililani Mauka Residential Community | AM | 1995 | 11 | 1003 | ITE 2nd Edition | 4615 | 1996 | 02/06 | 346 |
| Mililani Mauka Residential Community | AM | 1995 | 11 | 165 | ITE 2nd Edition | 4615 | 1996 | 02/07 | 367 |
| Mililani Mauka Residential Community | AM | 1995 | 11 | 1070 | ITE 2nd Edition | 4615 | 1996 | 02/08 | 504 |
| Mililani Mauka Residential Community | AM | 1995 | 11 | 3800 | ITE 2nd Edition | 4615 | 1996 | 02/09 | 2447 |
| | | | | | | | | | |
| Waikele Development | AM | 1995 | 9 | 390 | ITE 3rd Edition | 2531 | 1993 | avg | 405 |
| Waikele Development | AM | 1995 | 9 | 280 | ITE 3rd Edition | 2531 | 1993 | avg | 630 |
| Waikele Development | AM | 1995 | 9 | 2550 | ITE 3rd Edition | 2531 | 1993 | avg | 2778 |
| Waikele Development | AM | 1995 | 9 | 4270 | ITE 3rd Edition | 2531 | 1993 | avg | 5063 |

| Project | AM/PM | Forecast Year | Horizon | Forecast Traffic | Forecast Method | Peak hour in+out | HDOT Count Year | HDOT Count Date | HDOT Traffic |
|---|---|---|---|---|---|---|---|---|---|
| Waikele Development | AM | 1995 | 0 | 350 | ITE 3rd Edition | 2531 | 1995 | avg | 657 |
| Waikele Development | AM | 1995 | 0 | 1020 | ITE 3rd Edition | 2531 | 1995 | avg | 503 |
| | | | | | | | | | |
| Waikele Development | AM | 1995 | 0 | 890 | ITE 3rd Edition | 2531 | 2000 | avg | 544 |
| Waikele Development | AM | 1995 | 0 | 150 | ITE 3rd Edition | 2531 | 2000 | avg | 143 |
| Waikele Development | AM | 1995 | 0 | 1860 | ITE 3rd Edition | 2531 | 2000 | avg | 1107 |
| Waikele Development | AM | 1995 | 0 | 330 | ITE 3rd Edition | 2531 | 2000 | avg | 381 |

# APPENDIX B: ITE DATA SHEET

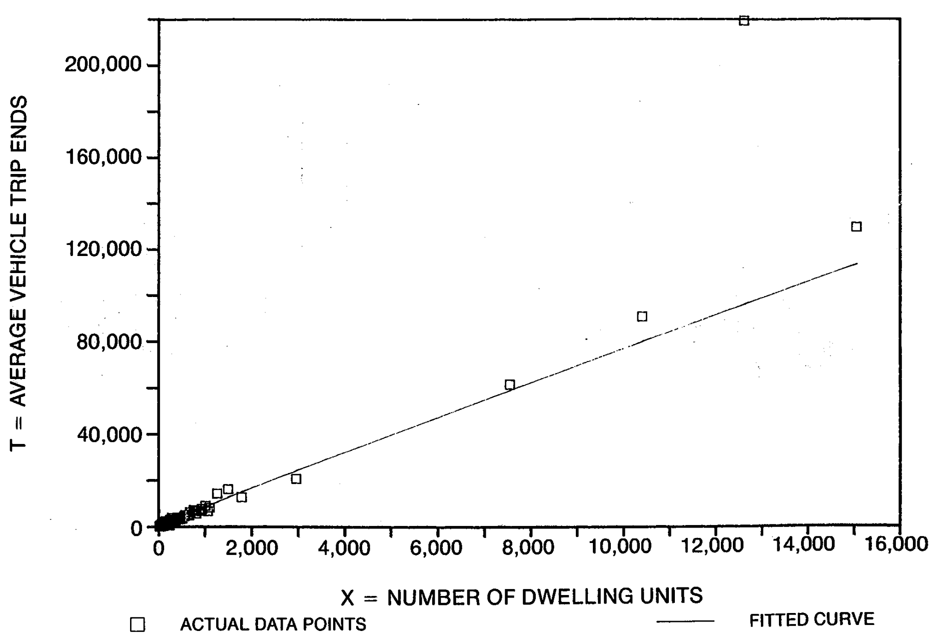
# SINGLE FAMILY DETACHED HOUSING (210)

Average Vehicle Trip Ends vs: **DWELLING UNITS**
On a: **WEEKDAY**

## TRIP GENERATION RATES

| Average Weekday Vehicle Trip Ends per Dwelling Unit | | | | |
|---|---|---|---|---|
| *Average Trip Rate* | *Range of Rates* | *Standard Deviation* | *Number of Studies* | *Average Number of Dwelling Units* |
| 10.062 | 4.307–21.900 | 4.36 | 320 | 366.5 |

## DATA PLOT AND EQUATION




Fitted Curve Equation: $Ln(T) = 0.94\ Ln(X) + 2.6$
$R^2 = 0.959$

DIRECTIONAL DISTRIBUTION: Not available

# Single-Family Detached Housing
# (210)

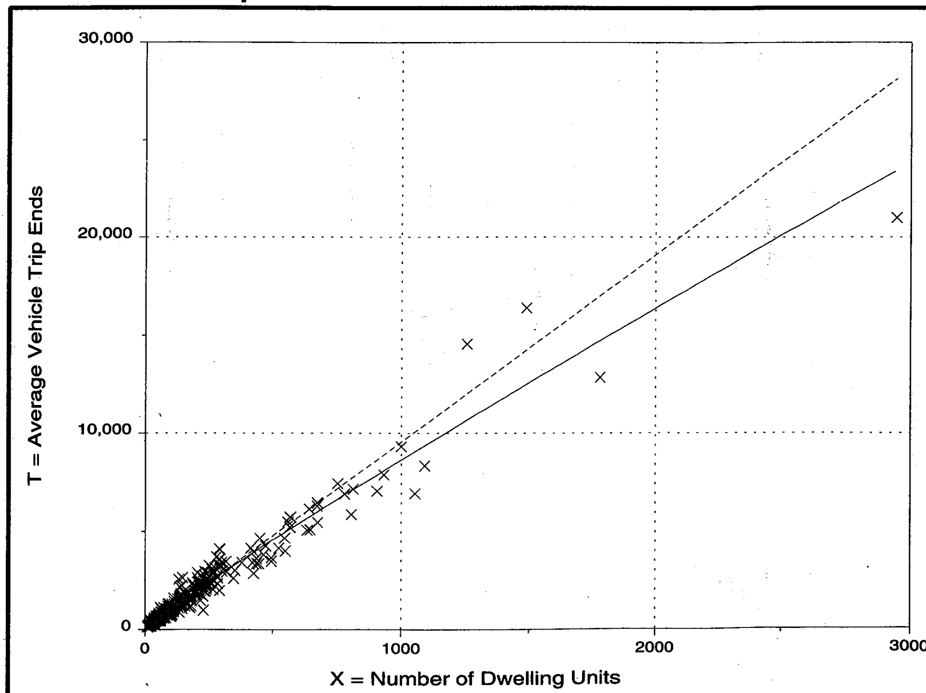
**Average Vehicle Trip Ends vs: Dwelling Units**
**On a: Weekday**

Number of Studies: 348
Average Number of Dwelling Units: 206
Directional Distribution: 50% entering, 50% exiting

## Trip Generation per Dwelling Unit

| Average Rate | Range of Rates | Standard Deviation |
|---|---|---|
| 9.55 | 4.31 - 21.85 | 3.66 |

## Data Plot and Equation




× **Actual Data Points** ——— **Fitted Curve** ------ **Average Rate**

**Fitted Curve Equation: Ln(T) = 0.921 Ln(X) + 2.698** **$R^2$ = 0.96**

# Single-Family Detached Housing
## (210)

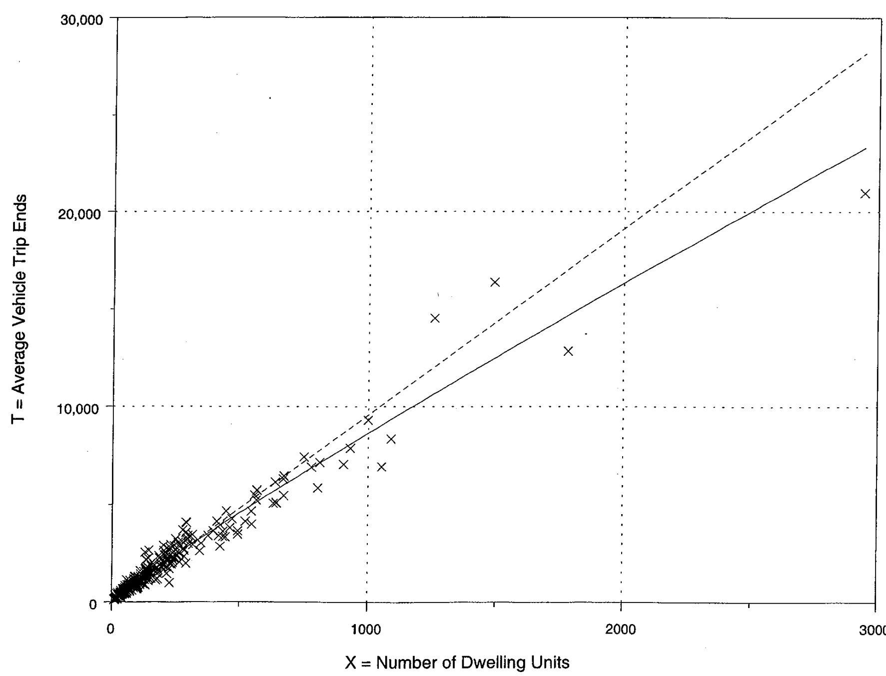
**Average Vehicle Trip Ends vs: Dwelling Units**
**On a: Weekday**

Number of Studies: 350
Avg. Number of Dwelling Units: 197
Directional Distribution: 50% entering, 50% exiting

### Trip Generation per Dwelling Unit

| Average Rate | Range of Rates | Standard Deviation |
|---|---|---|
| 9.57 | 4.31 - 21.85 | 3.69 |

### Data Plot and Equation




**Fitted Curve Equation: $Ln(T) = 0.92 Ln(X) + 2.71$** $R^2 = 0.96$

# Single-Family Detached Housing
(210)

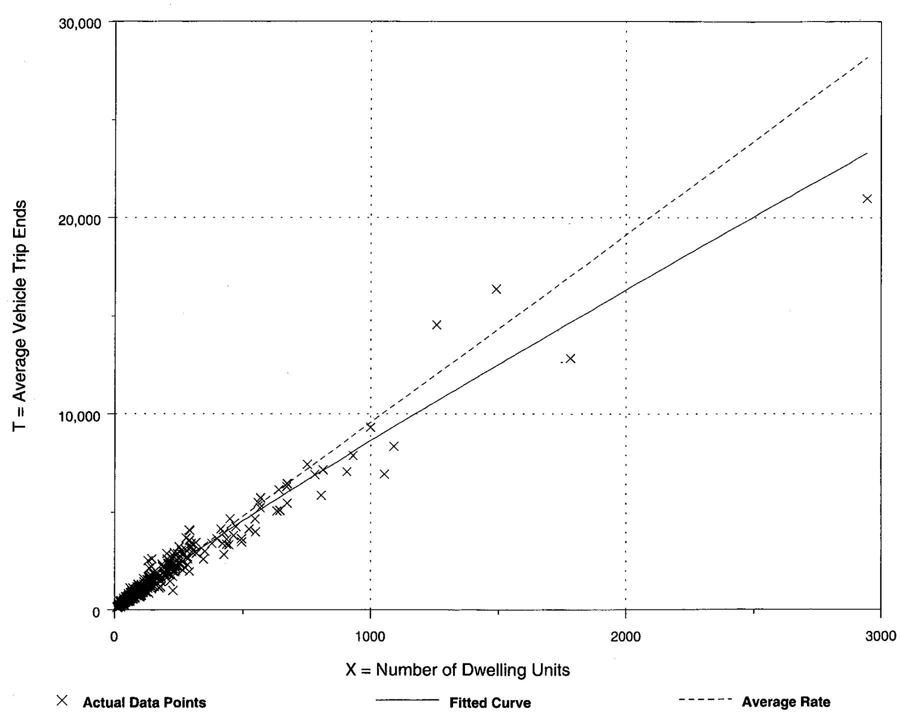
**Average Vehicle Trip Ends vs: Dwelling Units**
**On a: Weekday**

Number of Studies: 351
Avg. Number of Dwelling Units: 197
Directional Distribution: 50% entering, 50% exiting

## Trip Generation per Dwelling Unit

| Average Rate | Range of Rates | Standard Deviation |
|---|---|---|
| 9.57 | 4.31 - 21.85 | 3.69 |

## Data Plot and Equation




**Fitted Curve Equation: $Ln(T) = 0.92 Ln(X) + 2.71$** **$R^2 = 0.96$**