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16. Abstract:

Air transportation plays a vital role in the Texas economy. Air passenger/cargo traffic is projected to continue to increase considerably at many of the state's large airports. Ground access to airports is an important function that must be provided for at the regional level as well as in the immediate vicinity of the facility itself. Congestion problems affecting airport access are in some instances reaching unacceptable proportions; there are also concerns regarding the negative impacts such congestion is having on air quality and other environmental considerations. Accordingly, these issues require concerted action to meet project needs.

To address the above challenges and current gaps, this project will take a comprehensive look at the landside access issues associated with major airports in the state. It will seek to improve on existing planning procedures and processes to meet the unique needs of airport traffic demand, for both people and goods. To be effective, planning for airport access must be multimodal and intermodal; consider operational, regulatory, and capital-intensive infrastructure provision issues; consider multiple levels of scale/resolution; and recognize the unique dynamic aspects of air traffic demand, i.e., its temporal patterns.

This report documents domestic and international best practice case studies. The overall impact of the entire airport transportation network must be considered in order to address ground access issues. This study confirms the objectives and tasks laid out in the research proposal.

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DOMESTIC AND INTERNATIONAL

BEST PRACTICE CASE STUDIES

by

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Airport Access: Intermodal Strategies to Address Congestion at Airport/Highway Interfaces

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Research performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, FHWA.

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TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION 1

U.S.AIRPORTS 2

NON-U.S.AIRPORTS 3

CHAPTER 2. DOMESTIC BEST PRACTICE CASE STUDIES 7

INTRODUCTION 7

CHICAGO O'HARE INTERNATIONAL AIRPORT 7

Statistics 7

Intermodality 8

Parking 8

Rail Service 9

Future Projects 10

DENVER INTERNATIONAL AIRPORT 11

Statistics 11

Intermodality 13

Rail Service 14

Ground Access Solutions 15

Future Projects 16

WASHINGTON REAGAN NATIONAL AIRPORT 17

Statistics 17

Intermodality 18

Rail Service 18

Future Projects 19

CHAPTER 3. INTERNATIONAL BEST PRACTICE CASE STUDIES 21

INTRODUCTION 21

FRANKFURT/MAIN INTERNATIONAL AIRPORT 21
General Characteristics 21
Intermodality 23
AIRail Terminal 25

HONG KONG'S INTERNATIONAL AIRPORT AT CHEK LAP KOK 31
Facilities 32
Surface Access 34
Rail Access 35
Road Access 36
Public Use Access 36
Ferry Access 38
Ground Transportation Center 38
Franchise Bus Station 39
Tour Coach Station 39
Travel Industry Vehicle Pick-up Areas 39
Taxi Station 39

ZURICH INTERNATIONAL AIRPORT 39
Modal Splits 42
Traffic Survey Results 44

CONCLUSIONS 48

CHAPTER 4. DALLAS/FORT WORTH INTERNATIONAL AIRPORT 49

INTRODUCTION 49
Ground Access Problem 49
Temporal Patterns 51
Vehicular Categories and Definitions 52
Data Sets 52

Conclusions 60

CHAPTER 5. SUMMARY AND CONCLUSIONS 61

Airport Rail 61

When and Why Rail Works 63

What the Case Study Airports are Doing 64

Off-Airport Terminals 66

Issues to be Considered in Developing Off-Airport Terminals 67

Implications for Texas Airports 69

Future Research 70

REFERENCES 73

APPENDIX 75

LIST OF TABLES

Table 2.1 Getting to O'Hare Airport from the Chicago Metro Region 8
Table 2.2 Chicago O'Hare Air Travelers' Trip Purposes 10
Table 2.3 Comparison of the Denver Airport Rail Estimates and Four Other Cities 15
Table 3.1 Frankfurt Airport Traffic Report (1st Half of 2000) 22
Table 3.2 Travel Time for Scheduled Destinations 30
Table 3.3 Selected Operating Characteristics, Zurich International Airport 41
Table 4.1 Summary of First Data Set 53
Table 5.1 Airport Rail Link Performance 62
Table 5.2 Characteristics of Airport Rail Stations 63

LIST OF FIGURES

Figure 2.1 Modal Splits for O'Hare Airport 10
Figure 2.2 Distance of Various Airports to CBD 12
Figure 2.3 Domestic Market Share, August 2000 13
Figure 2.4 Mode Split for Washington Reagan National Airport 19
Figure 3.1 Modal Split during the Past Five Years at Frankfurt Airport 24
Figure 3.2 Modal Split from July 1999 to July 2000 at Frankfurt Airport 24
Figure 3.3 Overall Modal Split at Hong Kong's Airport 34
Figure 3.4 Passenger Modal Split 43
Figure 3.5 Employee Modal Split 43
Figure 3.6 Split among Airport Visitors 44
Figure 3.7 Comparison of Public Transport at Various Airports 44
Figure 4.1 DFW Airport Layout Plan 50
Figure 4.2 Pass-Through Transactions at DFW Airport 51
Figure 4.3 Vehicle Type and Purpose Split at DFW Airport 54

EXECUTIVE SUMMARY

This report documents the ground access practices at selected national and international airports. The intent is to provide case study examples of successful practices and experiences that represent different approaches to the ground access challenges encountered at most major airports. While the symptoms may be similar, the approaches to solving the underlying problems often reflect particular conditions prevailing at the airport in question, and in some cases denote cultural differences pertaining to auto dependence versus transit orientation. Nonetheless, successful airports have achieved their success because they have excelled at and/or innovated in their approaches to ground access.

The domestic airports reviewed in the report include Washington Reagan National, Denver, and Chicago O'Hare airports, in addition to the Dallas-Fort Worth Airport. The international airports considered include Frankfurt, Hong Kong, and Zurich. Notable among the international airports is the strong degree of multimodal integration in the approach to ground access. Airports thus become major nodes in a multimodal network, allowing convenient transfer from virtually any mode to the air portion of the trip. While highway access is a key consideration in all airports, rail access is integral to the ground access picture, with the airport serving as a major rail station providing access not only from the extended urban area but also to other cities and countries reachable via intercity rail. Zurich also provides a good illustration of successful reliance on remote satellite terminals, where air travelers can check in, check their luggage, and then proceed on to their gates at the airport terminal. The notable characteristic of these successful examples of multimodal integration at airport terminals is the existence of strong rail networks that are independent of the airport.

The domestic airports reveal less reliance on rail transit, even where it is available, though considerable variability exists in this regard across the airports considered. None of the domestic airports offer the same degree of convenience in rail access as do the international airports considered. Rail access at these airports is also primarily from other parts of the urban area, rather than from neighboring cities or states. The principal current

challenge lies in accommodating paratransit services as well as conventional bus transit service.

Dallas-Fort Worth Airport is analyzed in detail in terms of the temporal characteristics and composition of the incoming traffic demand. Repeatable patterns are extracted within and between days, and differences between weekdays and weekends are quite evident. Understanding actual arrival patterns is essential to the planning and design of both strategic and operational solutions to ground access problems. In addition, these patterns form the basis of input to advanced network-level modeling tools.

The conclusion of this review, conducted as the second and third tasks of a two-year project, is to confirm the objectives and tasks laid out in the original research proposal.

CHAPTER 1
INTRODUCTION

Air transportation plays a vital role in the Texas economy. Air passenger and cargo traffic is projected to continue to increase considerably at many of the state's large airports. Ground access to airports is an important function that must be provided at the regional level as well as in the immediate vicinity of the facility itself. Congestion problems affecting airport access are in some instances approaching unacceptable proportions, including negative impacts on air quality and other environmental considerations.

To meet longer term accessibility goals, and to address growing congestion and air quality concerns in their respective metro areas, several large airports in the U.S. are seriously examining access using alternate transport modes. The international experience, especially in Europe, has placed greater reliance on rail for airport access.

This report documents selected domestic and international best practice case studies. It corresponds to an interim step in a broader study of intermodal strategies to address congestion at airport/highway interfaces. These strategies seek to improve on existing planning procedures and processes to meet the unique needs of airport traffic demand, for both people and goods. As part of this study, it is necessary to understand those successful practices that are in operation at several airports in the U.S. and throughout the world. Thus, practices at several airports are evaluated, providing a starting point from which to examine their relevance to airports in Texas, and how they might be adapted to the Texas context.

Perhaps the biggest obstacle faced by the project team in the course of documenting these practices was the ability to obtain the data. A combination of phone calls, e-mails, and site visits provided the information included in this report. However, this process revealed widespread variation in the extent to which even major airports maintain complete and reliable information on access patterns for the airport. Airport websites were usually the starting point in this process; however, considerable variability exists in the extent to which relevant information might be available at these sites. Moreover, language was an additional complicating factor in this process for the non-U.S. airports. For example, the study team had to translate German documents from Zurich and Frankfurt airports.

To determine the airports included in this documentation of best practices, the study team screened a large number of airports and narrowed it down to seven: four U.S. and three international airports. The main consideration in the selection process was to include cases where an appreciable level of public transport usage is available.

The following paragraphs present an overview of each airport and the motivation behind its selection. First, the U.S. airports are presented, followed by the international ones.

U.S. AIRPORTS

Different communities in the U.S. have adopted different approaches to privileging access to vital airports by providing dedicated links to these airports. These links also serve other traffic under restricted conditions that ensure priority service levels to airport-bound users; an example is Highway 66 to Washington-Dulles Airport, a special freeway that allows only High Occupancy Vehicle (HOV) traffic besides airport-bound vehicles. Several airports in mostly congested cities now provide heavy or light rail access to the airport, with terminal points that are more or less conveniently located relative to the terminal.

In this report a documentation of the range of access modes introduced at four airports around the country will be presented. Airports whose characteristics will be presented are: Chicago O'Hare, Denver, Ronald Reagan Washington National, and Dallas-Fort Worth International. The selection of these airports is based on the relative importance of each and their relevance to the project topic.

Chicago O'Hare International Airport is one of the largest airports in the world, ranking second during 1999 with 72,609,191 passengers. Two of the airport's most notable features are Terminal 5, the international terminal, and the Airport Transit System (ATS), an elevated, automated people mover system that transports passengers from the terminals to long-term parking facilities in a matter of minutes. The public transportation market share at Chicago O'Hare is 9%, of which rail service is used by less than 4%.

Denver International Airport was considered because it is a new airport that might have the potential to achieve high levels of public transport usage. In 1999, its public transportation market share was 14%, with 12% of those using buses and the remainder shared-ride vans.

Ronald Reagan Washington National Airport (DCA) is convenient to the entire Metropolitan Washington Region. With its own stop on Washington's subway, Metrorail, DCA is a short ride from any station on the Metrorail system. This airport has the largest share of rail ridership of any other airport in the U.S., with 14% of all passengers using rail. In addition, its public transportation market share is 17.5% (1999). DCA ranked 65th worldwide in 1999 with 15,020,852 passengers.

Dallas-Fort Worth Airport (DFW) was selected because it forms the building block of this project, which focuses in the land-side access issues at the major Texas airports. DFW Airport, with 60,000,127 arriving, departing, and connecting passengers in 1999, ranked fifth in the world, in addition to ranking twenty-third worldwide for total loaded and unloaded freight, and mail (Ref 1). Moreover, DFW Airport employees and passengers now have a new travel option for getting to work or catching a flight: the Trinity Rail Express. The Trinity Rail Express (TRE) has extended its route farther west from downtown Dallas (Dallas Union Station) to Richland Hills, and now serves DFW Airport at the CentrePort/DFW Airport Station. From Monday through Saturday, DFW employees and travelers can ride the TRE train from any TRE rail station into the CentrePort station and ride a free shuttle service from CentrePort into the Airport (Ref 2). Nevertheless, it should be noted that DFW Airport was also selected because of the heavy reliance of its passengers on the use of private auto. This would provide an opportunity to address the issue of auto-oriented rather than transit-oriented passengers and attempt a scheme by which we could shift the mode choice towards public transit. Today, less than four percent of arriving and/or departing passengers travel by public means of transportation.

NON-U.S. AIRPORTS

Airport access planning holds considerable importance in many cities of the world, especially because normal congestion levels in these cities preclude reliable arrival at the airport using the regular transportation network, and because high urban densities require locating airports very far from the city core. A broader array of modal alternatives is normally available overseas for airport access, with heavier reliance on rail than in the U.S. Recent international experiences and innovations in this regard are reviewed in this report. Airports included in the discussion are: Frankfurt/Main Airport, Hong Kong International Airport at Chek Lap Kok, and Zurich International Airport.

These airports were selected after an extensive review of more than 15 airports worldwide, and their choice was based on the fact that each offers an example of a particularly successful approach to the access problem. For example, Hong Kong's Airport is one of the most recent airports placed in operation worldwide, and Zurich Airport provides a good illustration of passenger check-in at off-airport stations (Ref 3).

On peak days, over 150,000 travelers pass through Frankfurt Airport (FRA) on their way to destinations throughout Germany, Eastern and Western Europe, and the rest of the world. Frankfurt Airport received nearly 46 million passengers (45,869,959) in 1999, making it Germany's leading airport. Frankfurt Airport has, indeed, evolved into a full-service "intermodal travel port" where air, rail, and road networks are linked in a deliberately planned manner. Frankfurt Airport claims to have "pioneered" the integration of air and rail transportation systems and the opening of the new AIRail Terminal adds a further dimension in that respect, making it one airport with two train stations.

Hong Kong's International Airport at Chek Lap Kok was the largest engineering project ever undertaken in the history of Hong Kong. The plan to build the airport was launched in 1989. Upon deciding a location for the airport, the Government and the Provisional Authority stipulated that the new airport be easily accessible to all users, passengers and shippers alike. The airport was linked to the heart of Hong Kong by almost 40 kilometers of new roads, a dedicated high-speed railway and landmark bridges, and a new town. The railway is claimed to be the world's first railway built specifically for the purpose of serving an airport (Ref 4). During 1999, more than 83% of those arriving at the airport used a public means of transport for their access trip.

Zurich Airport is a major hub in Switzerland, with a railway station operated by Zurich Transport Federation (ZVV), and is integrated into the regional bus, train, and streetcar network. Combined tickets are available for all modes of transportation. Passengers enjoy the opportunity of checking in at any of 23 rail stations in Switzerland. Most airlines allow passengers to make reservations for their preferred seat on the plane at the baggage counter, to hand in their luggage, and to pick up their boarding pass. Thus passengers are able to travel without worry about their luggage or losing time at the check-in counter. This check-in is required 24 hours in advance of the takeoff. However, those passengers who do not wish to depart from one of these 23 check-in rail stations can make use of another type of service also provided by the ZVV. This service is the Fly-Rail Baggage Service, which allows passengers to check their luggage at one of 102 additional Swiss stations. Thus this luggage can travel via the airports of Zurich, Geneva, and Basel to any final destination worldwide. Moreover, from any airport in the world and with any airline, passengers traveling via one of the airports of the previously stated cities can choose to collect their luggage at any rail station in Switzerland (Ref 5).

This report presents an overview of the case studies reviewed under the second task of the project, and the project team's recommendations regarding the need for and the focus of subsequent tasks of the current research. Chapter 2 documents the U.S. best practice case studies; chapter 3 is a documentation of the international cases. Chapter 4 documents airport access and the temporal pattern of airport usage for Dallas-Fort Worth Airport. Chapter 5 provides a summary and conclusions based on the findings of the case studies.

CHAPTER 2
DOMESTIC BEST PRACTICE CASE STUDIES

INTRODUCTION

This chapter presents an overview of three domestic airports selected for their significance and for their approach to the provision of access services. The three airports are: Chicago O'Hare, Denver, and Washington Reagan. A fourth domestic airport is also examined, namely Dallas-Fort Worth. However, because of its direct significance to the scope of this project, it is discussed in a separate chapter, along with extensive analysis of access pattern data provided by the airport authority.

CHICAGO O'HARE INTERNATIONAL AIRPORT

Chicago O'Hare International Airport (ORD) is considered one of the commercial aviation capitals of the world. It has held that position for the past 30 years. In addition, it is the hub of national air transportation in the United States and the region's number one economic engine. But even today, not everyone realizes the size and scope of this mammoth facility. O'Hare plays a vital role in not only the country's transportation scheme, but also in the local and regional economy.

Statistics

O'Hare Airport handles more passengers and aircraft operations than any airport in the world. Approximately 180,000 travelers pass through O'Hare each day. O'Hare served over 70 million passengers in 1997. The total airport complex covers nearly 7,700 acres with 162 aircraft gates housed in four terminal buildings and has 50 commercial, commuter, and cargo airlines offering frequent service. Chicago's airports generate 339,000 jobs for the region, representing personal income of $13.5 billion a year.

Intermodality

There are several expressways that lead to Chicago O'Hare International Airport depending on one's origin or destination. Table 2.1 describes freeway access for O'Hare Airport from the Chicago Metro region and neighboring states.

Table 2.1: Getting to O'Hare Airport from the Chicago Metro Region

Destination	Expressway
Chicago Downtown	90 East
North Suburbs	294 North
South Suburbs	294 South
West Suburbs	294 South to 88 West
Rockford	90 West
Wisconsin	294 North
Indiana	294 South

Parking

Chicago O'Hare offers several parking options on or near the airport facilities. These options include valet parking, an hourly parking garage, daily parking, international parking, and economy parking.

Valet Parking is located in the parking garage on level 1-A. The cost of valet parking is $30.00/day (first hour, $10). Valet parking is the parking preference of many professionals. Valet parking is a short walk to the terminal and has the comfort of a covered drop-off and pick-up area. Plus, because it provides a dedicated exit lane and eliminates the need to search for parking, valet parking saves valuable time into and out of the airport complex.

Hourly Parking is also located in the parking garage on level 1-A. The cost of hourly parking is $50/day (first hour $3.00 and 4 hours $20.00). It is intended primarily for meeting or dropping off a traveling guest, and offers the convenience of a dedicated exit lane.

Daily Parking is located on the main parking garage on levels 2-6 and Outside Lots B & C. The cost is $21.00/day (first hour $3). Lots B and C are outdoor lots located immediately in front of the garage with access to Terminals 1, 2, and 3.

International Terminal Parking is located in Lot D. The cost is $29.00/day (first hour $3). Lot D is intended for short-term parking, i.e., meeters and greeters only. It is not intended for parking more than a few hours.

Economy Parking Lot E is $12.00/day (first hour $2). Lot E is intended for long-term parking. Passengers use the ATS (people mover) to reach the terminals. Economy Parking Lot F is $8.00/day (first hour $2). Lot F is intended for long-term parking. Passengers take the shuttle bus to Lot E and use the ATS to reach the terminals.

Rail Service

The Chicago Transit Authority (CTA) Blue Line train provides 24-hour service between downtown Chicago and O'Hare International Airport. Lower-level pedestrian passageways inside the airport terminals lead directly to the CTA station. The station is equipped with an elevator to take passengers with mobility impairments to and from the platform.

Blue Line train, operated by the CTA, connects the downtown area from the Dearborn Street subway to O'Hare International Airport, which is located 15 miles to the northwest of the city. Trips take about 35 to 40 minutes from downtown to the airport. There are 15 stations along the line, five downtown subway stations, and through- routing on one of two west-side alignments.

The rail terminal station in the airport opened in September 1984 (Ref 6). That station serves airport-destined traffic almost exclusively, as the station is located below the parking deck, in the middle of the large airport property. Walking distances in this sprawling airport are long enough to warrant many moving sidewalks, and an automated guideway transit circulator links the four terminals to remote parking. Some air passengers can reach the train station quickly, but the walk from United Airlines Terminal is lengthy and requires attentive routing. Figure 2.1 summarizes the ground access modes used by air travelers at O'Hare International Airport (Ref 7).

The purpose of passenger air travel was also surveyed at O'Hare Airport. In general, O'Hare is used extensively for business travel purposes. Vacation travel represents 28.5% of travel at O'Hare airport. Table 2.2 summarizes Chicago O'Hare air travelers' trip purposes.

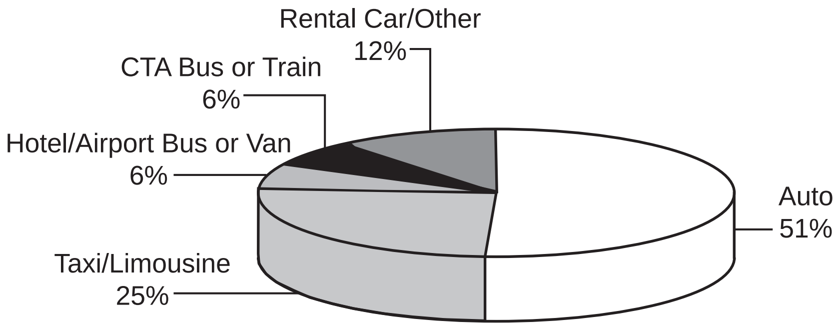

Figure 2.1: Modal Splits for O'Hare International Airport

Table 2.2: Chicago O'Hare Air Travelers' Trip Purposes

Trip Purpose	Percentage
Business/Convention	52.8
Vacation	28.5
Personal/Family Matters	18.7

Rail transit has become a significant ground access mode for Chicago O'Hare Airport. The potential exists to increase this type of transit travel, in relation to the trend of increased air travel and in relation to improving the service benefits offered by rail transit in comparison with the alternatives.

Future Projects

The parking garage at Chicago O'Hare International Airport is undergoing a $60 million face-lift. Since 1993, the FAA has authorized $2.3 billion in passenger facility charge spending on airport improvements at O'Hare Airport. In 1999, a $1 billion face-lift project rehabilitated the garage so it looks similar to Helmut Jahn's ultramodern design for United Airlines' remote midfield concourse.

DENVER INTERNATIONAL AIRPORT

Denver International Airport (DIA) in Colorado, one of very few major airports to open in the U.S. in the past decade, is considered one of the largest and most technologically advanced airports, with state-of-the-art navigational, weather, people-moving, baggage-handling, airfield, communications, and security facilities. Terminal and runway configurations allow expeditious hub rotations while enhancing airline labor and aircraft utilization and productivity, handling 92 landings per hour. Delays averaged just .5% of flights in the first year of operation, and its arrival and departure on-time performance continues to be exemplary (Ref 8).

Statistics

Denver International Airport comprises 53 square miles of real estate dedicated to commercial aviation, with the ability to expand from its initial five runways and 88 gates to 12 runways and more than 200 gates and to accommodate up to 200 million passengers per year.

Denver International's location is 24 miles northeast of the Denver Central Business District (CBD), which ranks it one of the more remote airports in operation. It is not as remote as Washington Dulles, Montreal Mirabel, Tokyo Narita, or the new Seoul International airports, as shown in Figure 2.2, but it represents a significant increase from the previous airport's (Stapleton) convenient 7-mile distance from the Denver CBD. Furthermore, with Stapleton's closing, DIA is the only commercial airport operating in Denver, unlike Washington, Montreal, Tokyo, or Seoul, where less remote airports are still operating.

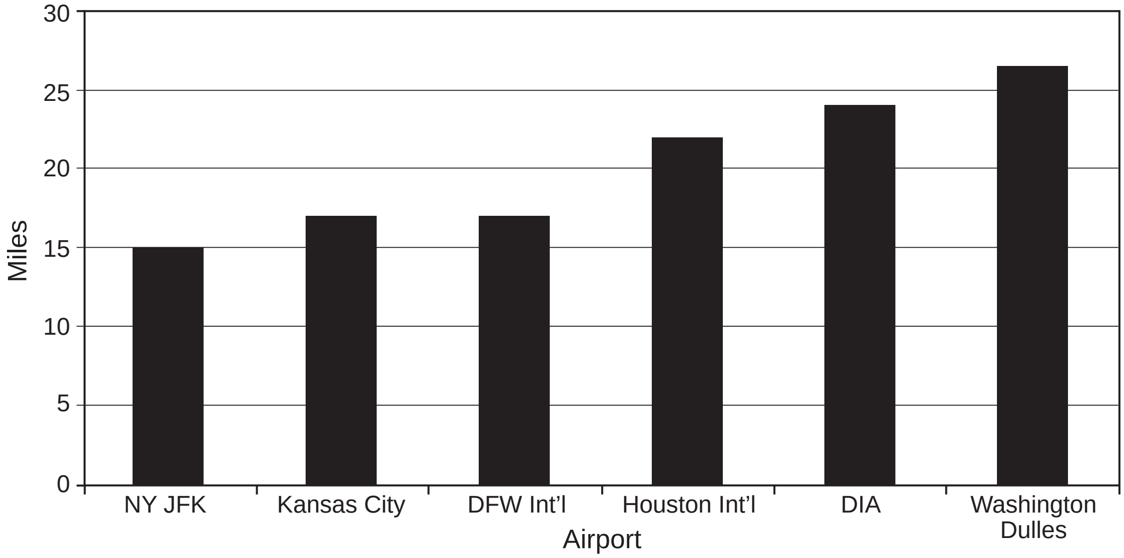

Figure 2.2: Distance of Various Airports to CBD

Denver International Airport opened in 1995 with five 12,000-foot runways, three concourses (with 22, 44, and 20 gates, on Concourses A, B, and C, respectively), and a terminal building with three modules. The repetitive modular design of both the landside and airside terminals and runways allows future expansion at reasonable cost while preserving their functional and architectural integrity. The key DIA feature is its modular design, meaning that the airfield is laid out in such a way that runways, concourses, and terminal space can be added in pieces in the future when traffic growth increases (Ref 8).

The design process was developed with a view to maximize expandability and flexibility of the airport over time. Virtually everywhere, ample space was left for future expansion. The mid-field location of the terminals, although adding distance from the city's center, allows reduced aircraft taxi time and enhanced operational efficiency.

When completed (sometime after 2020), DIA's capacity will be 110 million passengers a year (compared with about 31 million actual passengers in 1995) and 1.23 million takeoffs and landings.

Figure 2.3 is a chart that describes the domestic market share for each airport that is serviced by Denver International Airport (Ref 9).

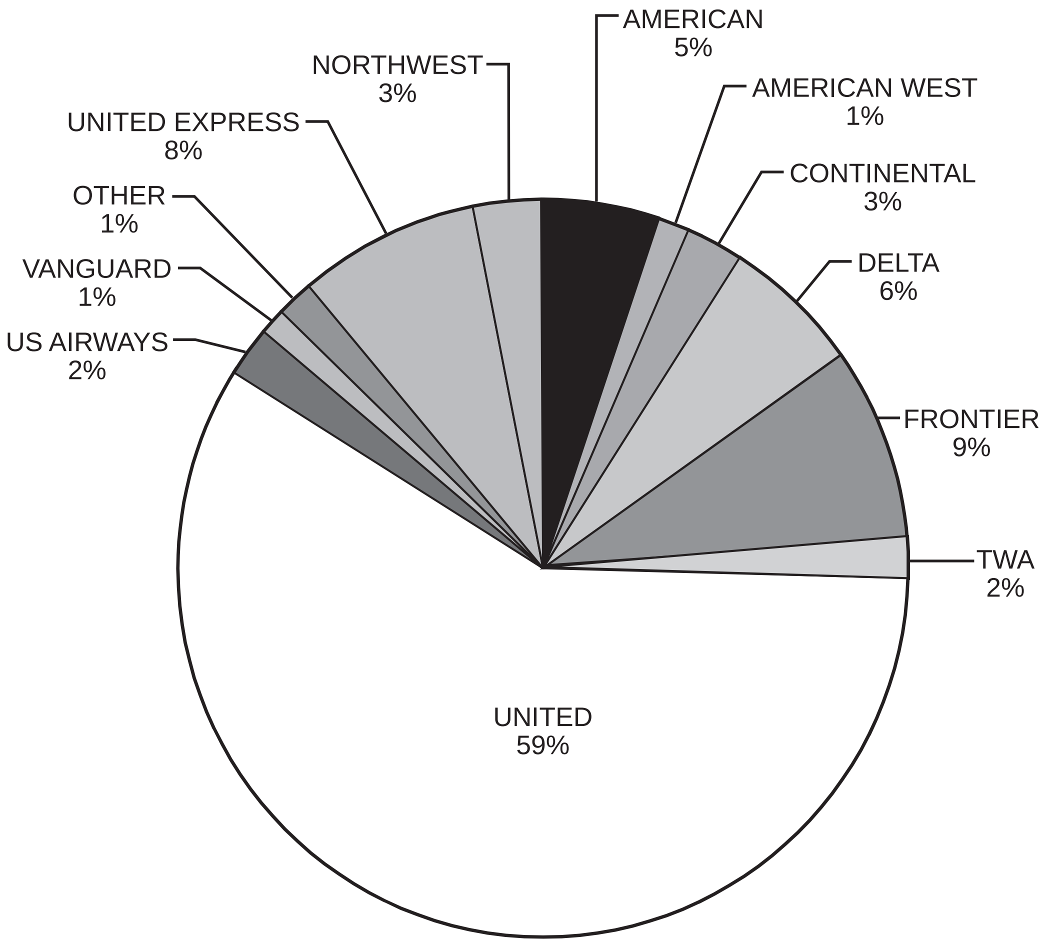

Figure 2.3: Domestic Market Share, August 2000

Intermodality

The principal access route to Denver International Airport is the 12-mile Pena Boulevard, a limited-access, four-lane highway that connects the airport with Interstate 70 leading to downtown Denver (24 miles away) and the rest of the metropolitan area. The overwhelming majority of ground travel to the new airport will be via the private automobile. More than 14,000 parking spaces are available at the site, and more are being built due to increased parking demand (Ref 10).

According to a passenger survey conducted in August 1998 (the peak activity month) at DIA, 70% of passenger travel originates from the 6-county metropolitan area. Most of these trips utilize Interstates 70 or 225, or a combination of Interstate 76 and arterial roadways to access Pena Boulevard. Interstate highways feeding into Pena Boulevard are considered congested during peak commuting periods, particularly the Interstate 70 corridor, which operates at or near capacity during the morning and evening commute times. This congestion renders Level of Service E or F conditions, which implies slow traffic and greatly reduced driver comfort and convenience (Ref 11).

The Regional Transportation District (RTD) operates public buses along four different routes, including service to downtown Denver, Boulder, and the Denver Tech Center. The one-way fare is $6 to downtown Denver and $8 to suburban locations. Charter buses, commuter shuttles, and mountain carriers (to ski areas) operate services to and from the airport, while hotel, motel, and off-airport parking companies provide courtesy shuttle service. The suburban routes operate year-round on an hourly basis; the Stapleton and Downtown routes run every half-hour. The services use over-the-road motor coaches instead of standard public transportation buses, providing a higher level of customer comfort and convenience for riding passengers.

Rental cars are available from remote lots accessible by company shuttles. Presently, 11 rental car companies maintain operations at or near the airport, and provide courtesy shuttles at the Level 5 curb.

Limousines and taxicabs are also available on demand. A one-way taxi ride to downtown Denver is approximately $40. An estimated two-thirds of daily taxi trips occur after 4:00 p.m. Taxis generally queue in the Commercial Vehicle Staging Area (on Shady Grove Street, just southeast of the terminal complex) waiting to be called to the Level 5 curbs, where starters assign passengers.

Rail Service

There is no rail service currently available at DIA; however, an Airport Rail Feasibility Study has been conducted by DIA to analyze various issues associated with the proposed Air Train project. The main focus of this Airport Rail Feasibility Study was to review the Air Train and East Corridor MIS studies and specifically consider the potential impact of airport rail service from the airport's perspective. Areas to be reviewed included (1) ridership, (2) rail alignment on airport property, (3) rail station interface with DIA terminal, (4) other airports' rail experiences, and (5) capital and operating cost of passenger rail as it relates directly to the airport.

The ridership forecasts were compared to other cities having rail access to airports. The forecast of 3.2% for DIA rail use by air passengers was similar to other cities. Table 2.3 shows a comparison of airport rail ridership in DIA and four other cities (Ref 12).

Table 2.3: Comparison of The Denver Airport Rail Estimates and Four Other Cities

	Denver (2020)	**Cleveland**	**Philadelphia**	**Washington**	**Atlanta**
Percent Rail of Air Pass	3.2	2.8	2.0	9.0	9.3
Rail Headway	20	12	30	5-10	8-15

Overall, the airport rail line consists of an alignment length of 23 miles. Approximately 12.5 miles of this is west of DIA property. The total on-airport segment of the airport rail alignment is 10.5 miles and is exclusively in airport right-of-way. The DIA portion of this rail alignment, as it leaves the Jeppesen Terminal, was analyzed using four alignment alternatives.

Ground Access Solutions

The Denver Regional Council of Governments (DRCOG) released a study in September 1992 analyzing the problems of access and mobility at the new airport. Because of the lack of transportation capacity in the new airport region, DRCOG predicted increased traffic congestion along roads leading to Pena Boulevard, such as I-70, I-225, and segments of Tower Road and 56th Avenue. The results of the study recommended several short-term strategies to reduce congestion, including new traffic management measures (improved traffic signal synchronization, intersection capacity improvements, etc.) and provision of reliable bus service, as well as implementation of the strategies contained in its 2010 long range plan, such as construction of beltway segments E-470 (around the eastern half of the metro area) and W-470 (in the northwest quadrant of the metro area), and increased provision of transit service (including possibly some form of rail transit). In addition, DRCOG also noted that these plans might be constrained by the ability to obtain the necessary financial resources, subject to the same impediments previously mentioned.

To generate the necessary funds, an access fee was imposed on vehicles accessing the airport. Each vehicle that enters DIA must pass through a toll plaza located several miles from the terminal to pick up a ticket indicating time of ground arrival. Whether parking or not, every vehicle is charged $2 per hour for access to the airport after the first 70 minutes. This means that cars only dropping off or picking up passengers are not subject to paying fees, unless the vehicles do not leave the toll plaza within 70 minutes of original arrival. This arrangement represents a relaxation of the original rate structure, which called for fees after only a 30-minute grace period. Given the distances, it would be quite challenging for cars to enter, pick up or drop off passengers, and exit in less than 30 minutes. This was especially significant when queues at the toll plaza were exceedingly long during the first year of operation, which resulted in many irate travelers being forced to wait in line to pay the access fees.

Recent changes in parking and access rates have lowered costs to the traveler, but DIA is still generating healthy total revenues from its parking and access operations. In a June 1995 bond prospectus, the city estimated a $19-million net profit for the airport in 1995, due largely to parking and concession revenues. It is not surprising that the City of Denver and DIA officials are not too concerned about intermodalism or ground transportation alternatives to the new airport.

Future Projects

Projects to alleviate the congestion in this corridor that have recently been completed or are planned for completion in the next 20 years include:

- Reconstruction of the interchanges at Interstate 70/Interstate 225 and Interstate 76/120th Avenue.

- Rehabilitation of Interstate 70 from Pena Boulevard to Tower Road.
- Rebuilding of 120th Avenue from Quebec Street to US 85.

WASHINGTON REAGAN NATIONAL AIRPORT

Ronald Reagan Washington National Airport (DCA) is conveniently located to the Washington D.C. Metropolitan Region. With its own stop on Washington's subway, Metrorail, DCA is a short ride from any station on the Metrorail system. Washington D.C. is a short taxi ride away as well.

Statistics

Opened on June 16, 1941, Washington National Airport was built by the federal government and dedicated by President Franklin D. Roosevelt.

The airport encompasses 860 acres: 733 on land and 127 on water.

The airport's name was officially changed to "Ronald Reagan Washington National Airport" in February 1998 by the United States Congress.

Terminal B/C opened on July 27, 1997. The new terminal has 1 million square feet of floor space spread over three levels, 35 gates, and direct connections to the Metrorail public transportation system and the parking garages via two enclosed pedestrian bridges. The terminals' two-level roadway system improves traffic flow through the airport by sorting incoming and outgoing traffic. DCA's historic "Terminal A" will undergo rehabilitation, and continues its aviation service with 9 aircraft gates.

In 1946, DCA passed a milestone of 1 million annual passengers; in 1999, approximately 15 million passengers used the airport with approximately 42,000 passengers a day flying on commercial, general aviation, and commuter flights.

Aircraft noise regulations were instituted prior to commercial jet operations at DCA. Aircraft flight patterns follow the Potomac River and pilots practice power thrust reduction on takeoff to reduce noise impacts. There are also aircraft noise limits on flights associated with nighttime noise requirements in effect from 10:00 p.m. to 7:00 a.m.

Serving as a "short-haul" airport, DCA offers nonstop service to destinations no farther than 1,250 miles from Washington, D.C.

Approximately 50,000 vehicles a day travel on the airport roadways.

Intermodality

Taxicabs serving the airport queue in a two-level 118,000 sq ft structure that accommodates 500 vehicles. Each day some 5,000 taxicabs are dispatched at the airport. The Airports Authority operates the Washington Flyer Express Bus providing transportation to downtown Washington, D.C., and to Dulles Airport, and the SuperShuttle is a shared-ride van service that will pick up passengers at their home, business, or hotel within the Washington metro area and transport them to the airport.

Public parking is available for approximately 7,500 vehicles, providing Hourly, Daily, and Economy Lot choices. An Hourly Surface Lot and both Daily Surface and garage parking serve Terminal A. Terminals B and C are served by Hourly and Daily parking garages. The Economy Lot is serviced by Courtesy Shuttle Buses to and from all terminals.

Shuttle buses run between Metro and Terminal A, where Trans World Airlines, Midway Air Lines, and Northwest Airlines continue to operate. From the Metro stop, passengers follow signs to "Shuttle to Terminal A" bus stops on Level G (Ground) of Garages B and C.

Rail Service

Metrorail, the region's rapid transit system, stops adjacent to Terminals B and C. Metrorail fare cards may be purchased from machines at either of two Farecard plazas located on Level 2 near pedestrian bridges that lead into and out of Terminals B and C. A third Farecard plaza, for disabled and other passengers using elevators, is under the Metro platform, midway between the north and south mezzanines.

Upon exiting Metro's DCA stop, passengers view the pedestrian walkway that takes them into the airport terminal's concourse, or middle level, where the jet gates are located. Moving walkways accelerate the walk across the pedestrian bridge linking Metro to

Terminals B and C. One significant shortcoming of Metrorail is the distance from various areas of the air terminal to the rail terminal that might be considered excessive while carrying baggage.

The mode split for Ronald Reagan Washington National Airport is summarized in Figure 2.4.

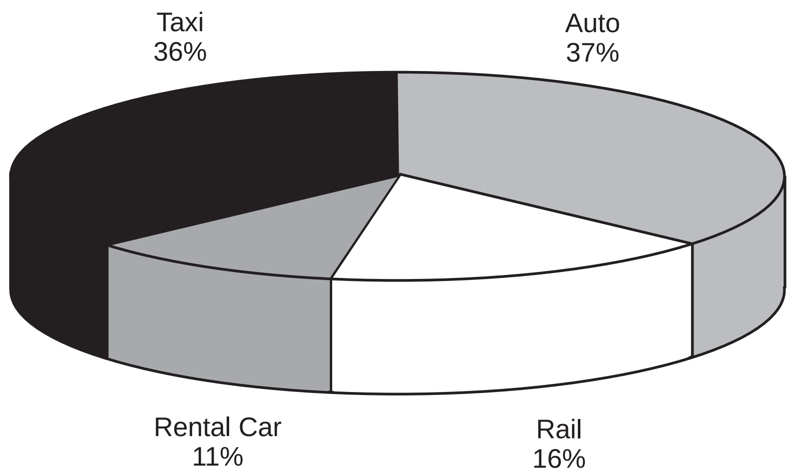

Figure 2.4: Mode Split for Ronald Reagan Washington National Airport

Future Projects

The Metropolitan Washington Airports Authority is spending $2 billion on construction of new and expanded terminals at Washington’s Ronald Reagan National Airport. Improvements will include a new North terminal with 35 gates, and an expansion of the main terminal with an additional nine gates.

CHAPTER 3
INTERNATIONAL BEST PRACTICE CASE STUDIES

INTRODUCTION

This chapter presents an overview of three international best practice case studies. Airports whose characteristics are presented are: Frankfurt/Main Airport, Hong Kong International Airport at Chek Lap Kok, and Zurich International Airport. Each airport is selected because of its distinctive access characteristics. This chapter is structured into three principal sections, each corresponding to one airport. The first airport presented is Frankfurt, then Hong Kong, and finally Zurich. A final concluding section is included.

FRANKFURT/MAIN INTERNATIONAL AIRPORT

Frankfurt/Main International Airport (FRA) is a major venue for international trade, and a leading Central European hub for global air transportation. FRA keeps people and goods moving. FRA is the largest passenger and cargo gateway in Europe, number seven worldwide. The region offers advanced intermodal infrastructures that integrate networks of autobahns, railways, inland harbors, and air links to more international destinations than any other European airport (Ref 3).

General Characteristics

On peak days, over 150,000 travelers pass through Frankfurt/Main International Airport on their way to destinations throughout Germany, Eastern and Western Europe, and abroad. In 1999, FRA received nearly 46 million passengers (45,869,959), making it Germany's busiest airport that has evolved into a full-service "intermodal travel port," where air, rail, and road networks are claimed to be "optimally" linked (Ref 3).

Statistics from the FAG Market Research group indicate that of the 46 million passengers that passed through Frankfurt Airport in 1999, 44% were business travelers, with transfers accounting for 49%. Of departing passengers, 18.3% traveled to domestic destinations (within Germany) while 81.7% traveled to international destinations. The share of the European Union (EU) of total passenger traffic at FRA in 1999 was 34%. Additionally, the number of aircraft movements in 1999 was 439,093 departures and arrivals, with a daily peak of 1,404 departures and arrivals registered on September 15, 1999. Table 3.1 summarizes the traffic statistics at FRA during the first half of the year 2000 and for the year 1999 (Ref 3).

Table 3.1: Frankfurt/Main International Airport Traffic Report

January – June 2000 (Cumulative)	
Passengers:	
Total	23,345,717
International	18,833,998
Domestic	4,250,229
Airfreight (in Metric Tons)	
Total	748,985
International	716,277
Domestic	24,758
Airmail (in Metric Tons)	
Total	67,485
International	32,542
Domestic	32,796
Aircraft Movements	
Total	224,380
International	175,434
Domestic	48,943
Frankfurt Airport Traffic Report 1999	
Passengers:	
Total	45,869,959
Peak month (August)	4,421,660
Peak day (October 1)	165,141
Airfreight (in Metric Tons)	
Peak month (October)	133,500
Peak week (December 13-19)	32,000
Peak day (November 7)	5,337
Aircraft Movements	
Total	439,093
Daily average	1200
Peak day (September 15)	1,404

Intermodality

Frankfurt/Main International Airport has become an important European hub for passengers and cargo services for a variety of reasons. Geography plays a role, as Frankfurt is strategically located in the middle of one of the world's largest economic markets where the various modes of transportation are strongly concentrated and interlinked. It is anecdotally stated in promotional material that "all routes air, roadways and waterways in Germany lead to Frankfurt and FRA" (Ref 3).

Frankfurt's location near the junction of the Rhine and Main rivers established the city along one of the world's most important inland waterways for passenger and freight traffic. At the northeastern corner of the airport, and not far from passenger terminals is Europe's first, and currently busiest, expressway cloverleaf, the Frankfurter Kreuz. This is the site of the intersection of the A3 and the A5 autobahns (the most important motorways in Germany). This allows quick access to Germany's renowned autobahn network and other expressways throughout Europe. Additionally, beginning with the golden age of trains, Frankfurt has been an important rail center. Frankfurt's central railway station, Hauptbahnhof, is one of Europe's busiest stations (Ref 3).

Intermodality is about the integration of different transportation systems — for instance Rail/Air — and all associated services along the entire travel chain. Frankfurt/Main International Airport has aggressively pursued such close integration, as reflected in the opening of the AIRail Terminal. In this sense, FRA has developed into an "intermodal travel port," making it one airport with two train stations. Figures 3.1 and 3.2 depict modal splits at FRA; the first is a plot of the variation of modal split for various modes over five years (1996-2000), while the second is a more focused plot of the modal splits during the one-year period from July 1999 to July 2000 (Ref 13).

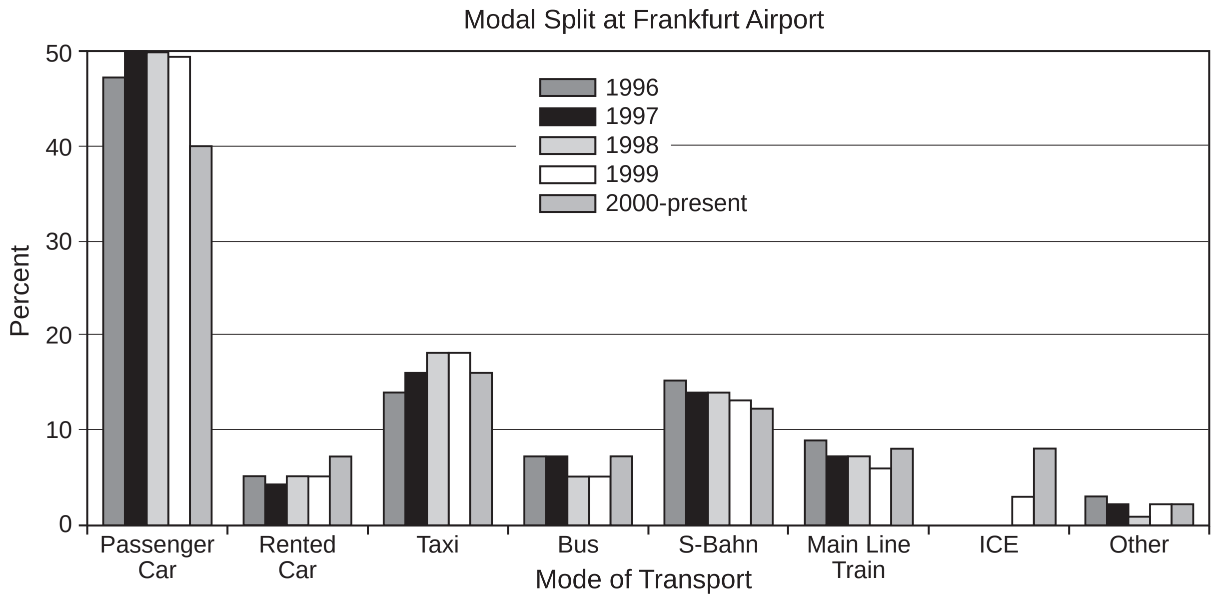

Figure 3.1: Modal Split during the Past Five Years at Frankfurt Airport

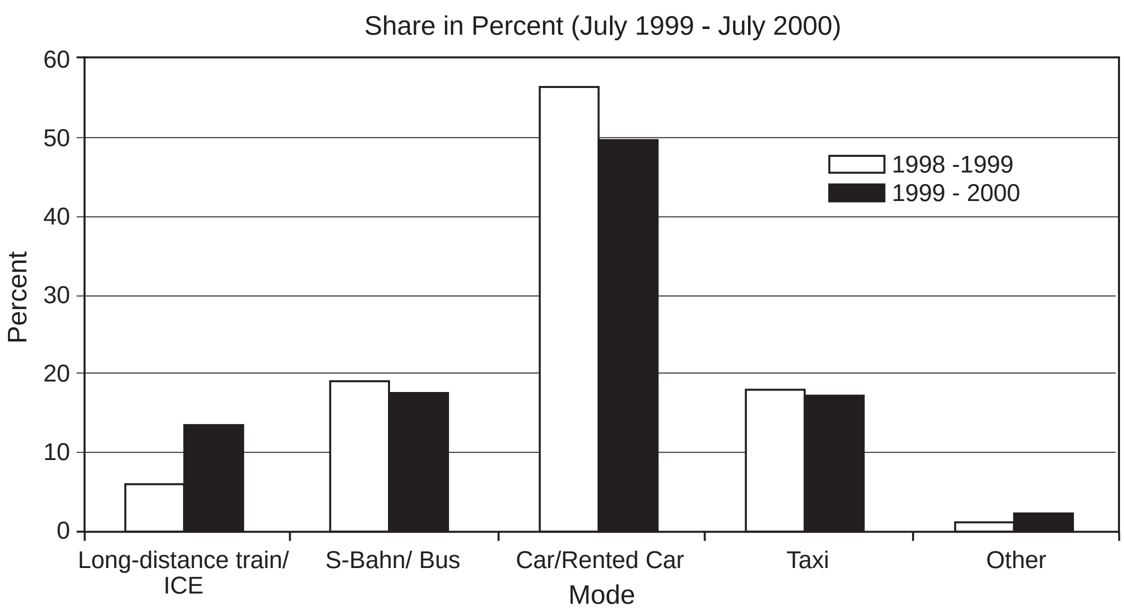

Figure 3.2: Modal Split From July 1999 to July 2000 at Frankfort Airport

AIRail Terminal

Frankfurt/Main International Airport is striving to become a key hub for the trans-European high-speed rail network. The ultimate (and elusive) goal is to achieve integration between air and rail systems resulting in a single easy-to-use service convenient for all travelers. The cornerstone of FRA's second passenger station, the so-called AIRail Terminal, was laid in place on October 1, 1997, marking the beginning of a new millennium and a new era in "seamless travel" for "rail and fly" services. FRA is trying to enhance its role by adding this state-of-the-art railway station designed exclusively for long-distance services, particularly high-speed trains. German Rail is forecasting that 25,000 to 30,000 passengers per day, or approximately 9 million annual passengers by 2010, will be using this high-speed railway network, especially after the new high-speed track between FRA and downtown Cologne (and Cologne Airport) is completed by 2002. The shift of many short-haul flights, particularly those within a 400- to 500-kilometer radius (249 to 311 miles) from the airport, to the high-speed rail network is being encouraged at FRA. Approximately 35 million people live within a 200-kilometer radius (124 miles) of FRA, which is more than the population surrounding Amsterdam, Paris, or London. This shift will positively impact the environment in two ways: road traffic to the airport will be reduced and the freed-up flight capacity (short-haul flights) can be utilized for expanding intercontinental air services (Ref 3).

With the emergence of the trans-European high-speed rail network, the strategic vision for FRA is to become a key hub for high-speed trains traveling from as far west as Britain via the Channel Tunnel, as far south as Italy via the Alps, as far north as Scandinavia, and perhaps, as far east as Warsaw and Moscow (Ref 3).

FRA is the only airport in Germany (though similar to Paris' Charles de Gaulle Airport) to be directly served by high-speed trains. Beginning May 30, 1999, high-speed rail services to major cities throughout Germany have been offered from the new AIRail Terminal (located near the Sheraton Hotel and Terminal 1). This station is served by a total of four national lines: two regular-speed InterCity (IC) lines and two high-speed InterCity Express (ICE) lines. Previously, passengers were required to take a commuter train to downtown Frankfurt's central station and transfer there (Ref 3).

On the other hand, the airport railway station beneath Terminal 1 that has been in operation since 1972 (now called the Regional Train Station) handles only regional services such as S-Bahn trains as well as RegionalExpress (RE) trains and StadtExpress (SE) trains to and from cities in the greater Frankfurt region. However, from 12:30 a.m. to 5:00 a.m., the Regional Train Station also handles long-distance trains because the Long-distance Train Station is closed during these hours. Nearly 90 trains per day use the Long-distance Train Station, which is served by four lines (Ref 3).

Passengers arriving at FRA's Long-distance Train Station (AIRail Terminal) by InterCity (IC) or high-speed InterCity Express (ICE) trains, from destinations across Germany, have the option of checking in for their flights at the new "Check-in T" area located in the connector building that links the Long-distance Train Station with Terminal 1, a short walk from the rail platforms. At "Check-in T," passengers are able to check in their baggage and receive a boarding card up to 45 minutes before their flight departure (Ref 3).

The AIRail Terminal has been linked to the European high-speed network by way of the Intercity Express, ICE Long-distance Train Station, beginning in May 1999. The following is a description of the station (Ref 13).

- Passenger throughput:
  - 1999: approximately 10,000 passengers daily
  - 2015 (projected): approximately 30,000 passengers daily
  - Total capacity: approximately 9 million passengers per year
- Two platforms with 4 tracks numbered 4 – 7
- The Long-distance Train Station is closed from 12:30 a.m.–5:00 a.m.; thus long distance trains operate from the Regional Train Station during this period.
- At present, 97 services are offered daily, with additional direct connections planned for the future.

Regional Train Station

This underground station opened in 1972, and provides regional and local train services (Ref 13).

- Approximately 230 trains daily
- Travel time to Frankfurt Central Station: 11 minutes ("S-Bahn" lines S8 and S9, StadtExpress and RegionalExpress at 8 – 15 minute intervals)
- Frequent regional train services to Koblenz, Saarbrucken, Bamberg/Hof
- Capacity: currently approximately 4,000 passengers daily (plus airport employees and visitors, etc.)
- Two platforms, 3 tracks numbered 1 – 3

One Airport – Two Passenger Train Stations

The promotional public relations literature of FRA boasts that the so-called optimal integration of air and rail is an innovative and environmentally friendly mobility concept in that it offers a transfer of unprofitable and environmentally unfriendly short-haul flights to high-speed rail. Moreover, it offers expansion of the domestic and international catchment areas by means of additional ICE-trains, additional tracks in future years, and an increased customer attraction by providing improved connections within the region. In addition, this concept (one airport – two passenger train stations) is claimed to be advantageous to passengers for the following reasons (Ref 13):

- Direct connections to and from the airport by ICE and Euro/Inter-City trains to destinations within Germany and neighboring countries (Netherlands, Switzerland, Italy, Austria, Czech Republic, and Hungary).
- Coordination between rail and air timetables.
- Increased frequencies (hourly), resulting in reduced waiting times and shorter point-to-point journeys.
- Overall time savings are expected with the completion of the new ICE high-speed track Cologne/Rhine Main in 2002. For example, the trip from FRA to Cologne Train Station would be completed in less than one hour.

Bridges Between Air and Rail

The interchange between different modes of transportation is intended to be simple and convenient. The Long-distance Train Station is connected to the airport terminals in the following manner (Ref 13):

Terminal 1:

- Via the pedestrian bridge leading from the Frankfurt Airport Center (FAC) to Departure/Arrival Halls A and B.
- Via the Sheraton Hotel and pedestrian bridge leading to Departure/Arrival Hall C.
- Direct link to Departure/Arrival Hall B is scheduled for completion in 2001.
- Walking distance to the "Meeting Point" in Terminal 1 is about 7 minutes.

Terminal 2:

- Shuttle buses depart every 10 minutes, with the bus stop situated at the station in front of Terminal 1.
- Passengers can walk via Terminal 1 and ride the Sky Line shuttle train.
- Connections to the Regional Train Station and Bus Station are available via the staircases and lifts.

Accessibility Improvements

- Direct connections from Frankfurt Airport Long-distance Train Station are available every two hours:
- ICE – Line 3 (Hamburg – Hanover – Kassel – Frankfurt main station – Frankfurt Airport – Mannheim – Stuttgart)
- ICE – Line 10 (Berlin – Hanover – Dortmund – Cologne – Frankfurt Airport – Frankfurt main station – Nuremberg)
- ICE – Line 5 (Dresden – Hanover – Dortmund – Cologne – Frankfurt Airport – Frankfurt main station – Nuremberg)

And every hour:

- IC – Line 1 (Hamburg – Bremen – Munster – Dortmund – Cologne – Frankfurt Airport – Mannheim – Bale)

Avoiding the necessity of changing trains at Frankfurt Central Station has resulted in time savings to the following cities, starting in June 1999 (Ref 13):

Bale → AIRail Terminal	40 minutes
Hamburg → AIRail Terminal	40 minutes
Stuttgart → AIRail Terminal	30 minutes

Further developments intended by 2002 include (Ref 13):

- ICE new high-speed link Cologne – Rhine/Main joins the network.
- Introduction of the new generation ICE-trains with speeds up to 300 km/h (186.4 miles/h); thus the journey from Cologne Central Station to Frankfurt Airport will be completed in less than one hour.
- The new track will form the hub of a rapidly growing central European high-speed network.

Table 3.2 shows illustration travel times from selected European destinations to FRA, under current conditions as well as under the desired scenario for 2005.

Table 3.2: Travel Time for Scheduled Destinations

	Travel Time (hrs.)	
To Frankfurt Airport From	Today	2005
Amsterdam	4:50	3:00
Basel	2:41	2:13
Bonn/Sieburg	1:42	0:39
Brussels	5:01	2:50
Hanover Fair	2:34	2:15
London	7:30	5:30
Munich	3:59	2:58
Stuttgart	1:16	1:02

In addition, intelligent concepts that provide quality services for intermodal travel are key issue in the development of the new AIRail Terminal at FRA. For example, Lufthansa passengers may check baggage through to their final destination and pick up boarding passes on the evening before their departure at the main stations in Dusseldorf, Cologne, Bonn, Wurzburg, and Nuremberg. These same passengers may elect to check in at the German Rail Travel Center at the Saarbrucken main station up to one half-hour prior to the departure of the train to their airport destination. Adding to the convenience of such a system, passengers with the air-rail ticket may take advantage of reasonably priced travel from every train station in Germany to every airport in Germany — for air travel with over 80 partner airlines (Ref 3).

AIRail Express/Pilot Project on Rail Linking Frankfurt Airport with Stuttgart Rail Station

This project will begin on March 1, 2001, creating a connection between FRA (AIRail Terminal) and ZWS (Stuttgart Central RR station) with a travel time of 1 hour and 13 minutes. High-speed ICE trains will depart from FRA between 9:20 a.m. and 9:20 p.m. and will depart from ZWS between 5:11 a.m. and 5:25 p.m. with a frequency of seven trains in each direction beginning July 6, 2001. The trains will have 46 seats for passengers and six containers (Ref 14).

Baggage will be forwarded simultaneously to the passengers and loaded in specifically designed containers, which are placed in dedicated sections of the train. All security screening will be performed at FRA (Ref 14).

The latest check-in time would most likely be 15 to 20 minutes for business/private passengers prior to train departure (Ref 14).

A new collection/distribution station will be established in the AIRail Terminal, and will be linked to the computerized central baggage conveying and sorting system. In addition, specific facilities for check-in/check-out/customs and logistics will be found at ZWS (Ref 14).

In the spring of 2001, the AIRail Partners will launch an intermodal pilot project. Rail travelers destined for FRA, for travel on Lufthansa, will be able to check in baggage up to 30 minutes before the train departs from Stuttgart Central Train Station. Thus they will not have to claim their baggage until arriving at their final destination airport. Initially, 12 daily train connections will be available for this pilot route (Ref 14).

HONG KONG'S INTERNATIONAL AIRPORT AT CHEK LAP KOK

Hong Kong's International Airport at Chek Lap Kok (HKIA) is the largest engineering project ever undertaken in the history of Hong Kong. The plan to build the airport was launched in 1989. The authorities stipulated that the new airport should be easily accessible to all users, both passengers and freight shippers alike, and should meet the "highest standards" of operational efficiency (Ref 4).

The design team defined the shape and size of the projected airport land to be 1,248 hectares (3084 acres), which is approximately four times the size of Kai Tak, the previous airport in Hong Kong. For comparison, this is only one-tenth the size of the new Denver International Airport in the United States. Approximately 25% of the total airport area lies on the existing islands of Chek Lap Kok and Lantau, the remainder consisting of new land reclaimed from the sea (Ref 4).

The planning and design of the airport was similar to planning a new town. “Like any town, the airport requires its own network of road infrastructure and utility services to ensure the efficient movement of people, in the airport’s case both its passengers and the 40,000 people who work there.” Using those guidelines, the airport was linked to the heart of Hong Kong by almost 40 kilometers (25 miles) of new roads, a dedicated high-speed railway and landmark bridges, and a new town (Ref 4).

Facilities

The airport railway was the first railway built specifically for the purpose of serving an airport with its integrated design for stations and equipment. This railway has two types of services: an Airport Express and a local service, the Tung Chung Line, with trains operating at maximum speeds of 135 kilometers (84 miles) per hour. The Airport Express was designed as an all-seated, business-class type service carrying passengers between the airport and the Hong Kong Central Business District with two scheduled stops: at Kowloon and Tsing Yi. Initially, the service began operating with seven cars each having 64 seats, with space available for baggage. Off-airport check-in facilities for passengers are provided at Hong Kong and Kowloon stations, and checked-in baggage is carried in a separate car (Ref 15).

The local service is a mass transit commuter service operating between Hong Kong Island and Tung Chung New Town. It uses the same tracks as the Airport Express, but separate platforms. This service initially began operating with seven cars, which are capable of carrying 312 passengers, thus bringing much needed relief to the busy Nathan Road section of the Mass Transit Railway (Ref 15).

The Lantau Link, officially inaugurated on April 27, 1997, opened to traffic on May 22. This link is the vital connection in the transport network serving the new airport. It comprises the Tsing Ma Bridge, the Kap Shui Mun Bridge, and the Ma Wan Viaduct. The 3.5 kilometer (2.1 miles) long double-deck crossing provides the first road link between Lantau Island and the rest of Hong Kong. The open upper deck of the two bridges and the viaduct has six lanes for road traffic while the sheltered lower deck has a two railway tracks and two road lanes for emergency use (Ref 15).

The Tsing Ma Bridge is 2.2 kilometers (1.4 miles) long, making it the world's longest span suspension bridge carrying both road and rail traffic, while the Kap Shui Mun Bridge, at 820 meters (897 yards) long, is the world's longest spanning cable-stayed bridge also carrying road and rail traffic. Finally, the Ma Wan viaduct is 503 meters long (550 yards) (Ref 15).

At the airport, a transportation center is located directly in front of the terminal building. This building contains arrival and departure platforms for the high-speed rail to the city's urban business districts. Moreover, service is also provided for bus, taxi, and rental cars. A ferry terminal is also available, providing sea access to Hong Kong, Macau, and points along the coast of Southern China and the Pearl River estuary (Ref 16).

Once passengers reach the stations (coming from the airport), they are provided free shuttle bus rides to the area's hotels, and connections are available to the Mass Transit (MTR) subway network. Off-airport passenger processing is available at these stations, where passengers are allowed to check baggage which is then transported to the aircraft (Ref 16).

Trains depart every eight minutes from Hong Kong Station at Victoria to the airport. The trip takes about 23 minutes and costs about $12. Additionally, buses depart every 10 to 15 minutes, taking 65 to 70 minutes to reach the airport, at about half the fare of the train trip (Ref 16).

The airport rail station is on two levels. Trains arrive from Hong Kong at the airport's departure level, then continue to a back siding where they reverse and run at a lower level to load at the arrivals station before continuing to the city center. City stations are designed so that passengers are not required to change levels once they arrive by car or depart by taxi (Ref 16).

It was estimated that nearly 40% of airport passengers would be using this transportation center during the airport's first 12 months of operation. However, by 2010, 50% of all air passengers, their friends and families, and airport employees are expected to arrive at and depart from the airport by the Airport Express. Figure 3.3 shows the overall modal split at the airport, collected from the Modal Split Survey carried out in March 1999 by the Airport Authority in Hong Kong (Ref 14).

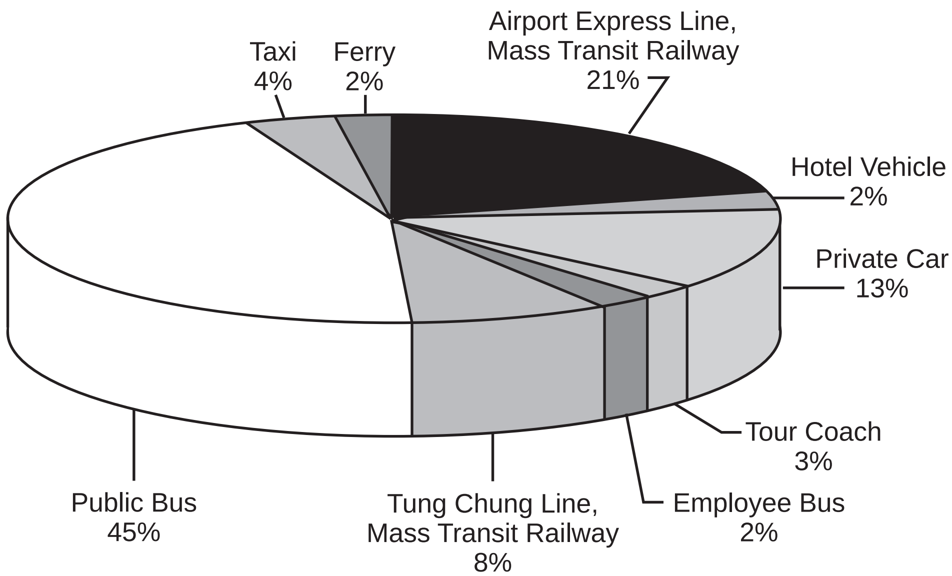

Figure 3.3: Overall Modal Split at Hong Kong's Airport

It should be noted that one of the most important design considerations for this airport was to provide travelers with very high levels of efficiency with a seamless transition from their aircraft to their choice of surface transport when they arrive at the airport. This is an issue of particular concern in Hong Kong, which is the final destination for 75% of its arriving passengers compared to 65% at airports such as Heathrow and Gatwick or 30% at Dallas-Fort Worth International Airport (Ref 4).

Surface Access

The provision of good surface access to Chek Lap Kok is essential to ensuring the efficient and unconstrained operation of the airport. Surface access includes rail, road, and ferry transport modes. The objectives in planning access arrangements for Chek Lap Kok Airport were two fold: to enhance accessibility to the airport from the urban areas and to optimize internal circulation within the airport site. This covers not only air passengers and escort trips, but also employees, delivery vehicles, and other trips associated with the terminal complex, the support and ancillary facilities, and the airport-related enterprises (Ref 17).

Off-airport surface access requirements were comprehensively evaluated during the Port and Authority Development Strategy (PADS) Study. The on-airport transport system was created during the development of the New Airport Master Plan. The public and restricted-use transportation requirements of each airport functional area were identified and then integrated into an overall rail, road, and ferry access network (Ref 17).

A comprehensive and convenient integration of rail, road, and ferry access enables air travelers, well-wishers, greeters, and airport employees to choose their most convenient mode of transportation (Ref 17).

The major considerations in the planning of surface access to Chek Lap Kok were the target modal split of 55% of airport trips by rail, and the forecast in the Airport Railway Feasibility Study, which indicated a range of 36% to 49% of air passengers and escorts by rail (Ref 17).

The following section identifies the multi-modal transportation network serving Chek Lap Kok. Both public and restricted-use roads are discussed because of the critical role that each plays in the operation of virtually every facility at the airport (Ref 17).

Rail Access

A high priority was placed on providing a convenient, efficient rail service to the airport. The two rail links provided for this purpose are the Airport Express (AEX) rail link and the Lantau Line (LAL) (Ref 17).

The AEX provides high-speed, high-frequency service specifically designed for air passengers. It operates from Hong Kong Island to Chek Lap Kok, with additional stations at Kowloon and Tsing Yi Island. It is aligned along the northern shore of Lantau Island, crosses over the Tung Chung New Town sea channels, and follows the eastern edge of the airport reclamation to the passenger terminals. The AEX lies east of the on-airport section of the North Lantau Expressway, the primary access road to the airport, but crosses under the road to the western side as the passenger terminal is approached. After crossing under the road, the AEX is divided vertically and serves both arrivals and departures levels along the eastern side of Terminal 1 and 2. The same AEX serves Terminals 3 and 4 via pedestrian access bridges and moving walkways. If need be, AEX will provide additional capacity by increasing the number of cars in service and decreasing the headway (Ref 17).

The LAL follows the same alignment and shares the same tracks as the AEX, but separate platforms are provided at the Hong Kong, Kowloon, and Tsing Yi Island stations. Provisions have also been made for several intermediate stations, each located on loops to allow AEX trains to pass stationed LAL trains. At Tung Chung, the LAL is separated from the AEX to serve the two stations in the new town. The LAL operates as a local service, similar to other MTR commuter rail lines. It also acts as a commuter service for airport employees (Ref 17).

Road Access

Road access can be divided into two separate operational and security-related categories. Public-use access roads link Chek Lap Kok to the external transport network. They comprise all roads available for use by the general public, on which no airport access restrictions apply. Restricted-use access roads link all areas of the airfield and aircraft apron, and are restricted for use only by authorized personnel and vehicles (Ref 17).

Public Use Access

The following roads provide access to Lantau Island and Chek Lap Kok (Ref 17):

- The North Lantau Expressway (NLE) and the Lantau Fixed Crossing, which opened in 1996, connect the airport to the Hong Kong road network.
- The Green Island Link, a tunnel scheduled for opening in about 2006, will connect the Port Peninsula Development to the western tip of Hong Kong.
- Route 3, the West Kowloon Expressway, and the Western Harbor Crossing form a new high capacity road link between the Chinese border and Hong Kong Island. This link is scheduled for opening in various stages between 1996 and 2006.

The NLE, the Lantau Fixed Crossing, Route 3, and the West Kowloon Expressway will provide a direct link between the new airport and Kowloon, a distance of approximately 30 km (18.6 miles). The Western Harbor Crossing will complete the link to Hong Kong, approximately 35 km (21.7miles) from Chek Lap Kok (Ref 17).

The following access roads link Lantau Island with Chek Lap Kok. (Ref 17):

- The primary access route to Chek Lap Kok, the NLE, crosses the sea channel at the southeastern corner of the airport reclamation and follows the AEX corridor along the eastern edge of the site to an access loop system adjacent to the passenger terminals. An interchange immediately north of the sea channel crossing links the NLE to the southern areas of the airport reclamation.
- A second road access located approximately 400 km (249 miles) west of the primary road access. This second road provides access to Chek Lap Kok from Tung Chung, which is not available via the NLE. The opening of the airport marked the completion of the primary and secondary access roads. The main functions of this second road are to provide direct access to Tung Chung and to serve the southern areas of the airport reclamation. It also serves as an important back-up facility in case the NLE crossing is blocked.
- A third access road crosses the sea channel to the airport reclamation from the westernmost edge of Tung Chung to avoid possible future capacity constraints on the second road access.

All roads on the airport site are designed to accommodate traffic flows forecast to 2040, although this level of service will be implemented in phases for the intermediate years. The primary access route to Chek Lap Kok, the NLE, has been designed to accommodate projected traffic flows to the 2011-2015 timeframe. After this time, additional highway capacity will be needed, and a potential solution, which has been identified, is the proposed northeast link. This additional road link will connect the airport with the north, as a significant proportion of the increase in traffic after 2011 is anticipated to be generated in the northern New Territories, Shenzhen Special Economic Zone, and Guangdong Province (Ref 17).

Ferry Access

The likely generators of demand for ferry services to the airport are Tuen Mun and similar locations, where no direct and convenient access to Chek Lap Kok was provided when the airport opened. A ferry pier is located at the northeastern tip of the airport reclamation, in proximity to the passenger terminals. Currently, a simple bus system carries the ferry passengers to the terminals. As more ferry services are introduced to Chek Lap Kok, this arrangement may be upgraded to a covered moving walkway due to the distances pedestrians would otherwise be required to walk (Ref 17).

Ground Transportation Center

The Ground Transportation Center (GTC) is the focal point for all surface transportation to and from the new airport (Ref 18). Occupying an area of 55,000 sq mi, the integrated center houses the Airport Express station, taxi ranks, and stations for franchised buses, tour coaches, hotel courtesy buses, and limousines. Each mode of transport has a completely segregated passenger handling facility with individual links to the passenger terminal. Directly adjacent to the passenger terminal, the GTC has four levels to handle the heavy traffic at Hong Kong International Airport (Ref 18):

- Highest level: departure curb (Cheong Hong Road). Due to simple routing design, buses, taxis, and private cars are able to drive up an elevated ramp to drop off departing passengers at the front door of the passenger terminal. From here, anyone entering the passenger terminal Check-in Hall crosses walkways over the magnificent atrium without any level changes. There are also designated bays along the curb for the disabled.
- Second level: Airport Express departures level platform. Departing passengers who travel by the Airport Express from Central Hong Kong or Kowloon cross one of the link bridges through an atrium to the passenger Check-in Hall.
- First level: Airport Express arrivals level platform. Arriving passengers traveling to the city on the Airport Express enter the GTC by one of the two link bridges from the passenger terminal meeters and greeters hall.

- Ground level: arrivals ground level transport facilities and service roads. This area houses road transport to most parts of Hong Kong. Clearly marked signs show the way to taxis, buses, coaches, and hotel shuttles and limousines. Private car pick-up facilities for arriving passengers are provided in the nearby car parks.

Franchise Bus Station

There are 17 pick-up bays and staging areas which can accommodate 16 buses shared by three franchise bus companies operating at the new airport (Ref 18).

Tour Coach Station

There are 18 pick-up bays and 24 short-term staging bays. Additional staging spaces are provided at Staging Area II (Ref 18).

Travel Industry Vehicle Pick-up Areas

The pick-up curb can accommodate 10 – 12 vehicles. Additional parking spaces are also available in Staging Area II for limousines and mini-buses (Ref 18).

Taxi Station

There are four pick-up lanes — three lanes for urban (red) taxis, and one for the New Territories (green) and Lantau (blue) taxis. Each pick-up lane has six bays. The New Territories taxis occupy four bays, and Lantau taxis have two bays for their dedicated use. Also there are 14 lanes allocated for taxis in the staging area with a capacity of 530 vehicles (Ref 18).

ZURICH INTERNATIONAL AIRPORT

Zurich International Airport (ZIA) is advertised as the central traffic junction in Switzerland. It has its own railway station, operated by the Zurich Transport Federation (ZVV), and is integrated into the regional bus, train, and streetcar network with combined tickets available for all modes of transportation. Six trains operate each hour between

Zurich's main station and the ZIA's railway station located underneath Terminal B and Parking B (Ref 5).

The airport is accessible by bus with ten bus lines that connect the ZIA with the most important towns and villages of the region. At the airport, the bus terminal is directly opposite Parking B. When trains are not operating (at night), passengers may use the Night Bus, which is a special service, providing transit to various regions of the country and certain communities beyond national borders. In addition, passengers may elect to travel to or from the airport by hotel bus, taxi, rental car, or private vehicle (Ref 5).

Passengers have the option of checking in at any of 23 rail stations in Switzerland. This service is one of the reasons for including ZIA in this case study, as it provides a successful example of remote check-in, in combination with a fixed guideway modal alternative, hence providing relief for the luggage problems otherwise found by passengers who use transit access. Most airlines allow passengers to make reservations for their preferred seat on the plane, check in baggage, and pick up boarding passes at the remote baggage counters which reduces time at the check-in counter. The main limitation is that this check-in has to be done 24 hours in advance of departure time. However, passengers who do not wish to depart from one of these 23 check-in rail stations can use another type of service also provided by the Zurich Transport Federation. This service is the Fly-Rail Baggage Service, which allows passengers to check in baggage at one of 102 additional Swiss stations. Thus this baggage can travel via the airports of Zurich, Geneva, and Basel to any final destination worldwide. Moreover, from any airport in the world and with any airline, passengers traveling via one of the above airports can choose to collect their baggage at any rail station in Switzerland (Ref 5).

Table 3.3 provides selected operating characteristics of Zurich International Airport during 1999 (Ref 19).

Table 3.3: Selected Operating Characteristics, Zurich International Airport

Flight Movements	**270,100**
Daily average	740
Passenger Total	**20.9 million**
Daily average	57,330
Peak day	87,320
Freight in tons	**495,100**
Daily average	1,356
Train Passengers (total)	**9.3 million**
Trains per day	272
Buses per day	650
Private cars per day	20,000

In addition, public transportation during 1999 exhibited the following characteristics (Ref 5):

- Fly-baggage (from hometown to destination), 270,000 clients/year.
- Rail baggage (from destination to hometown), 140,000 clients/year.
- Check-in at railway station in hometown, 23 train stations.
- Eleven bus routes connecting the region (650 departures/day–40 departures at peak hour).
- Car park prices for 1-3 days ranking in upper level of European market.

Rail access at Zurich International Airport has been available since the early 1980's. It has gone through several stages, which include (Ref 19):

- 1980: 4-track train station opened at the airport; intercity stop (Geneva – Berne – Zurich – Zurich Airport – St. Gall).
- 1990: Implementation of a fully integrated regional train system (zones/charges/timetables).
- 1999: Frequency increased to 8 trains/hour (each direction), 210 trains per day to Zurich main station.

The following is a list of measures that are being implemented at Zurich Airport in an attempt to improve access by public transportation and to enhance its usage (Ref 19).

- Sixty check-in counters available directly above the platforms

- New direct short cut from baggage reclaim hall to train station
- Separate bus lanes without lights
- New central bus station with 16 platforms
- Optimized bus stops in front of main buildings
- Fully developed bike concept
- Limited number of new parking slots (1995:11,500 / 2005:14,200)
- Additional and faster trains in the Swiss-/European system
- More train – peripheral connections without stop at Zurich (with special attention to regions with low public transport results)
- More local train lines through the train station
- Check-in at 60 railway stations all over Switzerland in 2002 (promotions/ sponsoring of baggage transport during peak season)
- Fly-baggage/rail-baggage included check-in to and from home
- Improvement of the train/bus timetable before 6 a.m.
- Increased seat capacity (double deck trains)
- Reduction and dislocation of central parking places for employees
- Improvement of car-sharing/car mobility efforts
- Road pricing/special tax on arrival/departure levels

Modal Splits

Zurich International Airport attracts a high level of public transport usage. In 1994, the passenger modal split was 34% public transport, while it increased to 42% in 1999. Figure 3.4 illustrates the modal split among passengers reaching the airport in 1999 (Ref 19). Figure 3.5 shows the employee modal split for 1999, while the modal split among airport visitors during 1999 is shown in Figure 3.6. Figure 3.7 compares public transport among different airports in Europe.

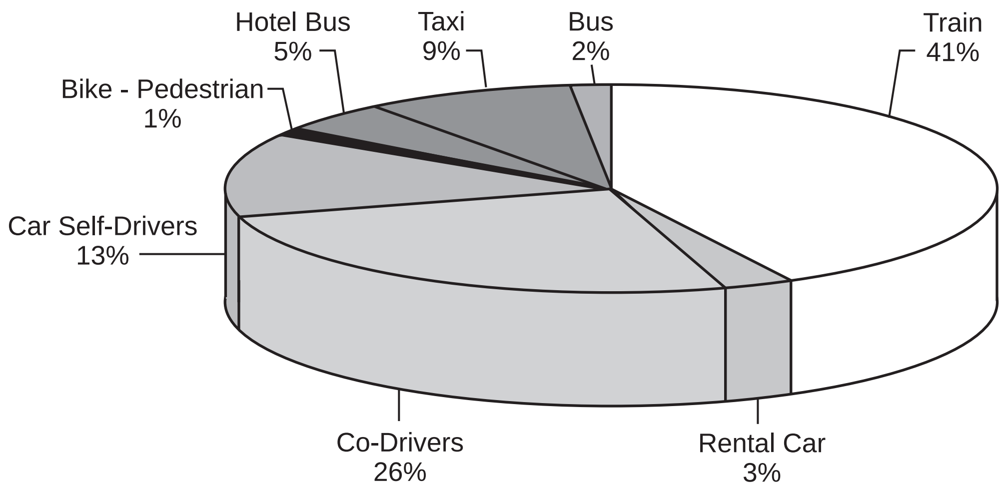

Figure 3.4: Passenger Modal Split

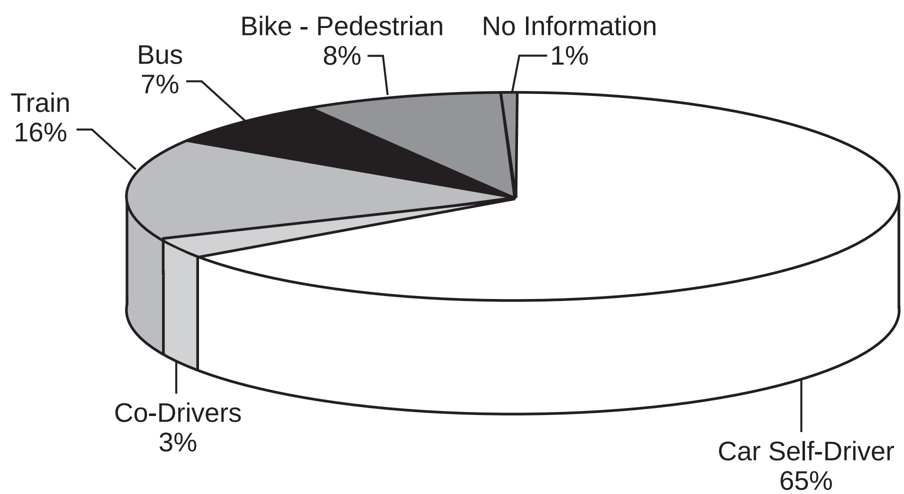

Figure 3.5: Employee Modal Split (Ref 19)

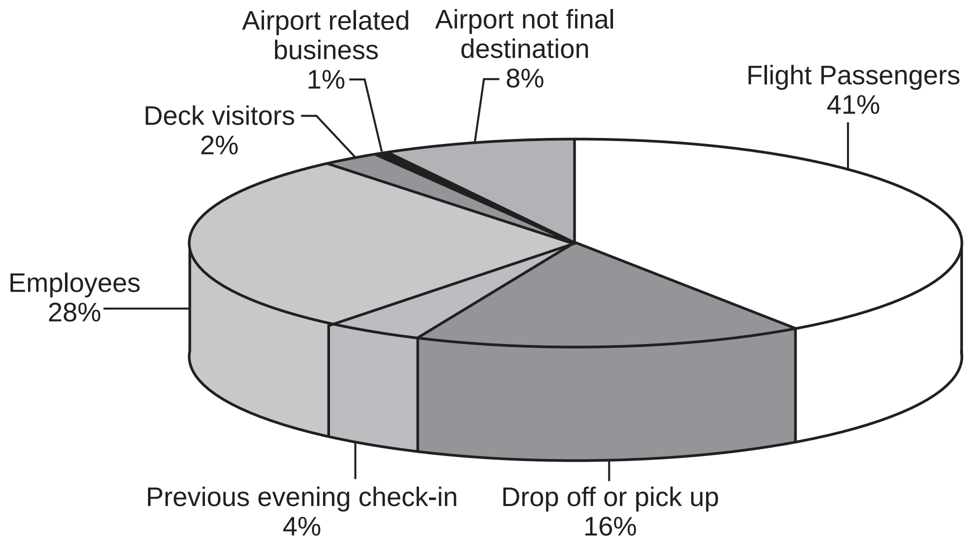

Figure 3.6: Split among Airport Visitors (Ref 19)

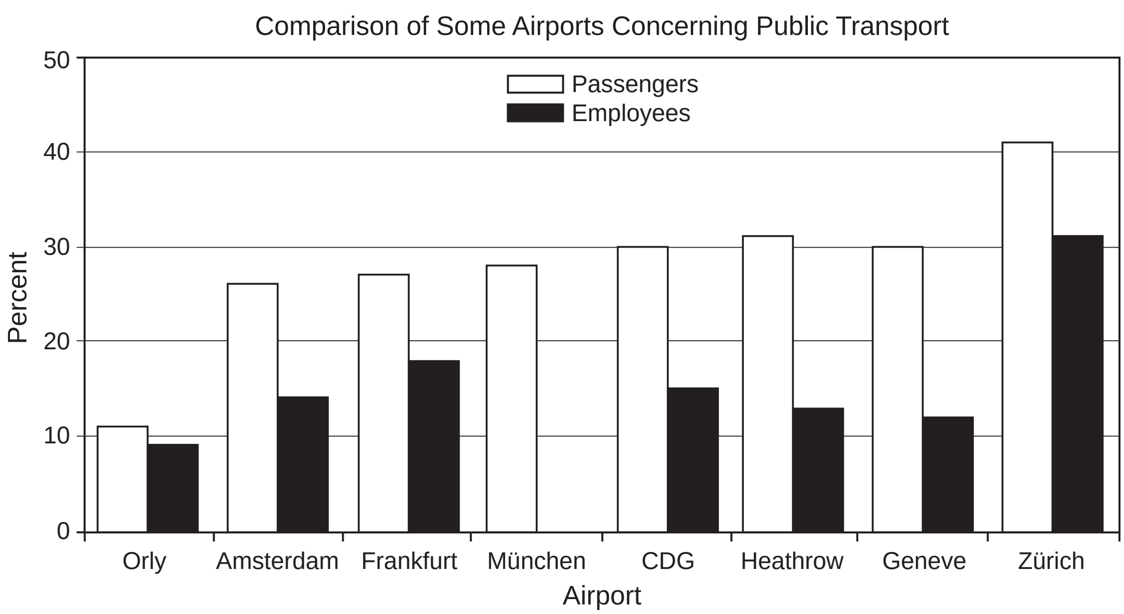

Figure 3.7: Comparison of Public Transport at Various European Airports (Ref 19)

Traffic Survey Results

The fifth development phase at Zurich International Airport resulted in increasing the proportion of total public transport traffic to the airport from 34% in 1994 to 42% in 1999.

As a result, the working group Prognos AG (Basel)/Emch + Berger AG (Zurich) was hired in the summer of 1999 to conduct extensive traffic surveys at the airport. The results of the first section of this data collection, the main survey 1999, are summarized in this section (Ref 20).

The goal of this survey was to determine the structure of the population of landside traffic arriving at the airport, specifically the means of transport selected by different traffic segments. The traffic segments considered in this study are: local passengers and airport employees. In addition, this study attempted to determine the reasons underlying passengers' choice of their means of transport to the airport, and also the reasons for choosing Zurich Airport in the first place. From 2000 to 2003, additional segments of local passengers and airport employees will be surveyed to derive insights that will aid in the development of effective measures to change the modal split (Ref 20).

The investigation areas for the autumn 1999 surveys were the so-called airport heads and the technical area. The following traffic segments were considered: passengers departing from Zurich, companions of passengers, passengers with previous evening check-in, airport employees, visitors of work places in the airport or meetings held at the airport, visitors of the observation deck, visitors whose main motive was to use airport restaurants or to visit store attendants, and people who got off at the airport but had no specific business there. Passengers that were just making travel connections through Zurich were not considered. The surveys were conducted for two weeks: from October 7 to 13 (as a holiday week) and from October 28 to November 3, 1999 (as a "normal" week) (Ref 20).

Based on the two collection weeks, approximately 50,000 persons (daily average) visited the airport in autumn 1999: 39% flight passengers, 16% companions or people picking passengers up, and 4% passengers with previous evening check-in. Employees constituted, on average, 27% of the traffic to the airport. Other segments were considerably less significant: Store and restaurant visitors, 3%; deck visitors, 2%; and visitors of concessions and those who had business meetings at the airport, approximately 1%. Another 9% were people who got off at the airport, but had no other destinations (Ref 20).

During the survey, the bus and rail modal split amounted to 39%. Although the target public transport (bus and rail) share of 42% was not achieved, the fact that this percentage had increased by about five percentage points over the preceding five years suggests some room for further progress. On the other hand, public transport accounts for 51% of local passengers, store and restaurant visitors, deck visitors, and those with business meetings at the airport. A below-average share (25.1%) was observed for airport employees, as well as for the relatively small segment of passengers with previous evening check-in (14.0%) (Ref 20).

Approximately 81% of the passengers who came to the airport via personal vehicles had an available public transportation mode connection to the airport. About 64% of public transport users among the passengers had the option to use a private vehicle. Approximately half of the private vehicle users indicated that the option of taking public transport to the airport would have been a viable option, which indicates some potential to influence their mode choice. In addition, approximately half of the employees showed potential to change the mode they use in one or the other direction. Respondents who were not captive to a particular mode, i.e., who freely chose one or the other option, were further asked about the factors that influenced their decision (Ref 20).

- Passengers: The probability of using public transportation decreases considerably if the trip with that mode lasts 30 minutes longer than it does with a private vehicle or if the passengers come with others to the airport. Passengers from Zurich and the Zurich Canton use public transport to a lesser extent compared to passengers from other cantons (Ref 20).
- Public transport use is more likely with longer air trips (i.e., more than 4-day journeys), with personal trips rather than business trips, and when the public transport trip is already contained in the flight ticket. Passengers with previous evening check-in predominantly use their private vehicles. On the other hand, travelers checking in on the departure day are more likely to use public transportation, particularly if the trip is taking place on a work day and if the passenger travels directly from home to the airport (Ref 20).
- Airport employees choose public means of transportation less often if the travel time is 15 minutes longer by bus or rail than by a private vehicle. However,

employees with irregular work shifts use public transport less than those employees with standard working times (Ref 20).

- Residence location strongly influences the choice of mode of transportation: public transport usage is lowest for employees from the Zurich Canton; it is somewhat higher for employees from Zurich city and above average for employees from neighboring municipalities, who may also come by foot or motorcycle (proportion by foot or motorcycle is approximately 10%) (Ref 20).
- The work start time affects the mode choice of employees only when the work shift begins before 5:45 a.m. Public transportation is not available prior to that time. After 5:45 a.m. public transportation usage remains relatively constant until the evening. Full-time employees use public means of transport less frequently than part-time employees and temporary employees. No significant difference in the bus and rail usage exists between the work sectors at the airport head and technical area (Ref 20).

The survey shows that practical considerations prevail when local passengers choose ZIA. Most aircraft passengers (approximately two-thirds) select ZIA because it is situated close to their residence or it is situated, in the case of a return flight, closer to their destination. In addition, approximately 12% indicated that the preferred airline connections are available at ZIA or that the preferred airline departs from ZIA (Ref 20).

From this analysis, the consultants proposed certain measures to affect the Modal Split. These include infrastructure and supply measures that will alter travel-time ratios between public transport and private vehicles in favor of public transport, particularly in places that are still inefficiently connected to the airport (e.g., coming from Schaffhausen-Winterthur or Bulach as well as some municipalities in the Zurich Canton). For travel mode selection, the perception of the travel times is also meaningful; hence a public communication campaign could further highlight that public transport already offers travel times that are competitive with the private auto. For those passengers who are using a combined airline and public transport ticket, stronger promotion of rail station checking and the introduction of special tariffs for the journey of small groups to the airport in addition to parking measures should be considered. For employees, demand measures for the use of public transport should target the group of shift-workers and employees having very early work start times. Employees who already have acceptable connections with bus or rail to the airport could be targeted and contacted directly, for example with individualized timetable information or test rides for public transport (Ref 20).

CONCLUSION

This chapter presented three case studies pertaining to three different non-U.S. airports, two in Europe and one in Asia. These airports were selected because of the unique access characteristics offered at each airport. This review has targeted airports that have successfully addressed the ground access issue through heavy reliance on public means of transport. At each of the airports addressed, this mode has been rail and in some cases a combination of rail and off-airport check-in (Switzerland). While the success of such options in any given setting depends on the particular conditions prevailing in these settings, this chapter has helped identify several options that might be adapted to fit the specific context of interest.

CHAPTER 4
DALLAS-FORT WORTH INTERNATIONAL AIRPORT

INTRODUCTION

The Dallas-Fort Worth International Airport Board, an agency created by Texas legislation with board members from the two member cities, administers Dallas-Fort Worth International Airport (DFW). Unlike most Texas airports, which are administered by city departments of aviation, a professional airport staff reporting to the airport board runs DFW airport. Given the airport's large size, this is an effective way to organize and respond to the specific needs of the airport. With more than 18,000 acres, DFW is the second largest airport in the U.S., as measured in terms of land area. With more than 2,500 aircraft operations a day, it is either the second or third busiest airport in the U.S., depending on how the actual measurement of annual aircraft operations is made. This chapter presents an overview of DFW stressing ground access and temporal patterns of traffic entering the airport. An extensive set of plots of traffic characteristics at the airport for different vehicular categories have been compiled and are presented in the Appendix.

GROUND ACCESS PROBLEM

Dallas-Fort Worth International Airport has a somewhat unusual ground access problem that does not appear to be found at other major airports. Because of its large acreage and strategic location between the high employment growth area of north Dallas and the high residential growth area of south Fort Worth, DFW has emerged into a major transportation artery between the two areas. Figure 4.1 provides the layout of the airport, showing its central multilane divided thoroughfare oriented north-south, which attracts a large number of commuter vehicles that do not intend to use the airport but merely pass through as a means of obtaining the shortest time commute. Anecdotal evidence reported by the airport staff has indicated that during rush hour, the waiting queue to enter the airport parking gate can exceed 20 minutes with all lanes open. As further evidence, DFW reported in an airport parking survey conducted by the Airports Council International that 16 million vehicles exited their parking facility toll booths in 1996, compared to 17 million origin and destination passengers. These figures are relatively high compared with those for other airports for the same year; for example, Chicago's O'Hare International Airport had 4 million vehicles exiting parking for 27 million origin and destination passengers.

Figure 4.1: DFW Airport Layout Plan

In an attempt to mitigate this problem by diverting this type of non-airport through traffic demand, the airport authority, during the spring of 1999, instituted a new parking rate of $2 for parking times between 0 and 8 minutes. The toll remains "no charge" for times between 9 and 30 minutes. The intended purpose is not to become a toll road authority but instead to reduce demand for the primary access roadway by charging a pass-through toll for drivers having no intention of stopping at the airport. Figure 4.2 is a plot of the total monthly transactions for the "passer through" vehicular category at DFW airport during the period from January 1999 to March 2000.

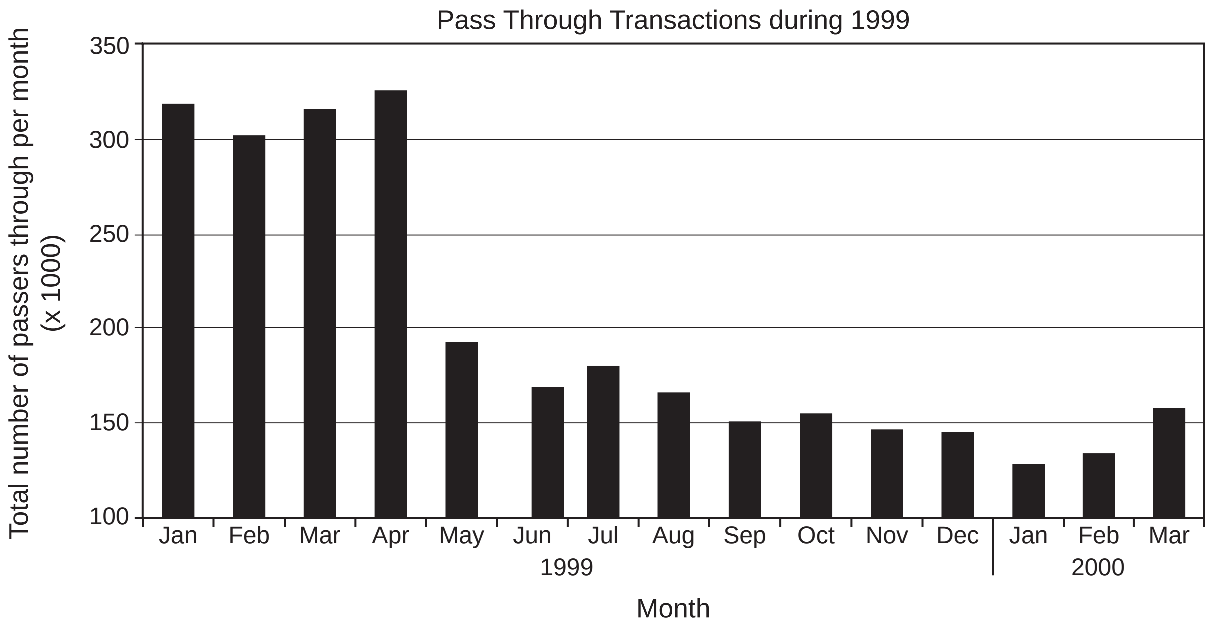

Figure 4.2: Pass-Through Transactions at DFW International Airport

It is evident that the toll measures were effective in reducing the number of vehicles that were using the access roadway with no intention of entering the airport.

TEMPORAL PATTERNS

The set of values for one particular population of vehicles entering the airport, demonstrated in Figure 4.2, shows the level of variation that has happened over the course of one year. Consequently, the decision was made to obtain as much data as possible on other vehicular categories entering the airport premises. An abundance of data for different vehicular categories was obtained from the airport authority. Following is a definition of those categories and a summary of the data analysis performed.

Vehicular Categories and Definitions

- Commuter/Pass-Through: A customer who enters one parking plaza and exits a different parking plaza in 30 minutes or less. The assumption here is that a person who enters from one plaza and exits from a different one in such a short period (<30 min) most likely has no business at the airport and thus is considered a "passer through."
- Courtesy Vehicle: Hotel or motel vehicle.
- Drop Off: A customer who enters a parking plaza and exits the same parking plaza in 30 minutes or less.
- Meeter and Greeter: A customer who enters and exits the plazas within 30 minutes to two hours.
- Non-Revenue Badge: Airline executives, city officials, etc.
- Off-Airport Rental: Rental cars.
- Public Parker: A customer who enters and stays more than two hours.
- Regulated Bus: City bus.
- Regulated Limo.
- Regulated Vehicle: Maintenance vehicles, airport management vehicles, emergency vehicles, etc.
- Rental Exit Pass: Today rental cars do not use the plaza-controlled roadways due to the new rental car facility. However, when they did use the plazas, renters were given rental exit passes to allow free entry and exit in the rental car.
- Shared Ride: A super shuttle park and ride (off-airport).
- SRD Tag: Employees using a mounted or handheld access card.
- Taxi: Regular airport taxi.

Data Sets

Table 4.1 represents the first set of data that was obtained, a summary of the peak day vehicular counts and the average daily transactions for each of the previous categories. The values are for 1999 and the first part of 2000.

Table 4.1: Summary of First Data Set

Peak Day	Category	# of Vehicles (Peak Day)	Avg. Daily Transactions
4/30/99	Commuter/ Pass Through	13,300	6,553
11/8/99	Courtesy Vehicle	1,954	1,188
11/29/99	Drop Off	17,945	11,927
11/28/99	Meeters and Greeters	20,276	10,115
3/31/99	Non-Revenue Badge	842	417
11/9/99	Off Airport Rental	982	487
1/15/99	Public Parker	14,838	8,464
1/31/00	Regulated Bus	263	38
11/8/99	Regulated Limo	2,257	1,161
4/27/99	Regulated Vehicle	4,165	2,405
1/25/99	Rental Exit Pass	6,477	860
11/8/99	Shared Ride	902	492
1/13/99	SRD Tag	4,451	1,675
11/8/99	Taxi	5,142	3,143

The second data set received from DFW comprises vehicular counts taken at the plaza entrance during March 2000. One value was reported every 15 minutes during the 31-day month for the 14 previously defined vehicular categories. Thus, an average 2,976 (96 x 31) values were reported per category, though there were some exceptions for some categories (in some cases no vehicles of that category entered the airport).

The data set was not given per category but rather per day, as each day the values for all 14 categories were recorded. Thus, an initial step was to establish a record per category for the whole month.

As a first step in the analysis process, the "mode" and purpose split at DFW was estimated, as shown in Figure 4.3. This was obtained by combining the data of the 31 days into one single figure and dividing that by the total number of vehicles that entered the airport during that month. As seen in the figure, the type of vehicle and purpose are somewhat confounded here. Note also that this is a distribution of the number of vehicles detected, not a split of passenger or trip makers by type of vehicles.

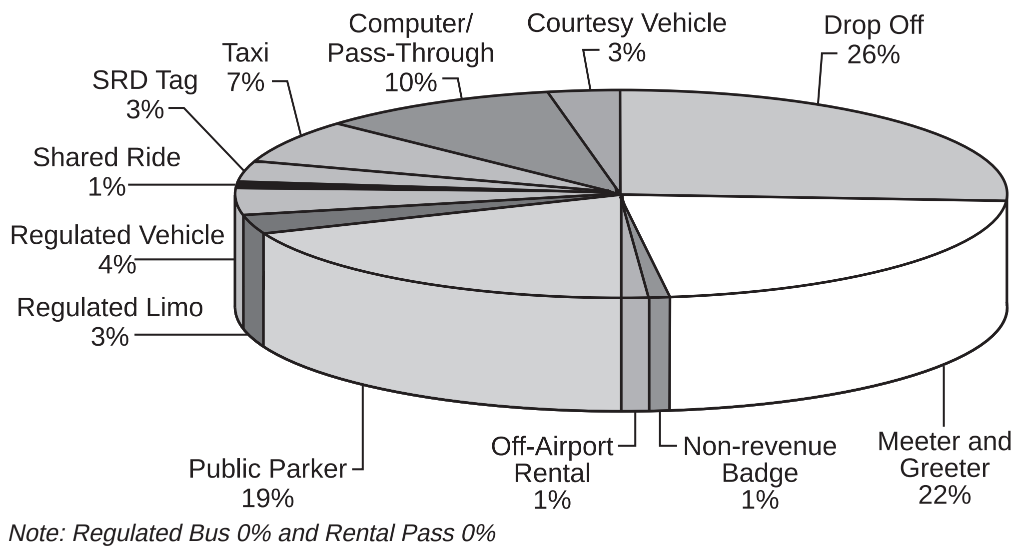

Figure 4.3: Vehicle Type and Purpose Split at DFW International Airport

Subsequently, the values were plotted versus time (for each category separately) in an attempt to understand variations and determine whether they were repetitive. For each vehicular category four plots are presented: The first is a plot of the values that occurred during the whole month of March. The second is a plot of the total daily values per category during the month of March. The third is the plot of a typical day in that month. The fourth and final plot is either that of the peak day or a day during which large variations were observed. All of these plots are included in the Appendix, but are described in this chapter.

The results of the analysis are summarized per category below, and the corresponding Appendix Figures are included for reference:

- Commuter/Pass-Through (Figures 1 – 4)

  The whole month plot shows that the number of Commuter/Pass-Through vehicles is essentially constant during the week with peaks occurring every Friday (March 3, 17, 24, and 31). It is noted that the total daily values are repetitive on a weekly basis. A typical day plot was obtained for Wednesday the 1st of March. The plot clearly reveals that two peaks occur: one during the a.m. period and the other during the p.m. period. In fact, the first peak of 102 vehicles occurs at 8:00

a.m. and the second peak of 104 at 4:45 p.m. The peak day plot (March 31) does not exhibit the previous behavior but rather shows a steady increase in the number of vehicles counted till 6:45 p.m. when a peak value of 189 occurs.

- Courtesy Vehicle (Figures 5 – 8)

  This category does not exhibit pronounced variations throughout the month of March; all days appear to be quite similar. It is noted that there is a weekly structure that repeats itself during the month in that every Saturday minimum values are observed. A typical day plot on Wednesday the 1st reveals that large fluctuations are observed during the day beginning at 6:30 a.m. with values ranging between 10 and 31 vehicles. Peak values occur on Saturday, March 11.

- Drop Off (Figures 9 – 12)

  Drop Off values tend to be stable during the week but peaks are observed during the weekends, mainly on Sundays, and on Mondays. The total daily plot does not add much to the information obtained from the first plot because no clear pattern is observed on a weekly basis. On Wednesday the 1st a peak value of 265 occurs at 3:15 p.m.; however, during the day no pronounced variations are observed. The peak value for this category occurs on March 12, when a value of 390 occurs at 3:15 p.m. This suggests that the Drop Off category does not exhibit major variations because peaks for the typical and peak day occur at exactly the same time and the behavior on those days is nearly identical.

- Meeters and Greeters (Figures 13 – 16)

  Meeter and Greeter values tend to increase during the week to reach peaks during the weekend, namely on Fridays, Saturdays, and Sundays. This is illustrated in the total daily plot, where a repetitive pattern is noted over the whole month of March. This pattern consists of constantly rising values, peaking on Sundays and then dropping back to minimum values every Tuesday. The typical day plot of Wednesday the 1st shows that values increase during the day to reach a peak value of 214 at 8:30 p.m. The same behavior is observed on Sunday the 19th (peak day), when a peak value of 487 is observed at 3:45 p.m.

- Non-Revenue Badge (Figures 17-20)

  For all practical purposes, non-revenue badge counts appear to be constant during the whole month of March. The daily counts reveal a pattern, which repeats itself on a weekly basis with peaks occurring every Friday and the minimum occurring on Saturday. On Wednesday the 1st, two peak values are observed, the first at 7:45 a.m. with a value of 14 and the second at 4:45 p.m. with a corresponding value of 15. In between those two peaks, variations occur but values are confined between 4 and 11. During the peak day (Friday the 3rd) variations are much more pronounced; however, the phenomenon of two peaks still holds. The peak value of 18 occurs at 7:45 a.m.

- Off-Airport Rental (Figures 21 – 24)

  For this category variations are minimal during the largest part of the month. However, starting on the 26th of March, values drop sharply to nearly zero, due to a policy change at DFW (relocation of facility), which has effectively succeeded in limiting the traffic impact caused by these vehicles.

- Public Parker (Figures 25 – 28)

  For this category it is noted that peak values occur late during the workweek, especially Wednesday through Friday. Values drop during the weekend and early during the week (Monday and Tuesday). A weekly repetitive pattern of peaks on Fridays and minimum values on Saturdays can be observed from the second plot. On Wednesday the 1st it is observed that the counted values are on the rise till the peak value of 433 occurs at 8:30 p.m. and then the values start dropping. This same behavior is replicated on Thursday the 9th (peak day) when the peak value of 472 occurs at 8:15 p.m.

- Regulated Bus (Figures 29 – 32)

  No clear pattern is observed during the month of March especially because values are highly variable. The typical day plot (Wed. the 1st) does not suggest any behavioral pattern besides the fact that a peak of 4 occurs at 5:00 p.m. The peak for this category occurs on Friday the 24th, with a value of 11 occurring at 12:45 p.m.

- Regulated Limo (Figures 33 – 36)

  The behavior here is similar to that observed for public parkers in which values drop sharply during weekends, though values during the workweek are nearly constant. The second plot reveals a highly repetitive pattern, which manifests itself in Saturday minimums and Friday peaks each and every week. On Wednesday the 1st, sharp repetitive increases and drops in recorded values are observed starting at 8:30 a.m. with a peak of 44 occurring at 8:00 p.m. The same behavior is observed on March the 9th (peak day); however the peak is 63 and occurs at 3:15 p.m.

- Regulated Vehicle (Figures 37 – 40)

  This is one of the most stable categories as virtually no variations are observed during the whole month. A pattern similar to that observed with the regulated limo category occurs here with the exception of Sunday minimums and Friday peaks. On Wednesday the 1st, values increase until a peak of 80 occurs at 3:15 p.m.; then a drop, which is a mirror image of the rise, occurs. A replica of that can be observed on Monday the 6th, when a peak value of 92 occurs at the same time (3:15 p.m.).

- Rental Exit Pass (Figures 41 – 44)

  Patterns are not easily detected in this category, as beginning March 26 rental exit passes were no longer issued because the rental car facility was moved to a new location. The same relocation also affected the off-airport rental category discussed earlier. However, before the 26th, a weekly pattern of Saturday minimums could be observed.

- Shared Ride (Figures 45 – 48)

  Variations are minimal during the month in question and thus very similar behavior is observed on the 1st of March and on the 3rd (peak day). On both of these days, values increase to a point where large variations are observed with peaks occurring starting at 4:45 p.m. The peak value of 19 occurring at 5:15 p.m. is observed on the 3rd of March. No clear weekly pattern could be observed from the total daily plot.

- SRD Tag (Figures 49 – 52)

  Plotting these observations during the month of March reveals that they are nearly constant during the workweek, while sharp drops are observed during the weekend. The total daily plot shows a plateau during the workweek and a drop in values on Saturday and Sunday. On Wednesday the 1st values increase till 2:45 p.m., when the peak value of 39 occurs, after which values commence a dropping phase. The same behavior is observed on the 6th of March but with a peak of 42 occurring at 3:15 p.m.

- Taxi (Figures 53 – 56)

  An interesting phenomenon can be noted with this category: Values are nearly constant during the entire week except on Saturdays, when sharp drops are observed. This could be attributed to the fact that the volume of passengers traveling on Saturdays is considerably lower than it would be during the remainder of the week. Furthermore, more travelers are dropped off by family members and/or friends during the weekend, as noted earlier.

The data set per category was further split into two distinct sets: weekday counts (Monday through Friday) and weekend counts, as weekends tend to exhibit different characteristics than weekdays.

Following is a discussion of the plots of the cumulative percentage counts (i.e., cumulative relative frequency) versus time for all 14 traffic categories combined (Appendix Figures 57 – 59). The first is a plot of the whole month combined, the second a weekday cumulative plot, and the third is a plot of the weekend cumulative percentage.

Figure 57 is a plot of the percentage counts for all 14 categories versus time. These were plotted on the same graph in an attempt to show the level of relative variation among them. It is evident that the majority shares the same general pattern with the exception of the public parker category, which is lower than the rest during most of the day. The regulated bus category is also not typical in that during the first part of the day the percentage values are less than the rest, whereas after 3:00 p.m., the slope of the cumulative plot for this category increases faster than the rest of the categories.

In the weekday cumulative percentage counts (Figure 58), 10 out of the 14 categories exhibit a common pattern, whereas four categories exhibit a somewhat peculiar pattern. These are regulated bus, regulated vehicle, meeter and greeter, and public parkers. During most of the day, these categories have cumulative percentage values less than those of the remaining categories, as the number of vehicles in these categories entering the airport is less than the number entering from the other 10 categories.

Figure 59, which corresponds to the weekend percentage counts, shows much less variation than the previous two. In fact, of the 14 categories only one shows any signs of discrepancy from the general pattern. This is the case of the regulated bus category, which has a completely different pattern as compared to the others. After 11:00 a.m. the slope of the cumulative count increases considerably and this continues till 5:00 p.m., when it stabilizes and drops sharply. This is attributed to the fact that the peak number of regulated buses entering the airport occurs during that period on weekends.

As a final step in the analysis process, the coefficient of variation per category was plotted versus time and the mean count for the whole month, weekdays, and weekends separately. The coefficient of variation, which is the standard deviation, divided by the mean, gives an indication of the level of variation in the counts. For example, a low standard deviation does not translate into steady conditions because the mean might be very low. Thus, using this indicator ensures that more tractable results will be obtained.

Per category, four plots are reported: the first is a plot of the coefficient of variation versus time for three different cases (all month, weekdays, and weekends), and the other three are the coefficient of variation plotted against the mean for the whole month, weekdays, and weekends. As established earlier, weekday airport access traffic should be analyzed separately from weekend traffic because of different characteristics. This is illustrated in Appendix Figures 60 – 155.

In all cases, high fluctuation in the coefficient of variation is observed during the first part of the day (between 12:00 a.m. and 6:00 a.m.), which is attributable to the very low traffic volumes in that period. In some instances, the high degree of variation was not limited to a certain period in time, but spanned the entire day, as was the case for the regulated bus category. This is expected as this type of traffic is not sustained (especially at airports), which leads to high fluctuations.

CONCLUSIONS

This chapter has presented a preliminary analysis of the temporal access patterns to the Dallas-Fort Worth International airport. The analysis reveals that access traffic volumes and composition can vary greatly during the course of a day, as well as over the course of a week. To effectively address airport ground access at the network level, large quantities of data are needed to represent these traffic patterns. This review and synthesis of traffic temporal patterns at Dallas-Fort Worth Airport has reinforced the need for this work and has validated the basic premises of the work plan developed to address the research objectives.

CHAPTER 5
SUMMARY AND CONCLUSIONS

The previous chapters showed examples of how airports in the United States and around the world have addressed the issue of airport access. It is evident from the discussion that several options are available and in some cases have been very successful in achieving high ridership levels on public means of transportation.

Airports around the world, particularly those represented in this report (Frankfurt/Main International Airport, Chek Lap Kok International Airport in Hong Kong, and Zurich International Airport), have planned for and achieved high public transport modal splits using ground access options not prevalent in the continental U.S. Two prominent options, rail and off-airport check-in facilities, deserve further evaluation.

This chapter evaluates the characteristics of successful implementation of our study airports for ground access by airport rail and off-airport terminal facilities for passenger check-in. The conclusions drawn from the study airports are then applied to airports in Texas.

AIRPORT RAIL

Of the public transport modes available at various airports, rail seems to capture the highest mode share at non-U.S. airports. This is the case partly because the available rail links are much more air-passenger oriented than those available at U.S. airports. This conclusion is based on a comparison of the performance of the rail links at these airports and the characteristics of the airport rail stations. Table 5.1 serves as a summary of airport rail link performance.

Table 5.1: Airport Rail Link Performance

Airport	Time to CBD (min)	Rail peak headway (min)	Mode Share %	Trains/ day	Convenience
Zurich	10	10	42.2	272	Zurich Airport is integrated into the regional transportation network operated by Zurich Transport Federation (ZVV), which offers combined tickets for rail, bus, and streetcar. The Airport is connected with all parts of Switzerland and most of the country's large cities and tourist centers.
Frankfurt	11	8 – 15 (Long distance trains every 1 – 2 hours)	31	230	Direct connections to and from the airport by ICE and Euro/Inter-City trains to destinations within Germany and neighboring countries. Moreover, rail and air timetables are coordinated. “Rail & Fly” or “Fly & Rail” tickets are available.
Hong Kong	23	8	29.2		2 types of rail services are available: Airport Express and domestic. Off-airport check-in facilities are available at several stations in Hong Kong.
Chicago O’Hare	44	7	4.0		24-hour service between downtown Chicago and O’Hare.
Ronald Reagan Washington National	17	3	14.0		

In addition, airport rail stations themselves have special characteristics that determine whether rail will be successful in attracting a high market share or not. Table 5.2 is a summary of the characteristics of the rail stations at the various airports that have been addressed in this study.

Table 5.2: Characteristics of Airport Rail Stations

Airport	Station Location	Distance to Terminal (m)	Convenience
Zurich	Under Terminal B and Parking B		Baggage can be checked in directly or passengers taking their own luggage can use luggage trolleys, which have been designed for use on escalators.
Frankfurt	Near Terminals 1 and 2		Passengers can check-in at the "Check-in T" area, which is a short walk from the rail platforms.
Hong Kong	Directly connected to the passenger terminal.		The ground transportation center available at the airport is unique in that it offers convenient access to all forms of transportation.
Chicago O'Hare	Under garage	100	A moving walkway is available for passengers to transfer between the station and the terminal.
Ronald Reagan Washington National	Across parking lot	500	Poor connections exist between the station and the terminal.

When and Why Rail Works

Transporting passengers to and from an airport would seem to be an ideal role for mass transit. Airports are a significant destination in most cities, making it plausible to justify rail connections to them. (However, in most U.S. cities where airport rail links do exist, they do not transport a significant percentage of airport passengers, and traffic congestion enroute to most U.S. airports continues to worsen.) European airport rail links attract a much higher percentage of air passengers (25% – 30%) than U.S. airport links (1% – 10%). This might be due to the fact that European passengers are more likely to use rail to reach their final destination (from the airport, or, alternatively, from their origin to the airport), whereas Americans are more likely to require a personal vehicle at some point during their trip.

To achieve a high market share for public transportation at an airport, several features are necessary. For example, rail ridership is greater at non-U.S. airports, in part because of the significant reliance on rail in European and Asian cities as the dominant form of public transportation and the extensive inter-city (or regional) and intra-urban networks. The factors that allow rail to attract large market shares at the European and Asian airports are not directly transferable to conditions in most cities in the United States. Thus, 90% or more of all airline passengers are using private or non-public transportation access modes at most airports, including those with rail service. Key factors that might affect the use of rail service include:

- Proportion of airline passengers with trips ending downtown.
- Characteristic of the passenger market (e.g., whether traveling alone or with others, amount of baggage, familiarity with the regional transit system).
- Regional travel time.
- Convenience to walk between station and destination.
- Extensive regional coverage.
- At-airport travel time: Passengers using rail prefer to minimize time required to travel from station to flight gate.
- Frequency of service and associated waiting time.
- Availability of parking at non-airport stations.

What the Case Study Airports are Doing

- **Proportion of airline passengers with trips ending downtown.** For example, at Ronald Reagan Washington National Airport about 33% of all passengers have trips ending in the downtown area. Chicago O'Hare International Airport also has large proportions of passengers whose trips end downtown.
- **Characteristics of passenger market**. Passengers with few or no checked-bags are more likely to use rail service. Large family groups are less likely to use rail.

Washington National has 64% of passengers making business-related trips while Frankfurt has 44%.

- **Regional travel time.** The availability of direct service between the airport and downtown, allowing passengers to avoid transfers or multiple stops, is important. Passengers traveling between the airport and downtown encounter six to nine station stops at Washington National.
- **Convenience to walk between station and destination.** Passengers may find using rail service more attractive if their final destination is within easy walking distance of the station, and less attractive (and less convenient) if they must transfer to a second mode (e.g., a bus or taxicab) to travel to/from the station.
- **Extensive regional coverage.** A comprehensive rail network serving a larger catchment area will serve a larger potential market. Therefore, it will provide passengers with more travel opportunities (e.g., those who may wish to leave from their place of work and return to their home) than does a rail system consisting of a single line between downtown and the airport.
- **On-airport travel time.** The time (distance and convenience) passengers are required to travel between the station and their gate is very important. The average distance between the rail station at Chicago O'Hare and Washington National is 100 meters and 500 meters (109 and 547 yards), respectively. The availability of baggage trolleys, number of vertical elevations changes (elevator or escalator), and exposure to the elements are some of the measures of convenience that potential users weigh in their mode choice selection.
- **Frequency of service.** Average waiting times of 10 minutes or less are preferred. The availability of late-night and weekend service is also important. The CTA Blue line train provides 24-hour service between downtown Chicago and O'Hare International Airport. The rail peak headways at O'Hare are seven minutes. Washington National has rail peak headway of three minutes. The peak rail headways at Frankfurt, Zurich, and Hong Kong are 10 minutes, 8-15 minutes, and 8 minutes, respectively.

- **Availability of parking at non-airport stations.** Many transit agencies prohibit overnight parking at stations, discouraging passengers who may wish to leave their car at the rail station for their duration of their trip.

The case studies addressed in this report have served as a sample of U.S. and non-U.S. airports. The non-U.S. airports (Frankfurt, Hong Kong, and Zurich) had most of the successful characteristics and this explains the major difference in modal splits between these airports and the U.S. airports.

Airports in the U.S. have little control over many of the successful characteristics of European and Asian rail access for airports. Most U.S. airports do not have cities and regions with high regional rail usage, nor very high-consolidated trip generations. Therefore, it is unlikely that in the U.S. the potential market for rail service will achieve the higher modal splits seen in the study airports. Thus, despite the success of rail service in Europe and Asia it would appear that airport rail service, particularly investments in new rail service, is difficult to justify on a purely economic basis as few U.S. cities can generate the ridership for successful service.

OFF-AIRPORT TERMINALS

Previous chapters have discussed the methods airports around the world have used in addressing the ground access issues. The options varied from rail terminals directly serving airports, to ground transportation centers that house all transport options, and finally, in some cases, to off-airport check-in facilities which add to the convenience of traveling via public modes of transportation.

It was noted that some of these airports would not have been able to achieve such high levels of public transport modal splits without relying on a combination of factors. By far, the two most prominent features available are the integration of the airport rail stations in the national and sometimes international networks, and the availability of off-airport or satellite terminals. The high levels of public transportation usage cannot be attributed to satellite terminals alone: Rather, it is the integration of rail and off-airport terminals that has motivated this success. Off-airport terminals providing baggage check-in and/or claim facilities are in operation in several cities, including Hong Kong, London, and Zurich. In North America, various airlines once operated satellite terminals in several cities, including New York, Phoenix, and San Francisco. These satellite terminals have since been closed. No satellite terminal providing baggage check-in for multiple airlines for all passengers is now in operation in the United States. However, with the renewed interest in intermodal transportation, development of satellite terminals is being considered in several cities (e.g., Boston, Dallas, and Seattle).

Issues to be Considered in Developing Off-Airport Terminals

To develop a successful off-airport terminal, a number of planning issues must be considered:

- *Security requirements*: It is required that all airports and airplanes adapt and implement the approved Federal Aviation Administration (FAA) security program (mainly addressing passenger and baggage screening). The U.S. Congress and the FAA plan major changes in the near future for baggage security and screening, which is currently an airline responsibility. These changes are expected to require the screening of all checked baggage, both domestic and international. Currently, only international baggage requires electronic screening in the U.S. Implementation of new procedures will have to be evaluated to determine if the evidence encourages or discourages the likelihood of off-airport check-in terminals.
- *Close-out times*: There is a specified minimum time prior to flight departure by which passengers must have their baggage checked in at the satellite terminal. To achieve the economies of scale, this may require consolidating baggage into batches, which means that the cut-off time for off-terminal baggage check-in may be earlier than the minimum travel time allows between the satellite terminal and the airport. This reduces the attractiveness of such facilities for the busy business traveler.

- *Difficulty of providing baggage claim services*: If baggage claim is provided at the satellite terminal, would each airline have to provide lost baggage claim personnel or would they be consolidated? In addition to customer service issues, there is always the problem that checked bags and passengers will not always correctly match baggage claim locations. Inevitably, through confusion, mistakes, or changes in plans, a fraction of either passengers or baggage will end up arriving at the wrong location.
- *Travel time advantages*: The mode of travel between the terminal and the airport must provide reliable and reduced travel times as compared to private vehicles to be attractive (e.g., if bus can make use of HOV lanes or bus preemption at traffic signals it would become highly competitive).
- *Availability of parking:* If the desire is to attract local residential travelers to the satellite terminal, adequate parking at reduced rates must be provided.
- *Airline industry cooperation and support:* Currently, airlines are responsible for the security and delivery of baggage. Because of the competition between airlines, they would be less willing to have someone other than their own employees handling baggage when they are responsible. If an airline industry-supervised company handles the remote terminal, the airlines lose a relative amount of control over level of service issues they would normally have if they were employees (e.g., late baggage arrival resulting in flight delays). Without support from the airlines, a satellite terminal could not be successfully implemented.

One of the more prominent features that ensures a successful off-airport terminal scheme is the integration of the airport with the comprehensive rail network. In cities in Europe and Asia, where off-airport terminals have been successful, rail was an integral part of that success. For example, in Switzerland, off-airport facilities are available at 125 rail stations throughout the country; had they not had a comprehensive rail network there, off-airport check-in services would have been far less successful. The same has occurred in

Frankfurt, where off-airport check-in service is to be added soon after major improvements have occurred to the rail network that links the airport to the national and international network.

Although U.S. airports have few of the characteristics of the European airports that have led to successful satellite terminals, there is still some possibility that remote terminals might be responsive to passenger needs and help reduce the ground access congestion problem.

IMPLICATIONS FOR TEXAS AIRPORTS

A significant problem facing the larger airports in Texas is mitigation of air pollution problems. Houston is in severe non-attainment, Dallas could reach severe non-attainment levels in the near future, and Austin and San Antonio will be in non-attainment in the near future. The severe non-attainment designation by the Environmental Protection Agency (EPA) will have considerable influence on the nature and extent of the ground access planning that is expected to take place, and on the types of access alternatives that must be considered. In this respect DFW is in the process of adding commuter rail access to the airport using the Dallas Area Rapid Transit (DART) authority system. This is expected to reduce low-occupancy private automobile trips to the airport and thus help in the reduction of air pollution levels.

At George Bush Intercontinental Airport, typical ground travel times could be problematic from some parts of the city during certain times of the day. In response to the fact that Houston traffic is at times extremely congested, commuter flights are being flown from Hobby Airport and Ellington Field to George Bush Intercontinental Airport, thereby providing intra-city air shuttle service. The City of Houston and Continental Airlines, in order to have the airport expansion plans approved through the environmental review process, have both recently agreed to reduce the ozone emissions at the airport by 90%. To achieve these reductions, significant improvements in the emissions of ground vehicles and improvements to ground access will have to be implemented.

San Antonio International Airport and Austin Bergstrom International Airport share a common problem in that they are both owned by cities that are likely to be designated as non-attainment for ozone in the near future. Accordingly, ground access plans that help reduce ozone will be looked at more closely at these two airports. Although the Austin and San Antonio airports are relatively similar in size and in number of passengers, there are some problems unique to each. San Antonio has a higher percentage of international travel, and particularly international cargo. With two foreign trade zones on the airport, international cargo is of high importance.

It is likely that procedures and guidelines available at these four Texas airports are of a generic nature and are insufficient to address the strategic and tactical planning needs of major airport systems within their entire metropolitan regional context. When Texas airports are compared to the domestic and international case studies presented earlier, it becomes evident that these airports present unique ground access challenges that require coordinated planning. The nature of these issues is such that their scope is not separable from those of general transportation accessibility issues within the entire region of the airport. Airports like DFW have become major growth poles and hubs of economic activity in their respective regions. This role will continue to increase in tandem with the growing importance of convenient air travel for both passengers and goods in the global economy, which is critical to the future economic well-being of the state. Institutional factors, involving cooperation and communication among several government and quasi-governmental entities, play a considerable role in ensuring an effective planning process that provides for the needs of air passenger and freight travel in the overall mobility of the region.

FUTURE RESEARCH

The conclusion of this review, conducted as part of a two-year project, is to confirm the objectives and tasks laid out in the original research proposal. Characterizing airport landside access problems and determining peaking characteristics of airport usage laid the foundations for the next steps. In that respect, an intermodal perspective must be adopted in devising an evaluation framework for the various short-, medium-, and long- term solution strategies for the access problems.

The review and synthesis to date have further reinforced the motivation and the need for this work. It is evident that addressing ground access cannot be done solely at the airport level and must take into account the impact and role of the airport within the whole transportation network. Another factor is the impact of integrated ground access planning with respect to contributions of air quality emissions upon the airport and the community. Airports addressed in this review that have been able to achieve high public transport ridership levels are integrated into a comprehensive transit network, be it rail or other forms of public transport. Thus, the project team feels that it is necessary to come up with various schemes for improving airport access that might include rail or off-airport terminals as possible options and that these options are to be addressed at the area-wide network level rather than in the immediate vicinity of the airport. In this process, there is a need to develop more effective access-related planning tools and models with which to address the airport’s role in the context of its metropolitan area’s strategic mobility needs.

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APPENDIX

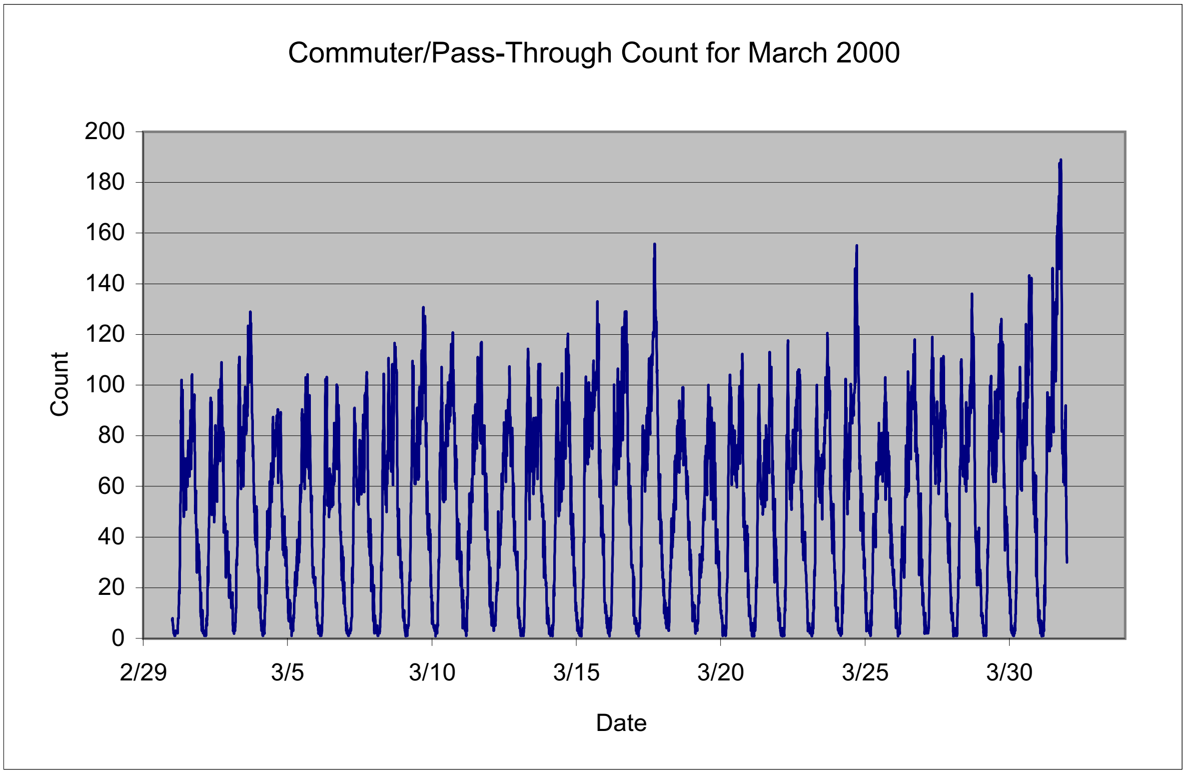

Figure 1: Commuter/Pass-Through Count for March 2000

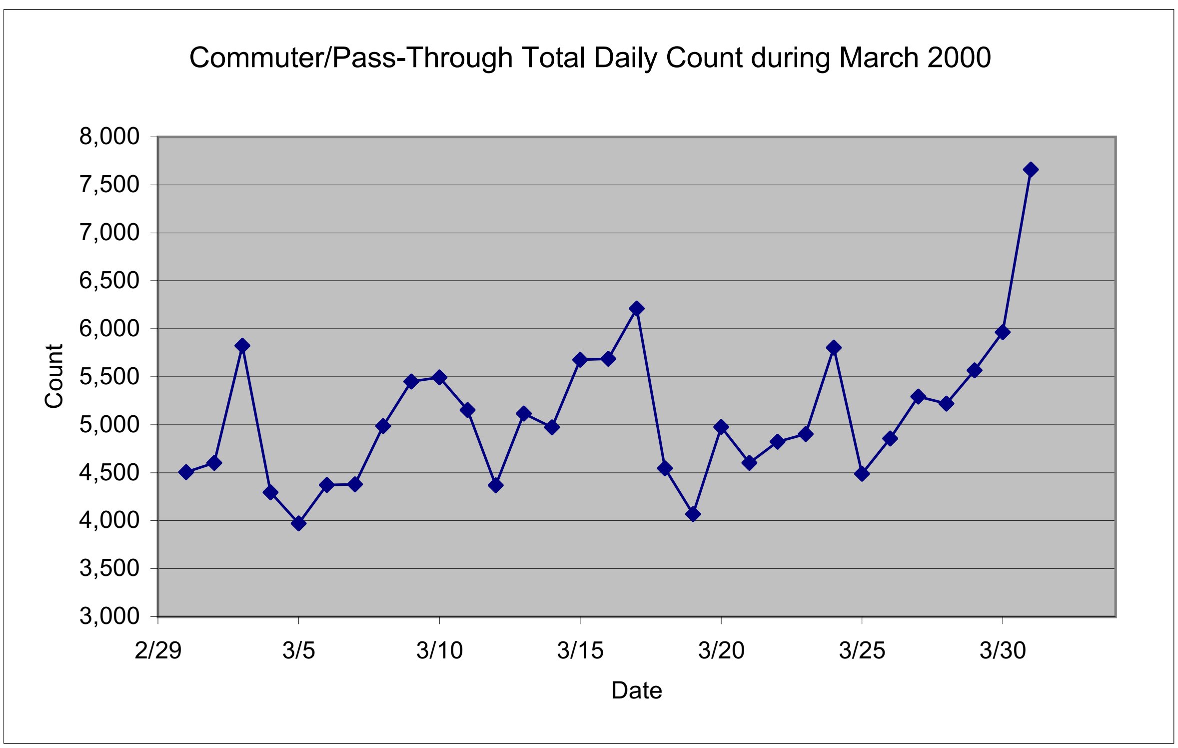

Figure 2: Commuter/Pass-Through Total Daily Count During March 2000

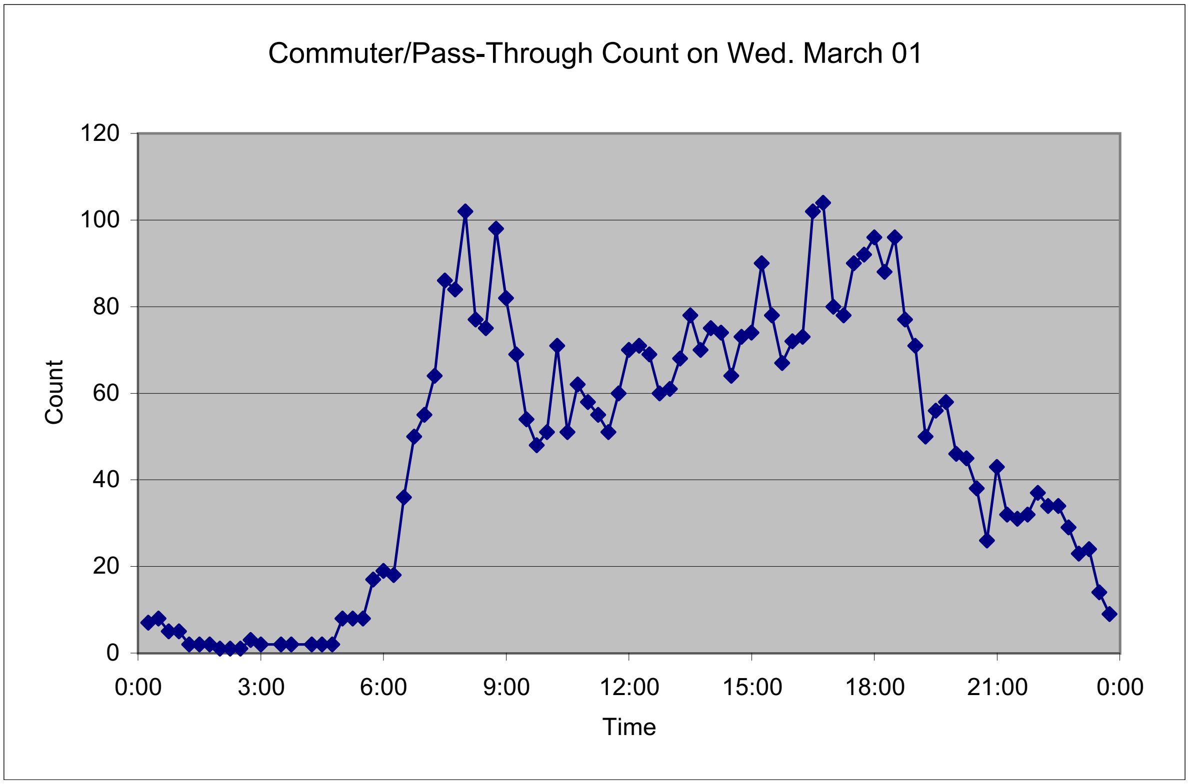

Figure 3: Commuter/Pass-Through Count on Wed. March 01

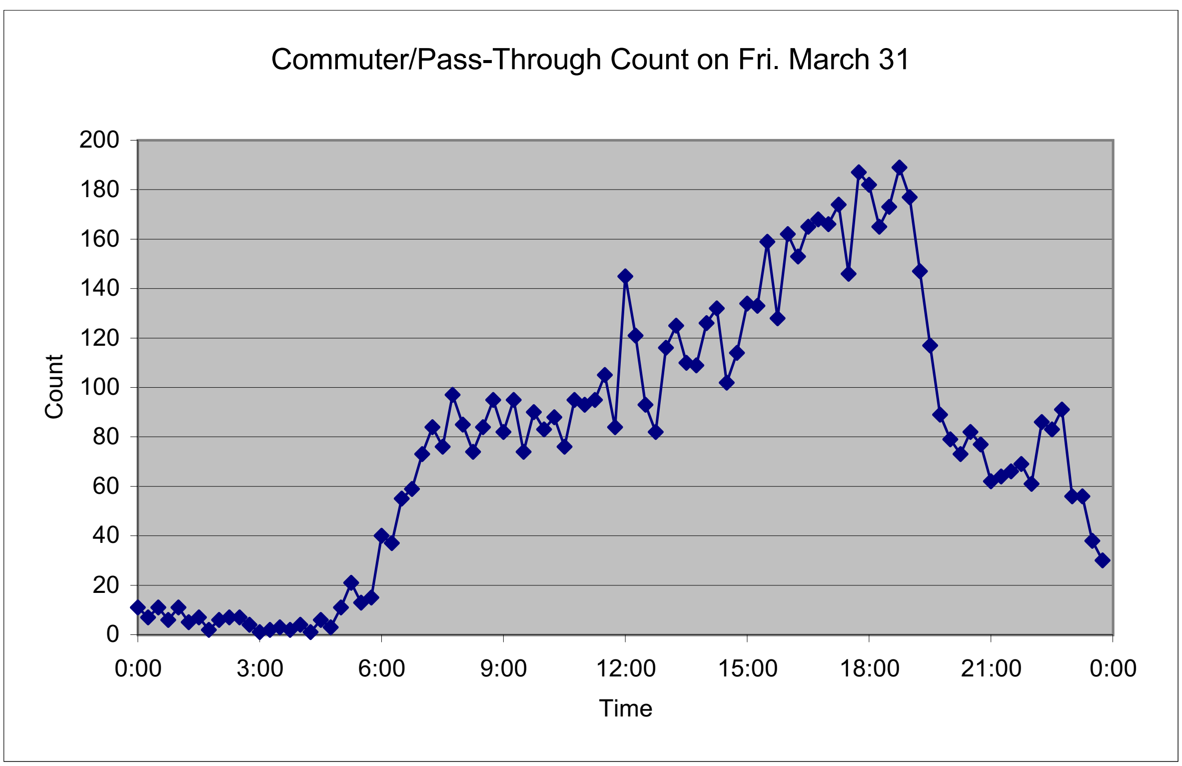

Figure 4: Commuter/Pass-Through Count on Fri. March 31

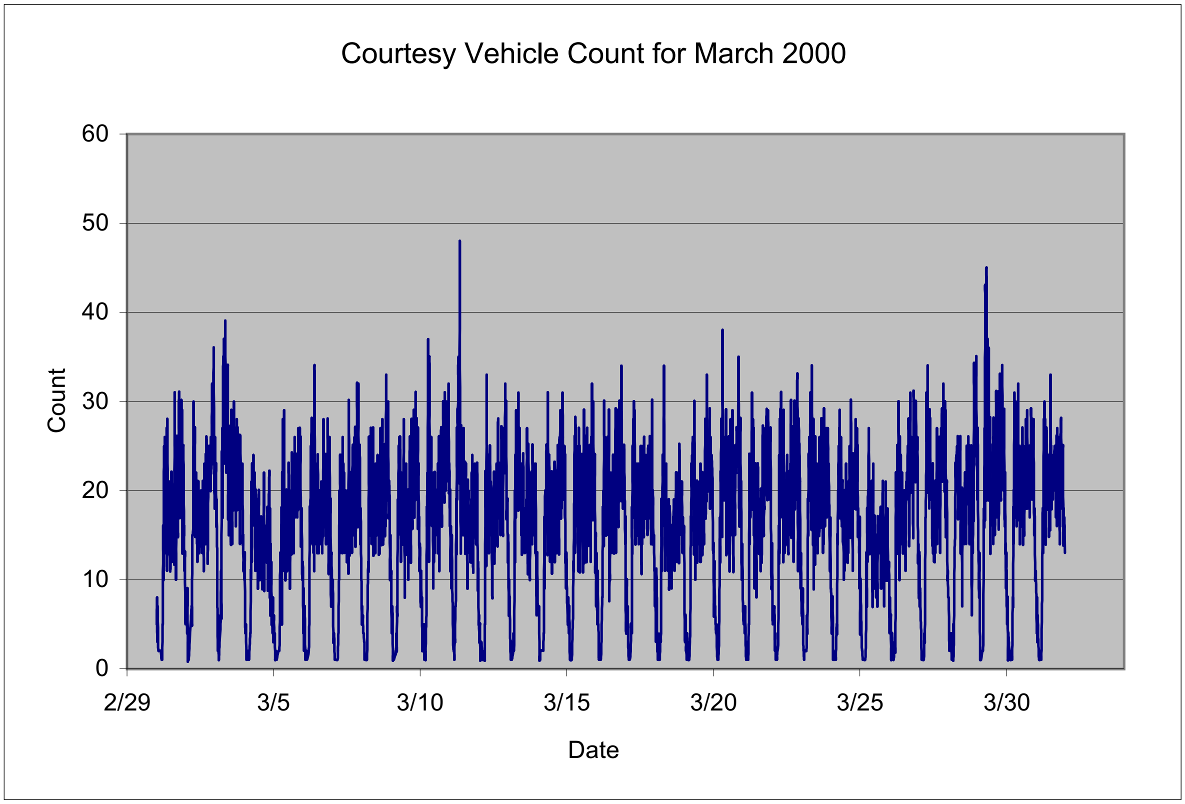

Figure 5: Courtesy Vehicle Count for March 2000

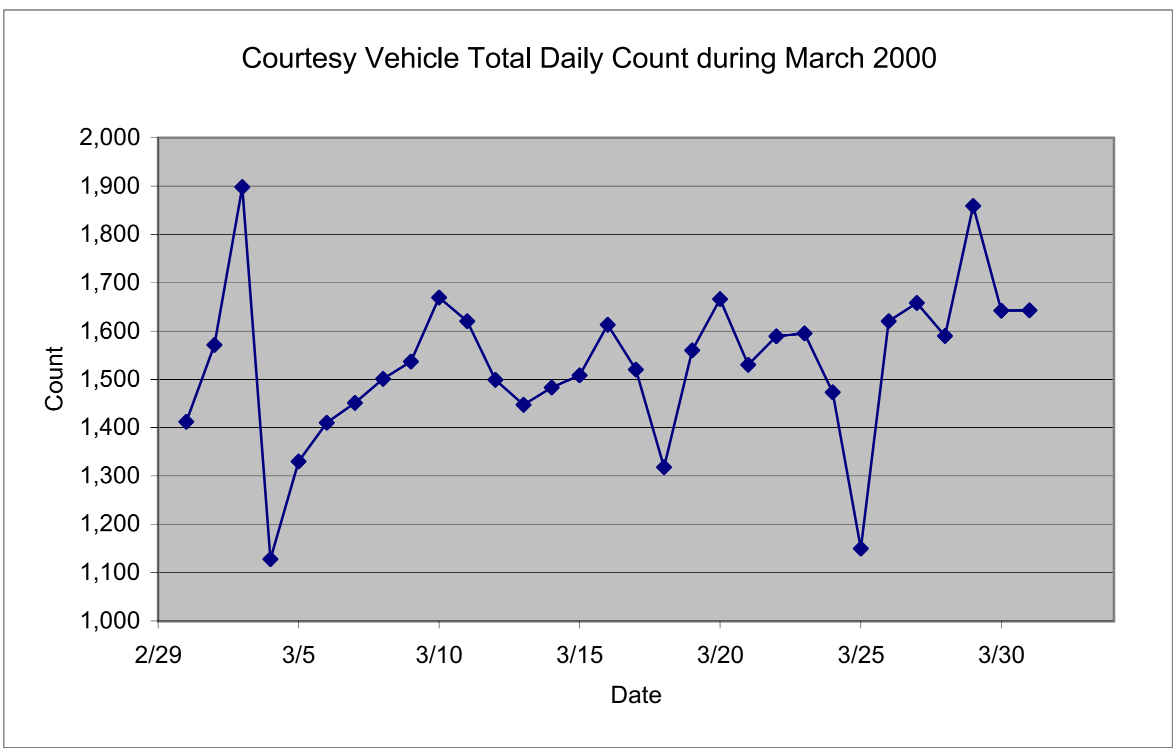

Figure 6: Courtesy Vehicle Total Daily Count during March 2000

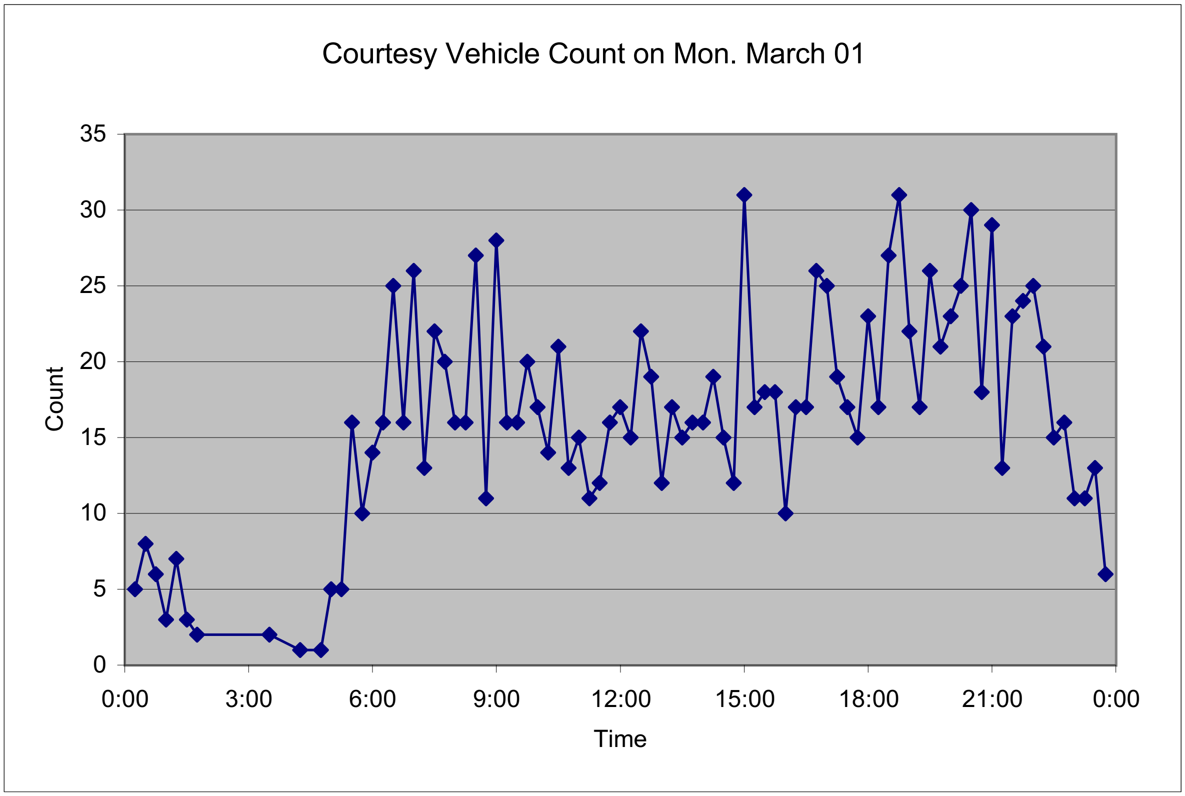

Figure 7: Courtesy Vehicle Count on Mon. March 01

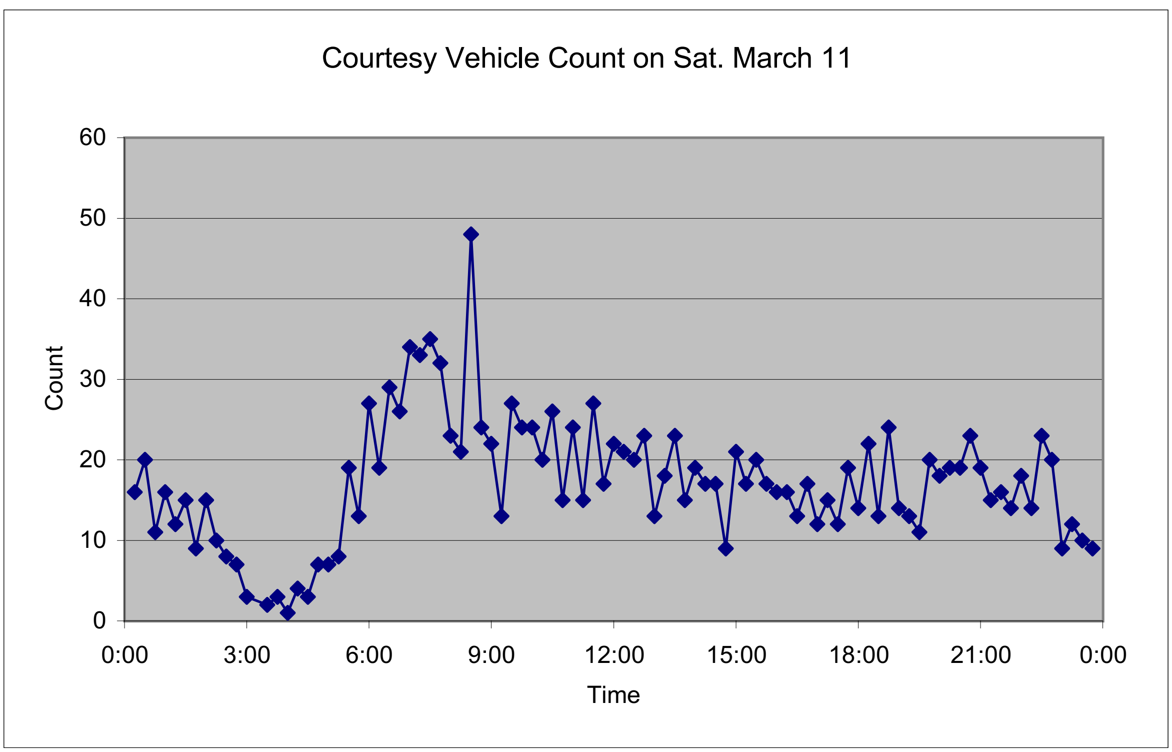

Figure 8: Courtesy Vehicle Count on Sat. March 11

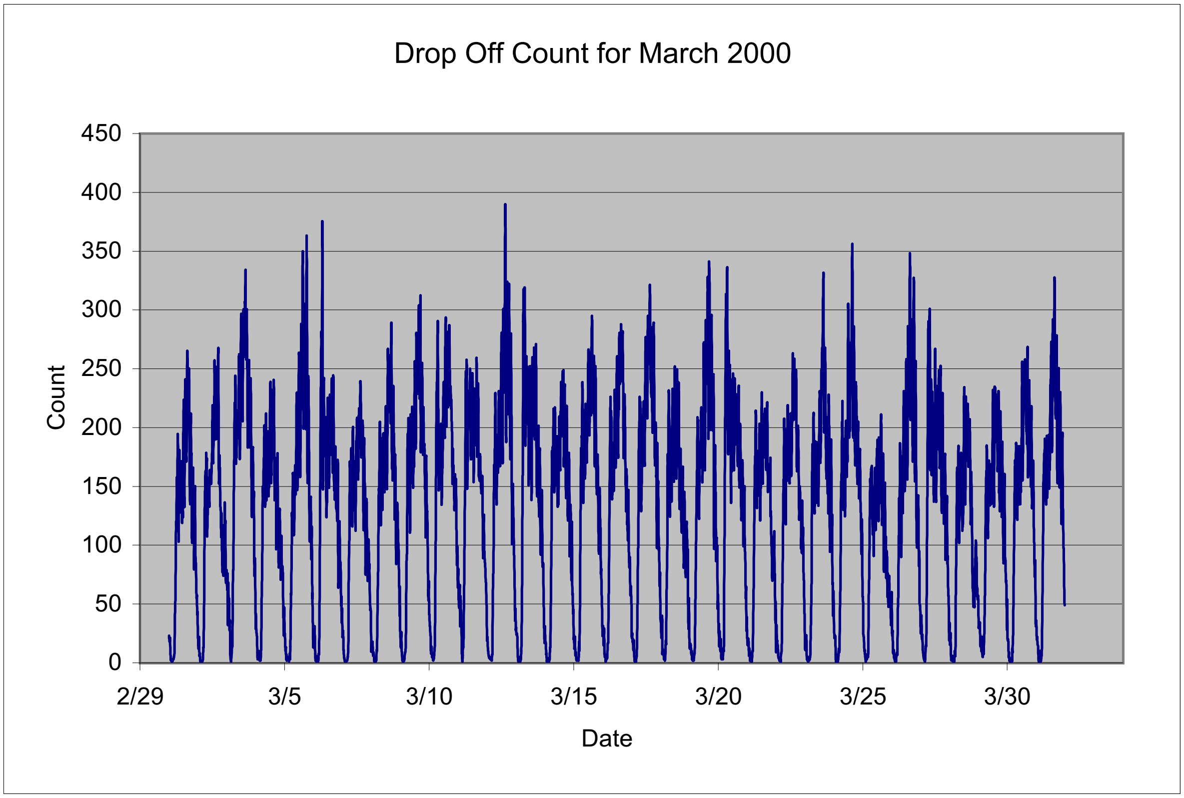

Figure 9: Drop Off Count for March 2000

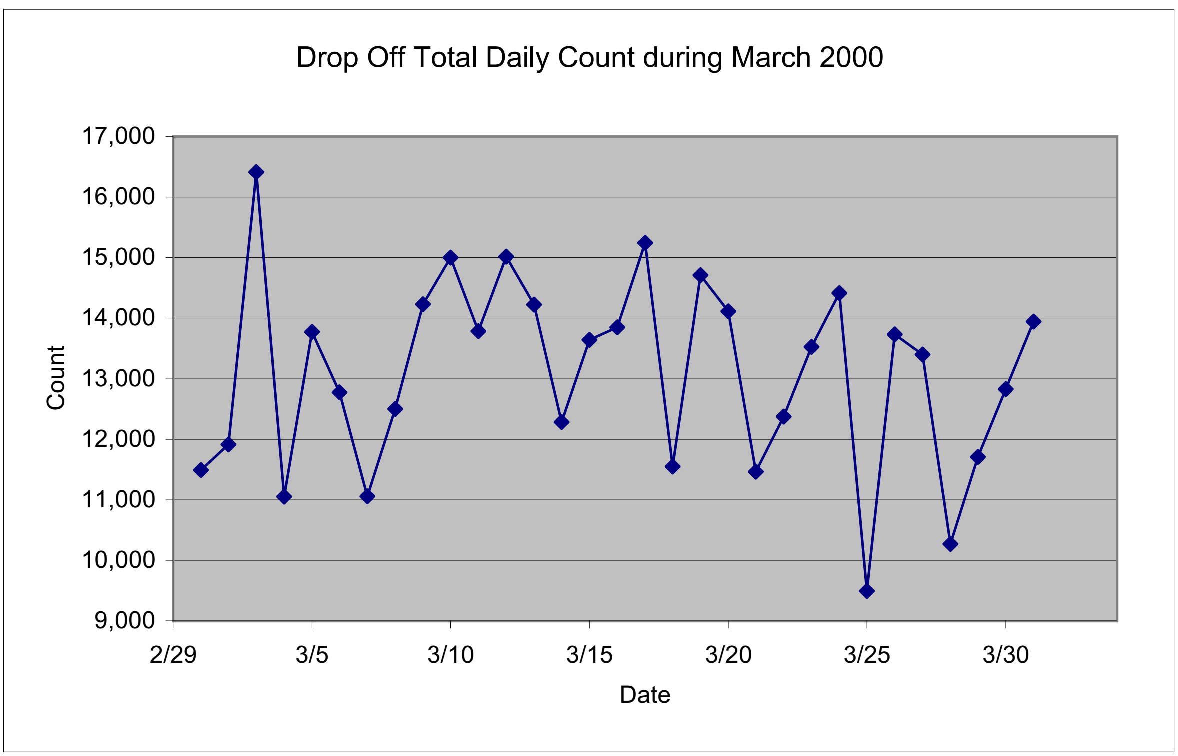

Figure 10: Drop Off Total Daily Count during March 2000

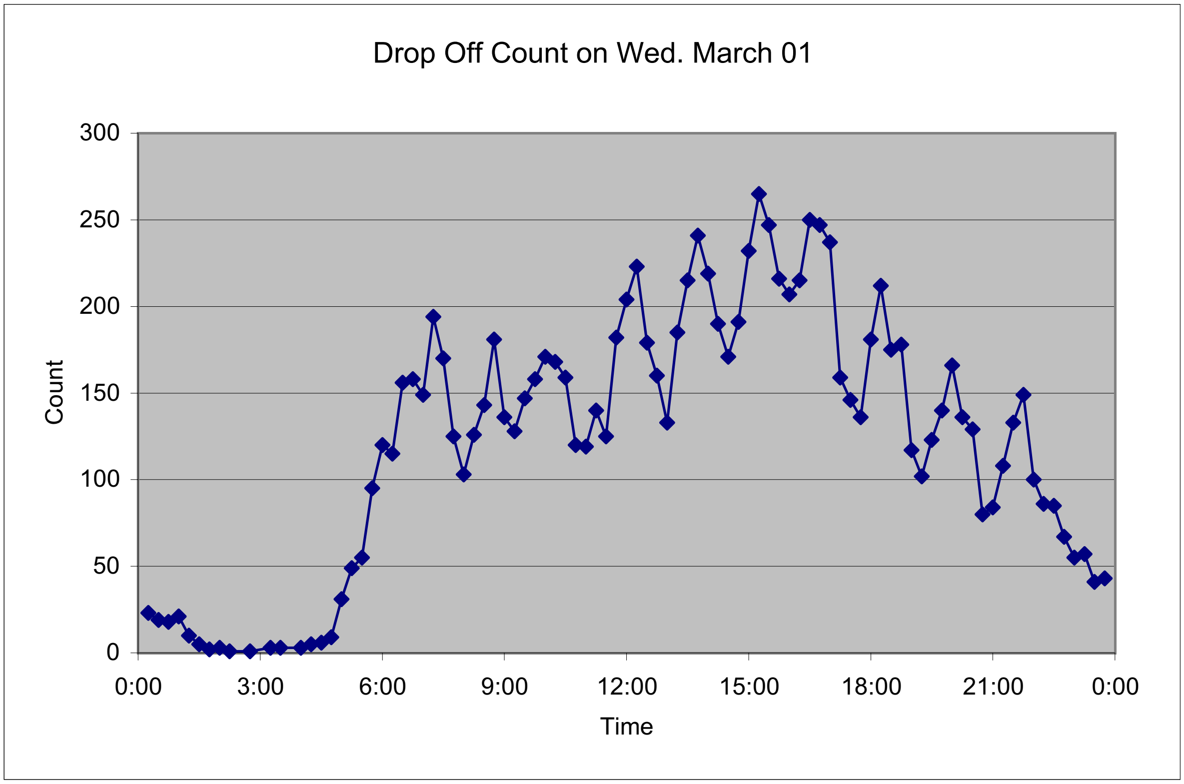

Figure 11: Drop Off Count on Wed. March 01

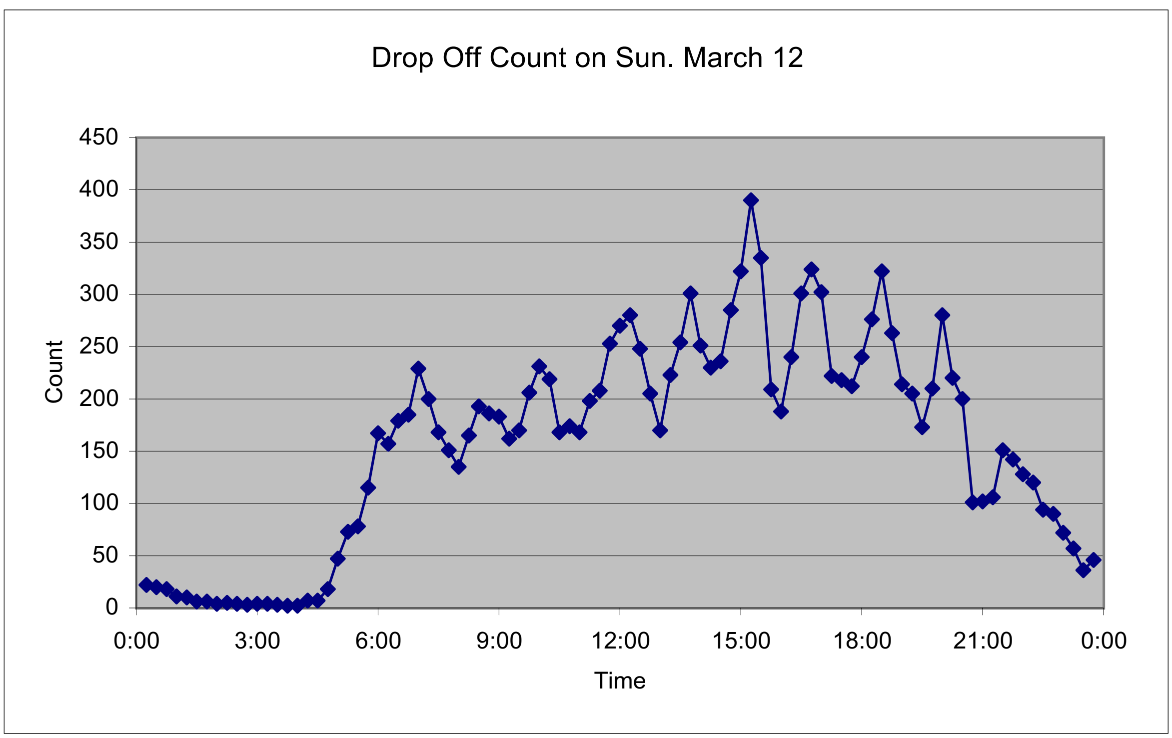

Figure 12: Drop Off Count on Sun. March 12

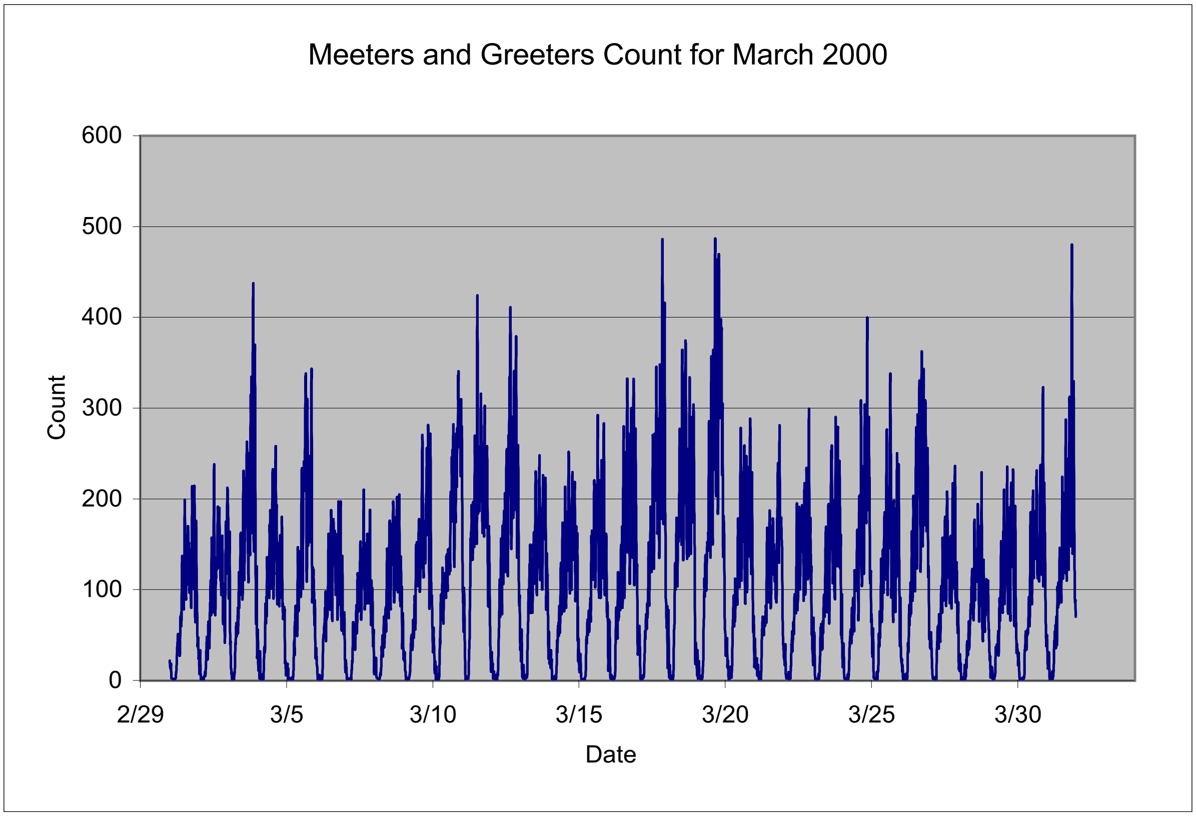

Figure 13: Meeters and Greeters Count for March 2000

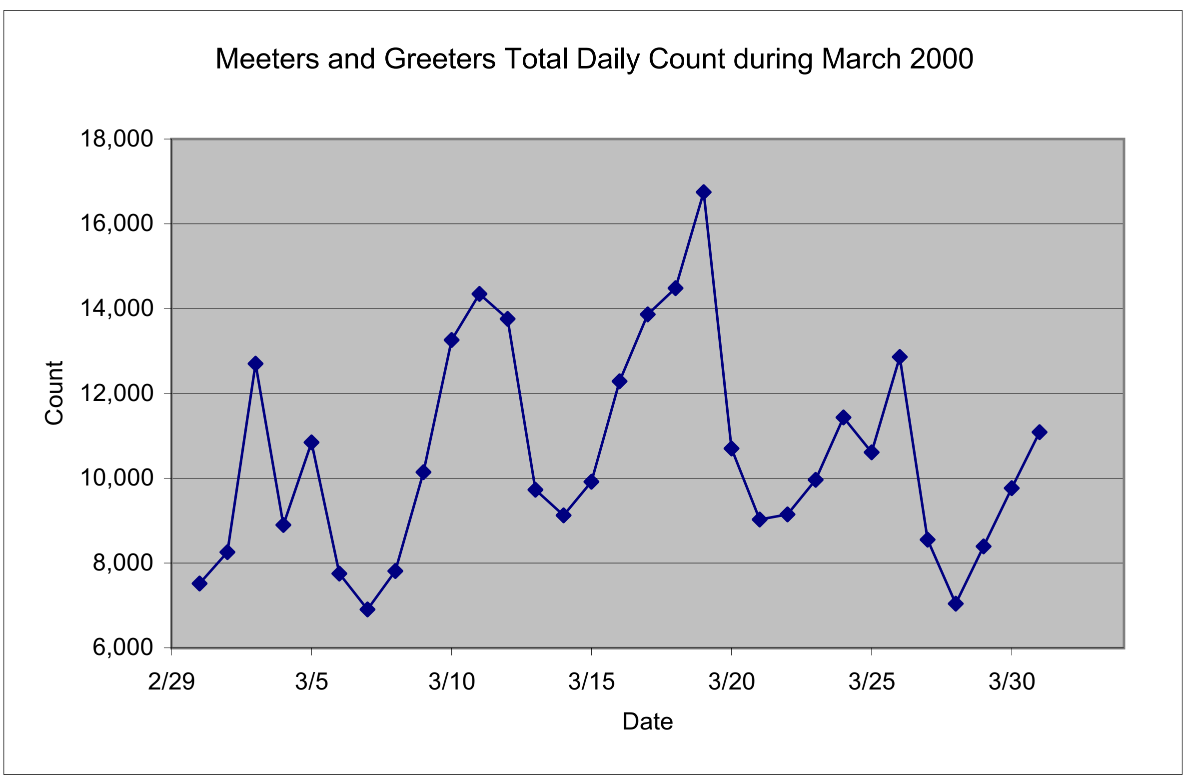

Figure 14: Meeters and Greeters Total Daily Count During March 2000

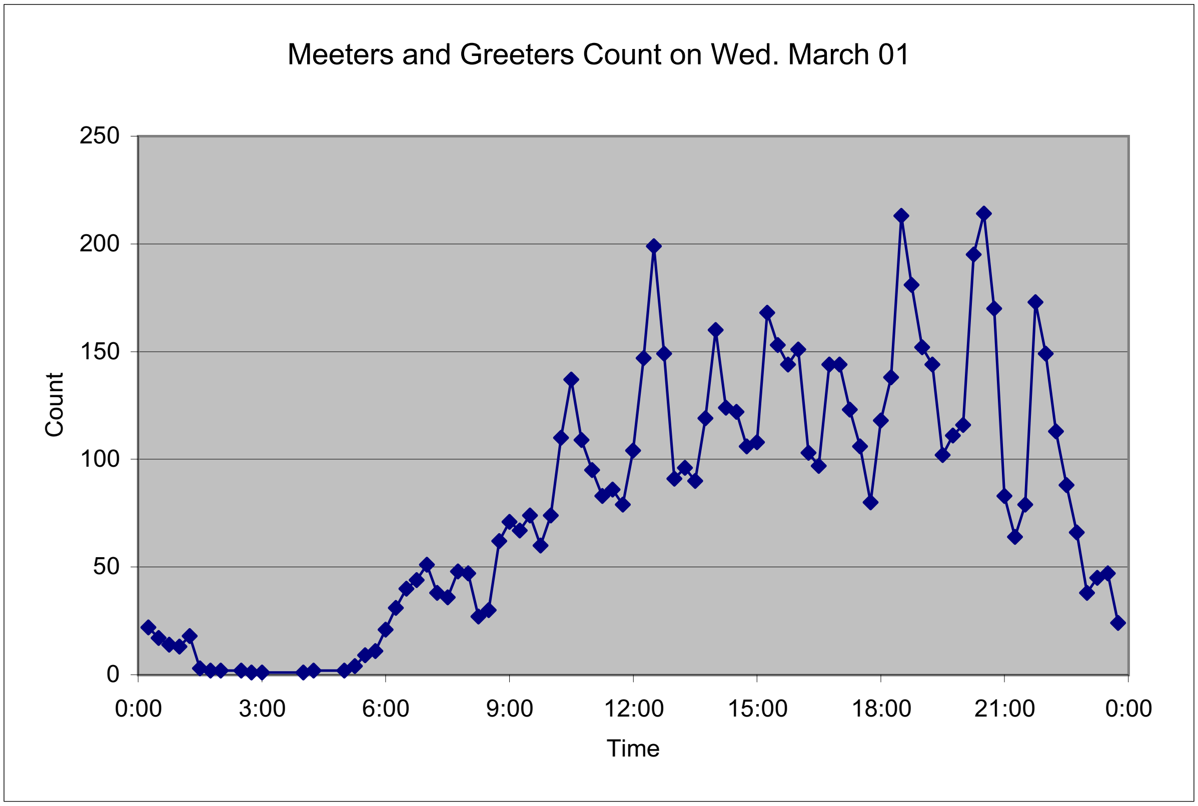

Figure 15: Meeters and Greeters Count on Wed. March 01

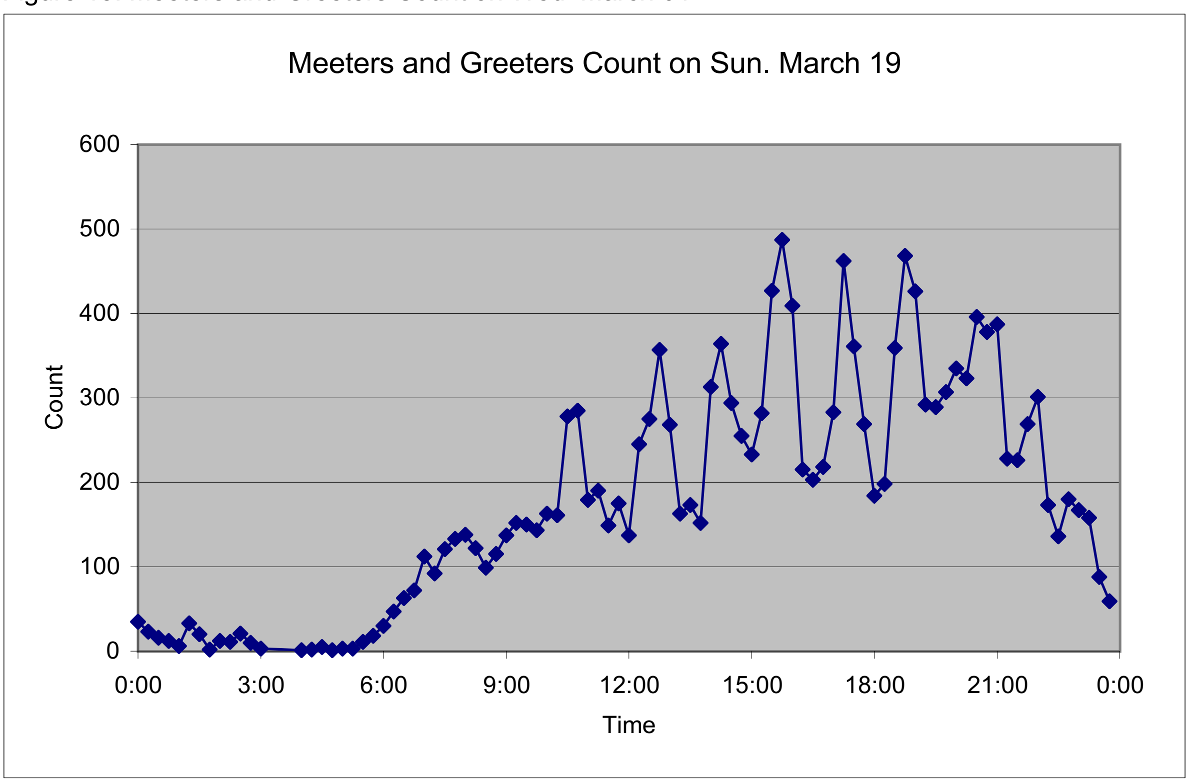

Figure 16: Meeters and Greeters Count on Sun. March 19

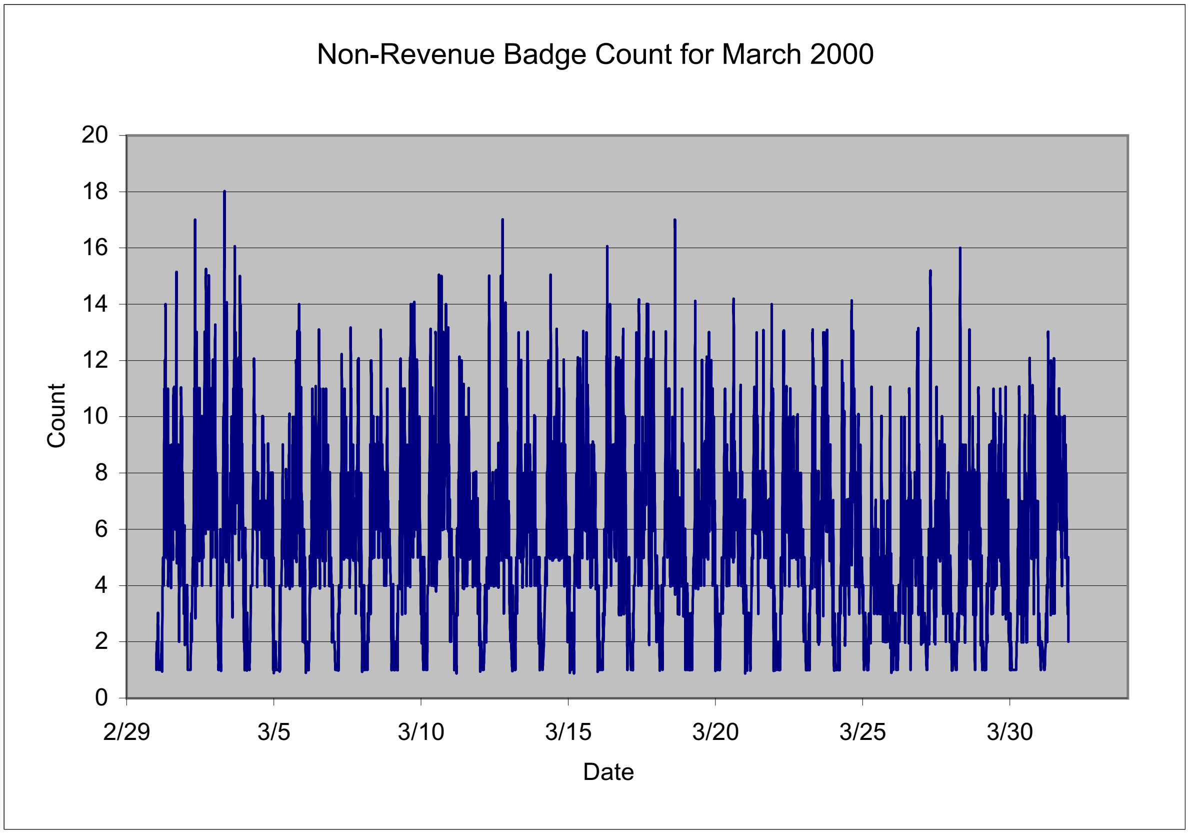

Figure 17: Non-Revenue Badge Count for March 2000

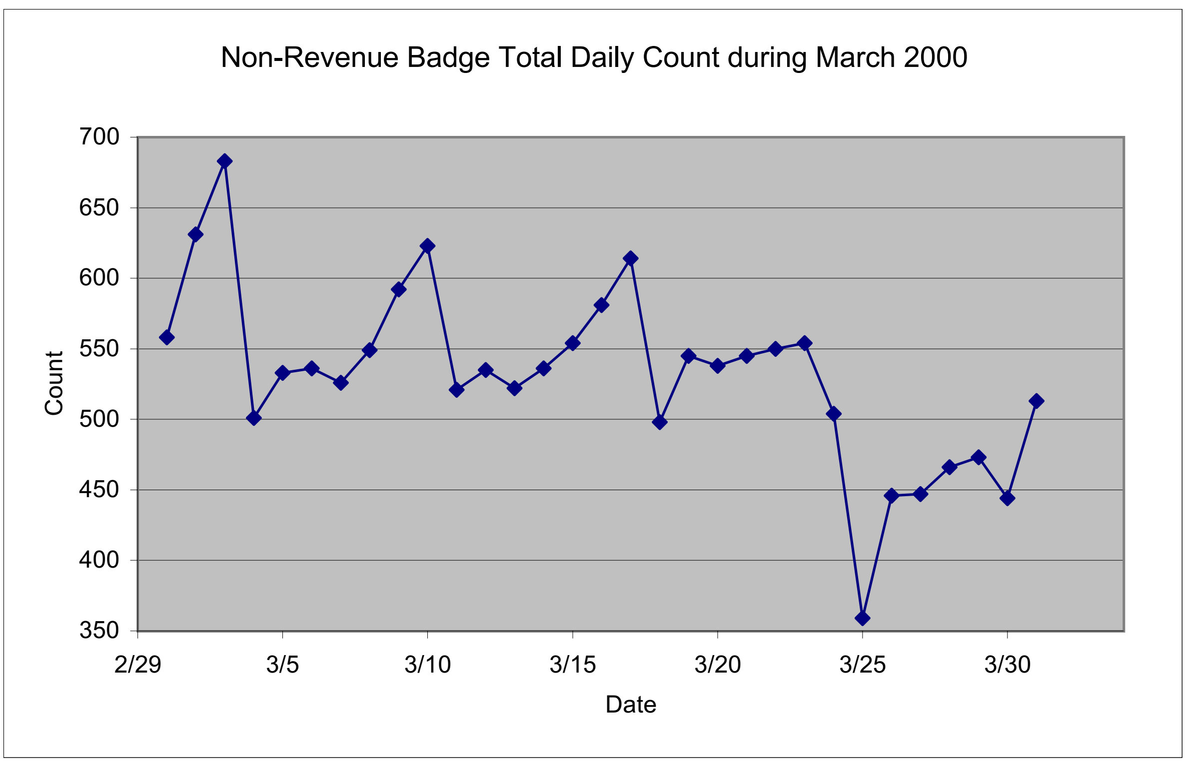

Figure 18: Non-Revenue Badge Total Daily Count during March 2000

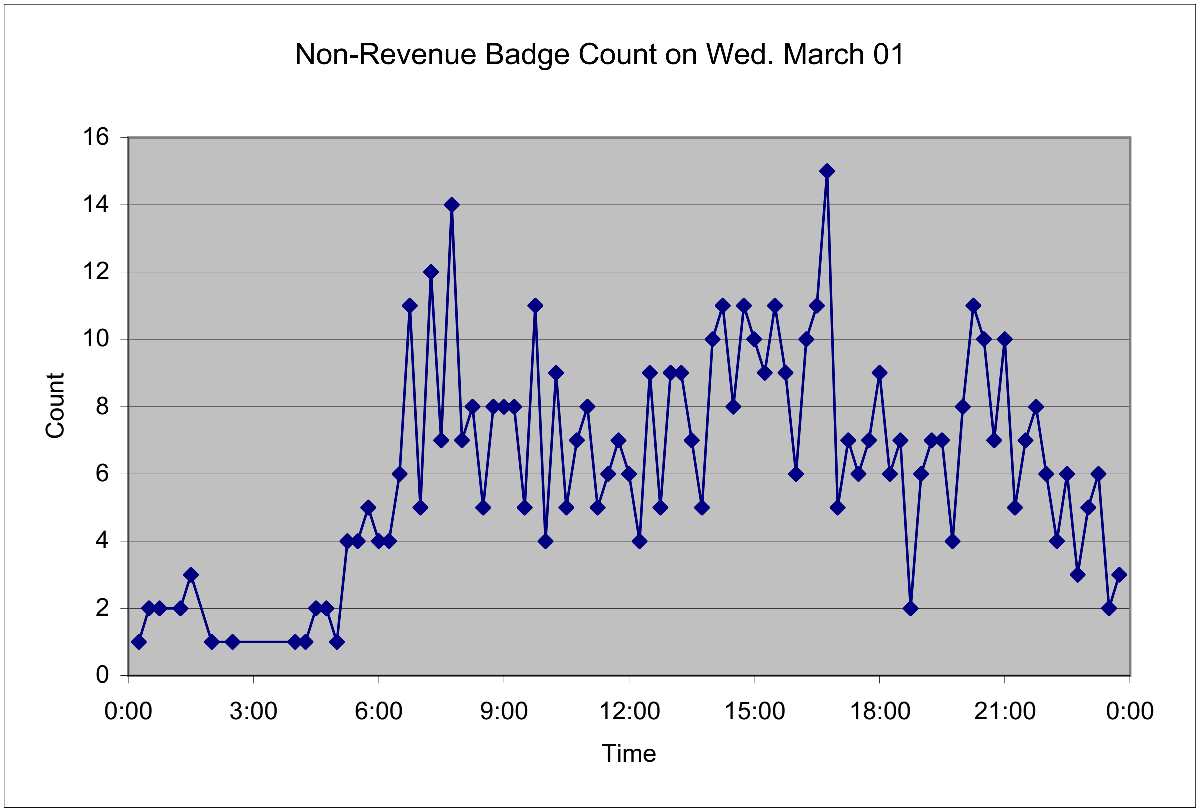

Figure 19: Non-Revenue Badge Count on Wed. March 01

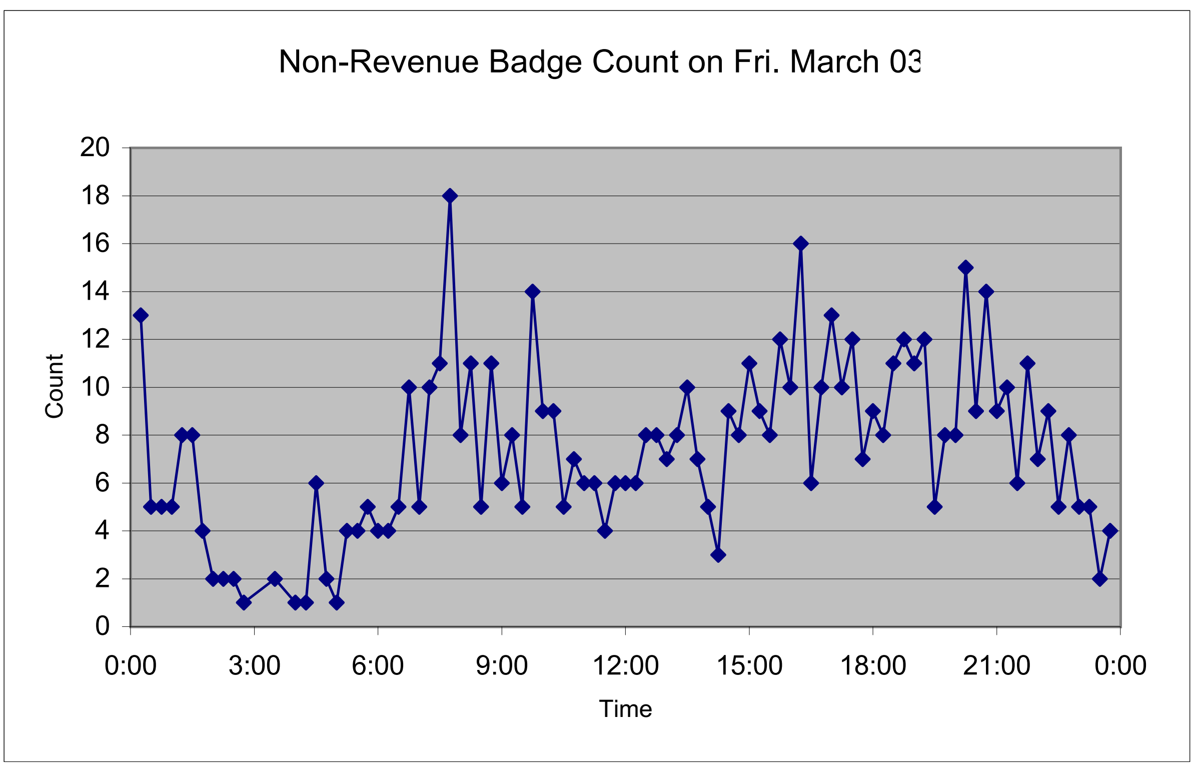

Figure 20: Non-Revenue Badge Count on Fri. March 03

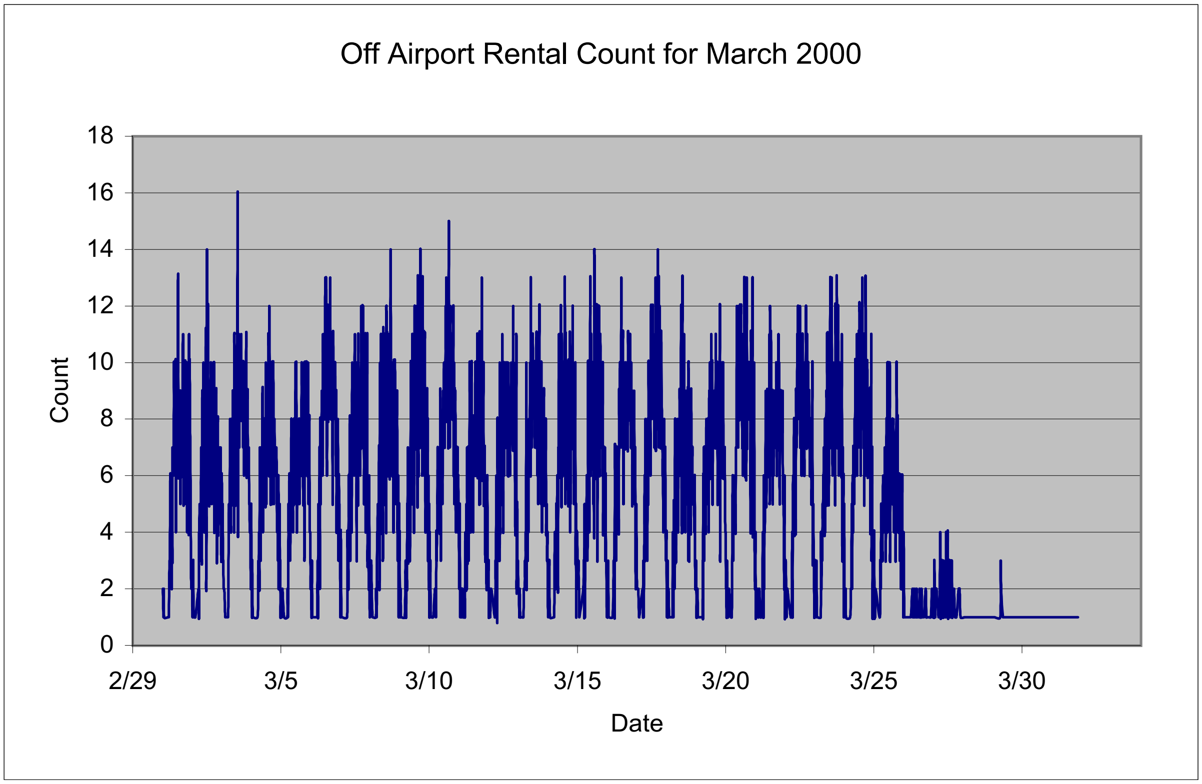

Figure 21: Off Airport Rental Count for March 2000

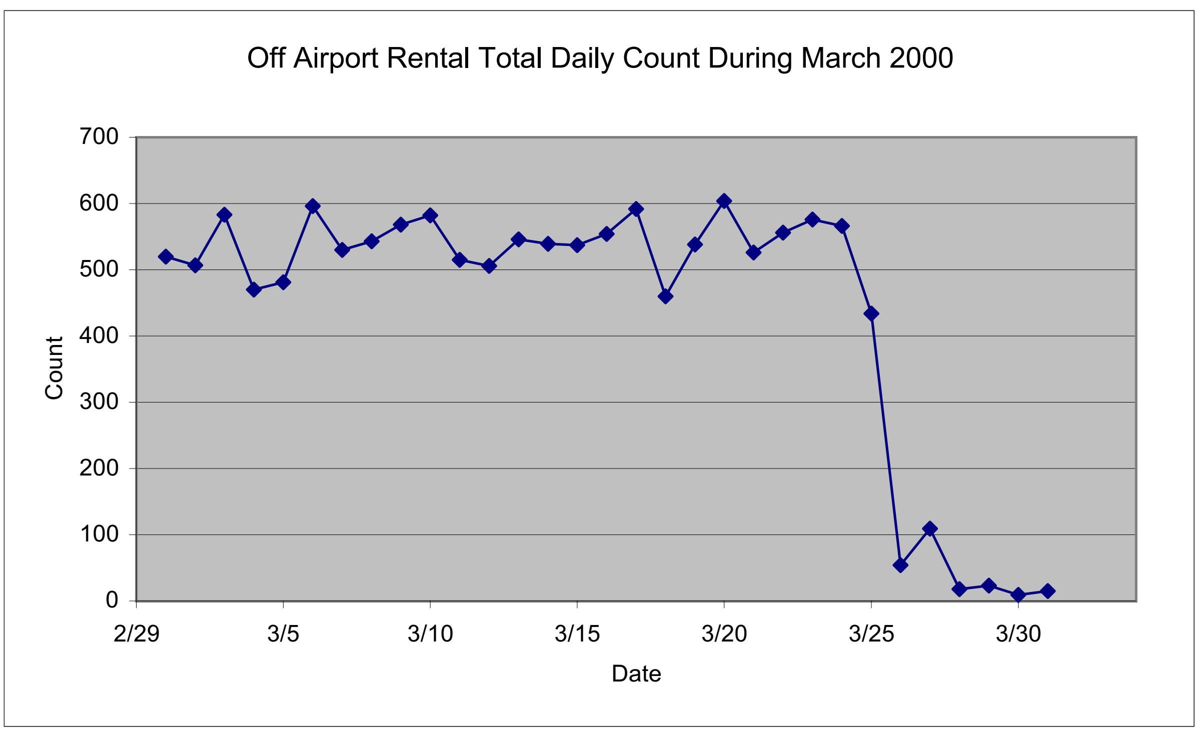

Figure 22: Off Airport Rental Total Daily Count During March 2000

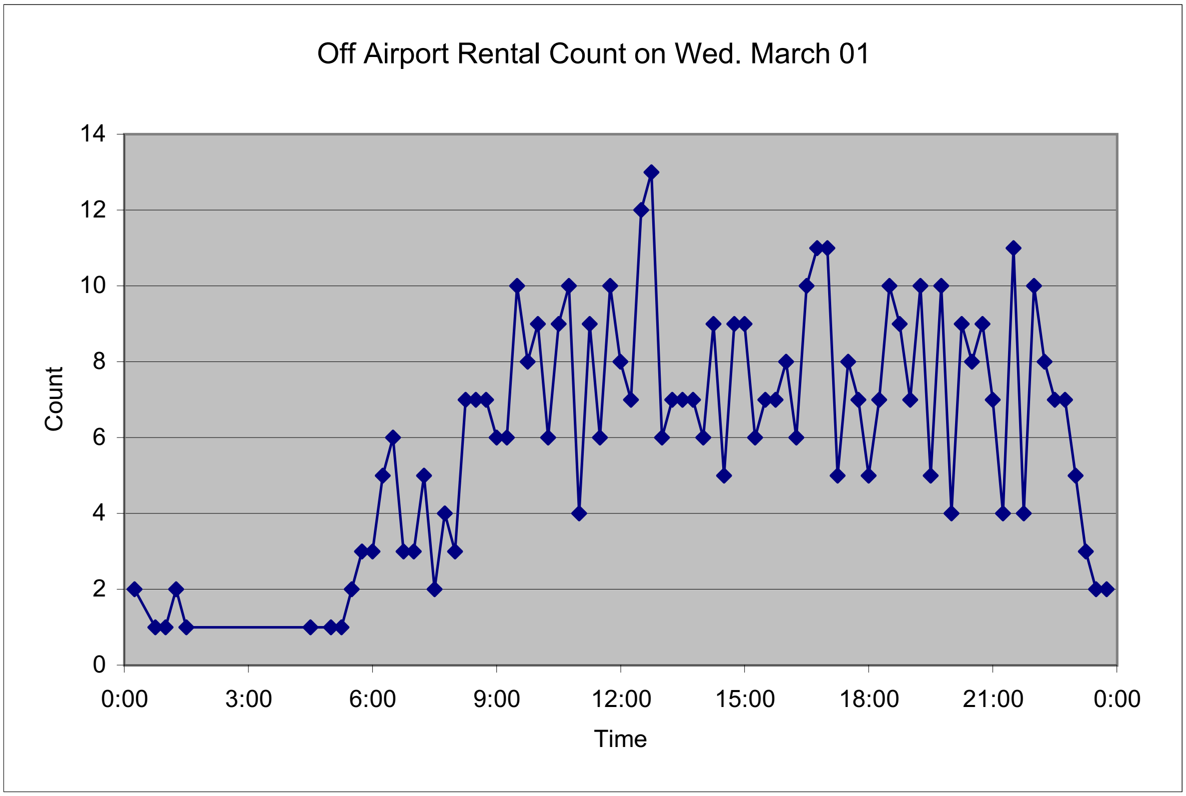

Figure 23: Off Airport Rental Count on Wed. March 01

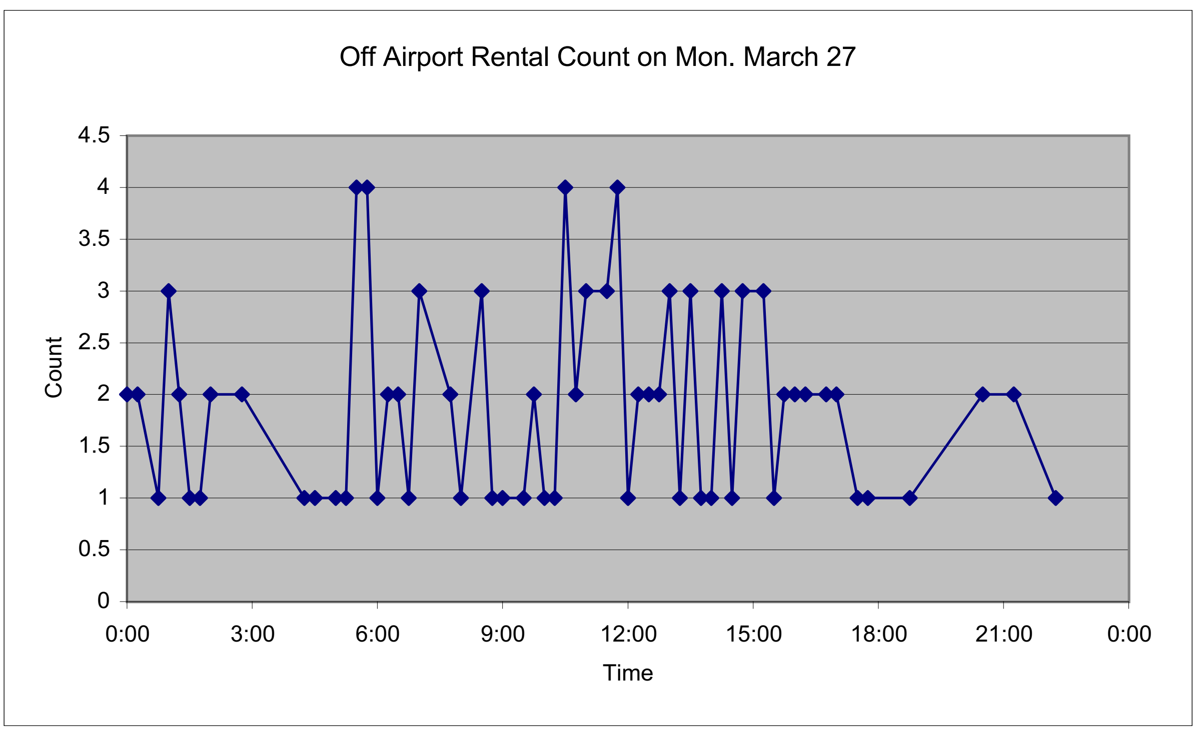

Figure 24: Off Airport Rental Count on Mon. March 27

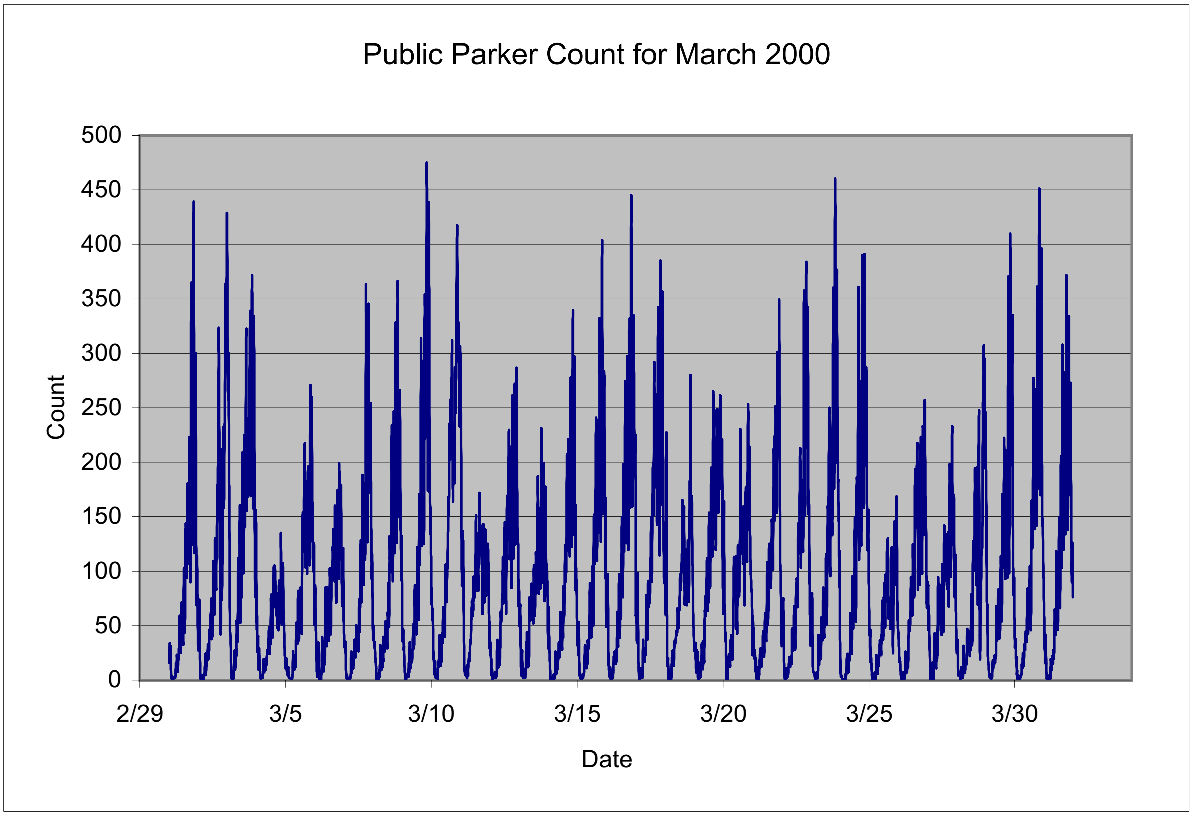

Figure 25: Public Parker Count for March 2000

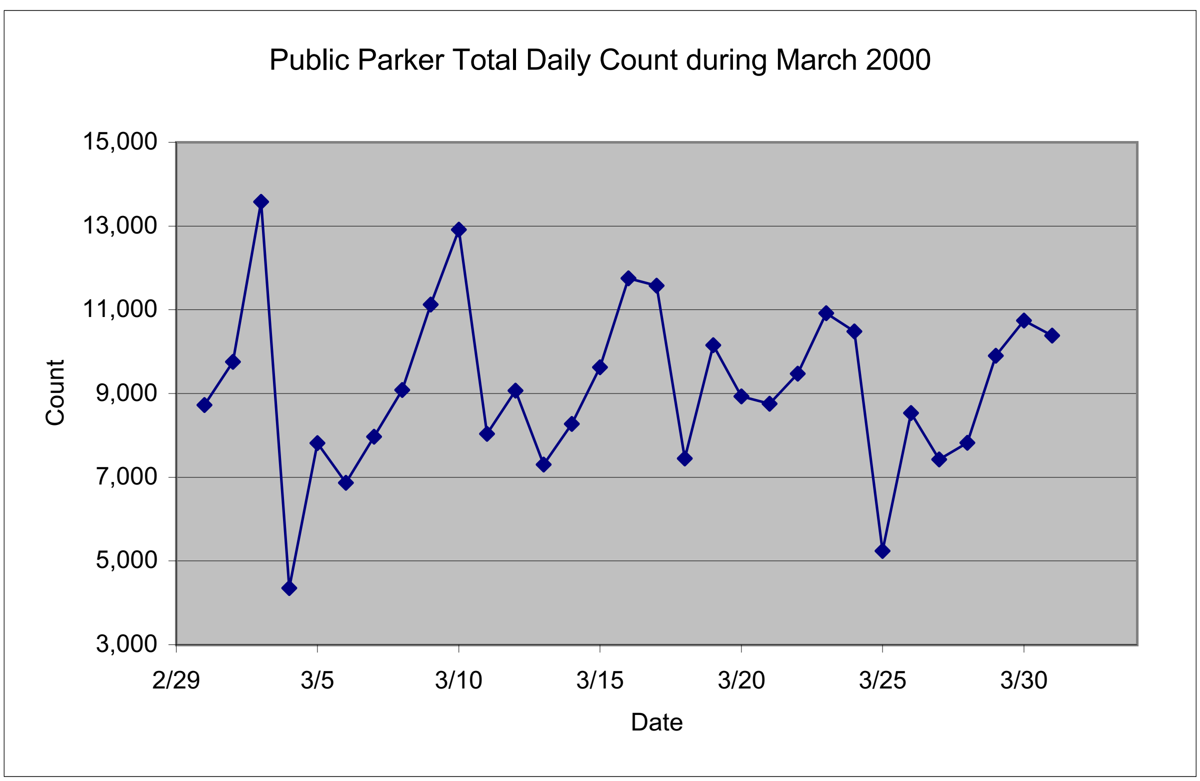

Figure 26: Public Parker Total Daily Count during March 2000

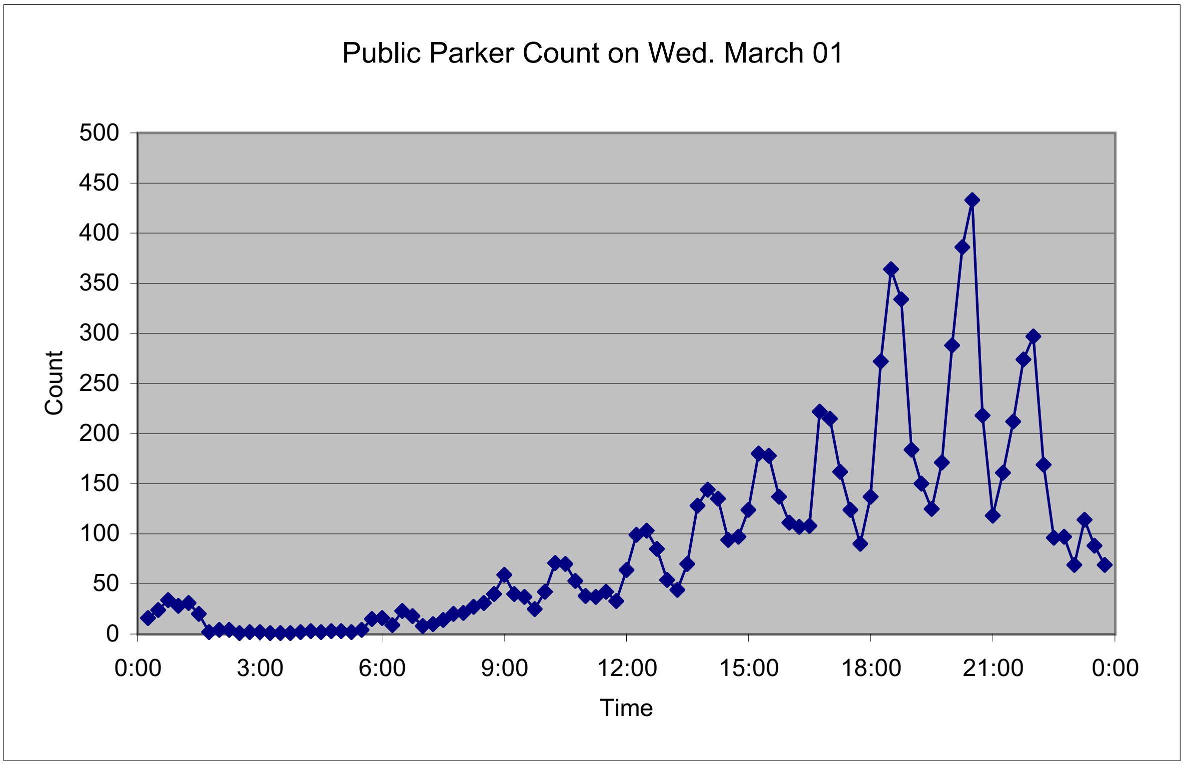

Figure 27: Public Parker Count on Wed. March 01

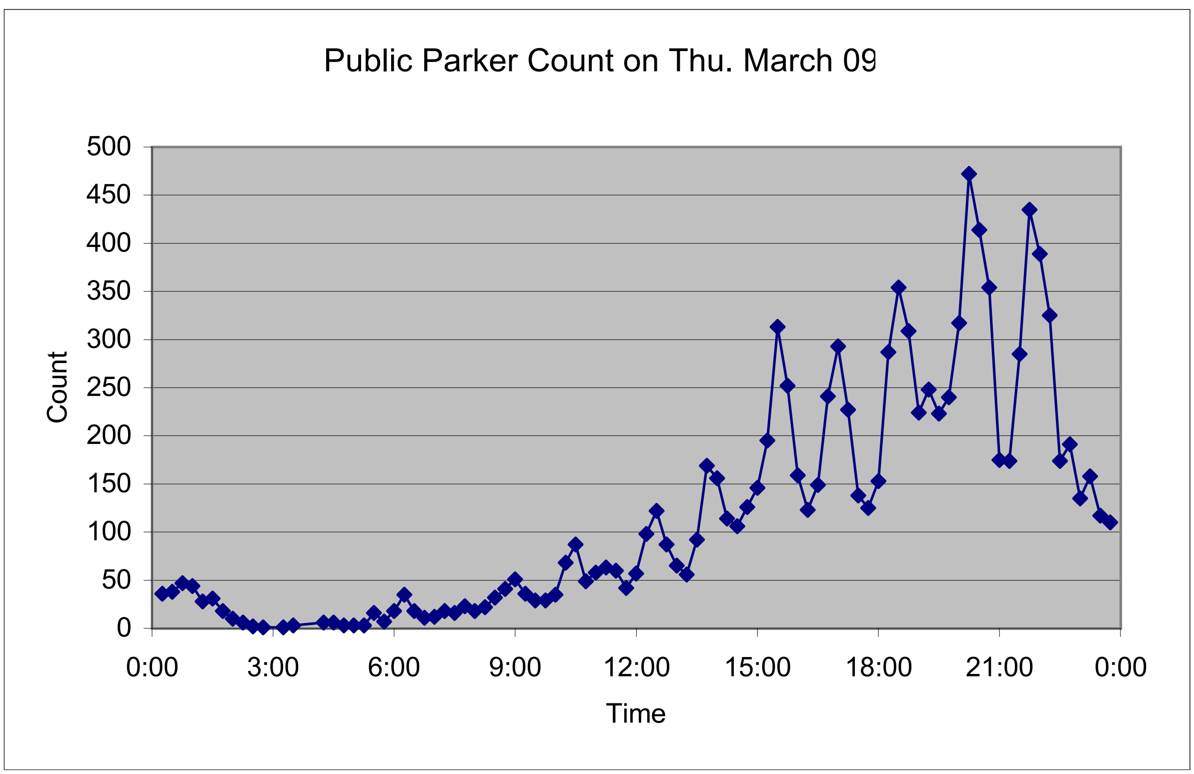

Figure 28: Public Parker Count on Thu. March 09

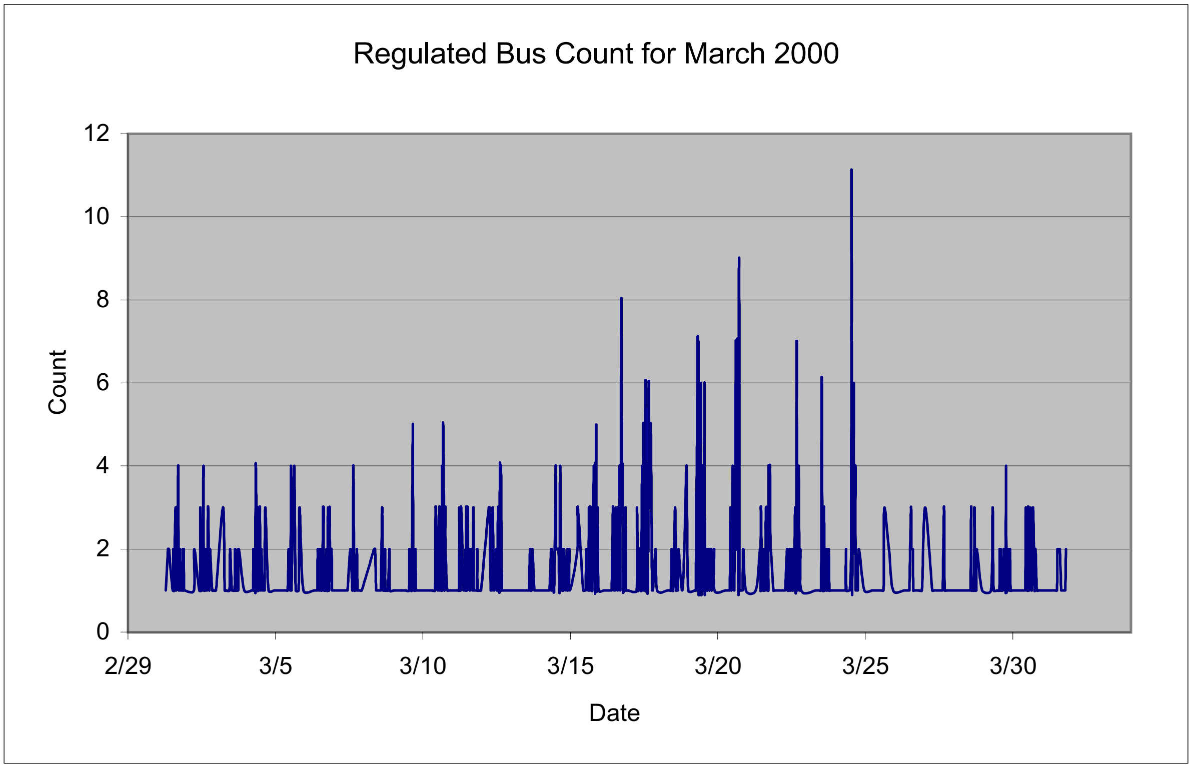

Figure 29: Regulated Bus Count for March 2000

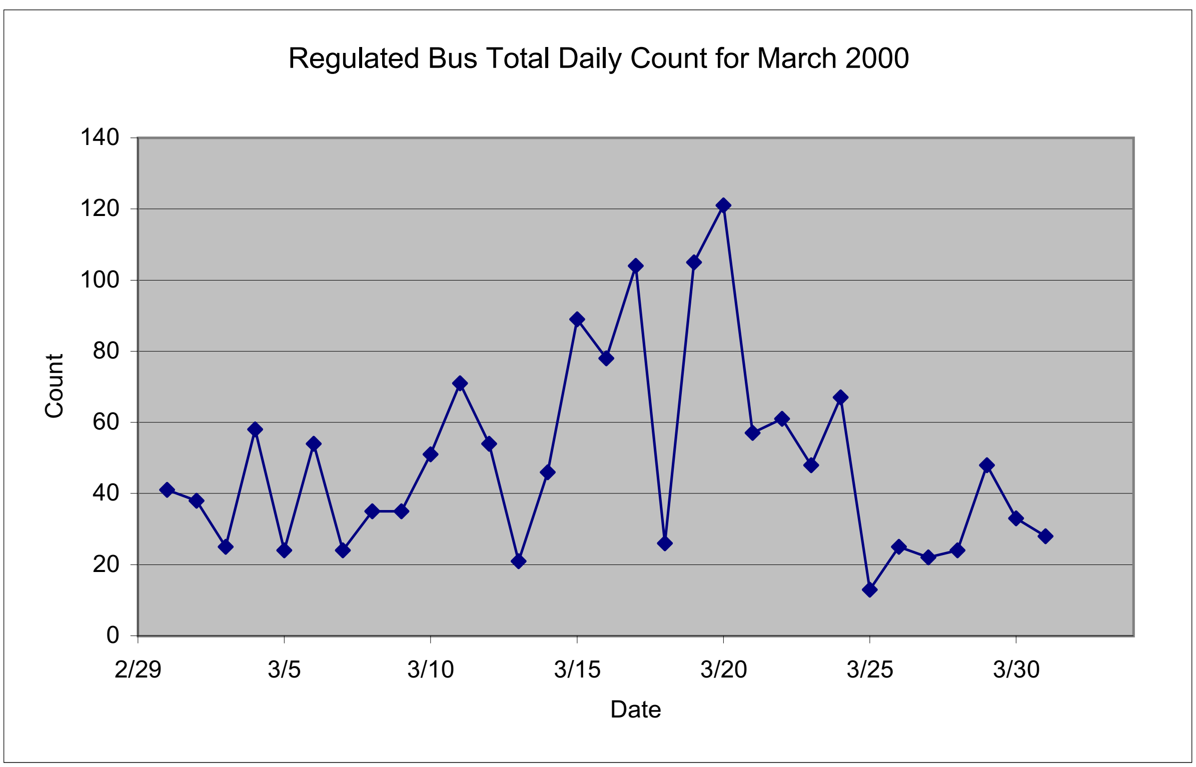

Figure 30: Regulated Bus Total Daily Count for March 2000

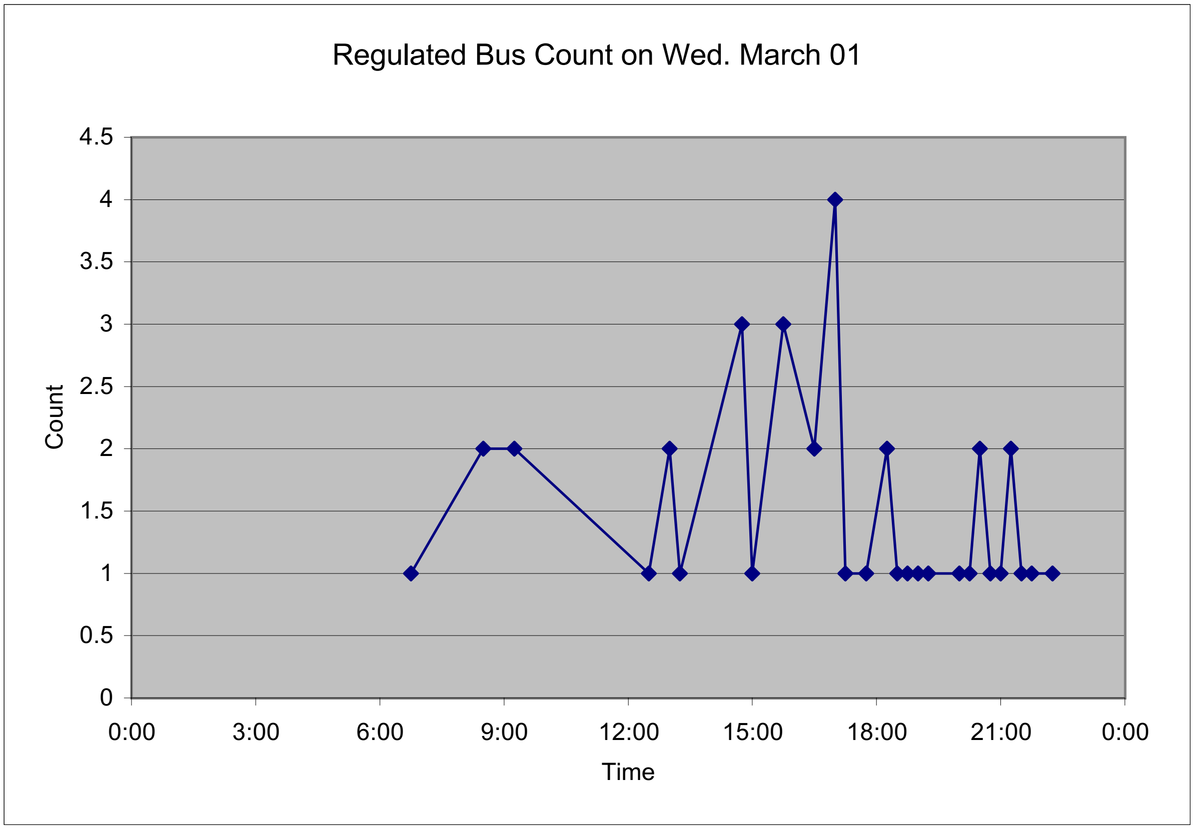

Figure 31: Regulated Bus Count on Wed. March 01

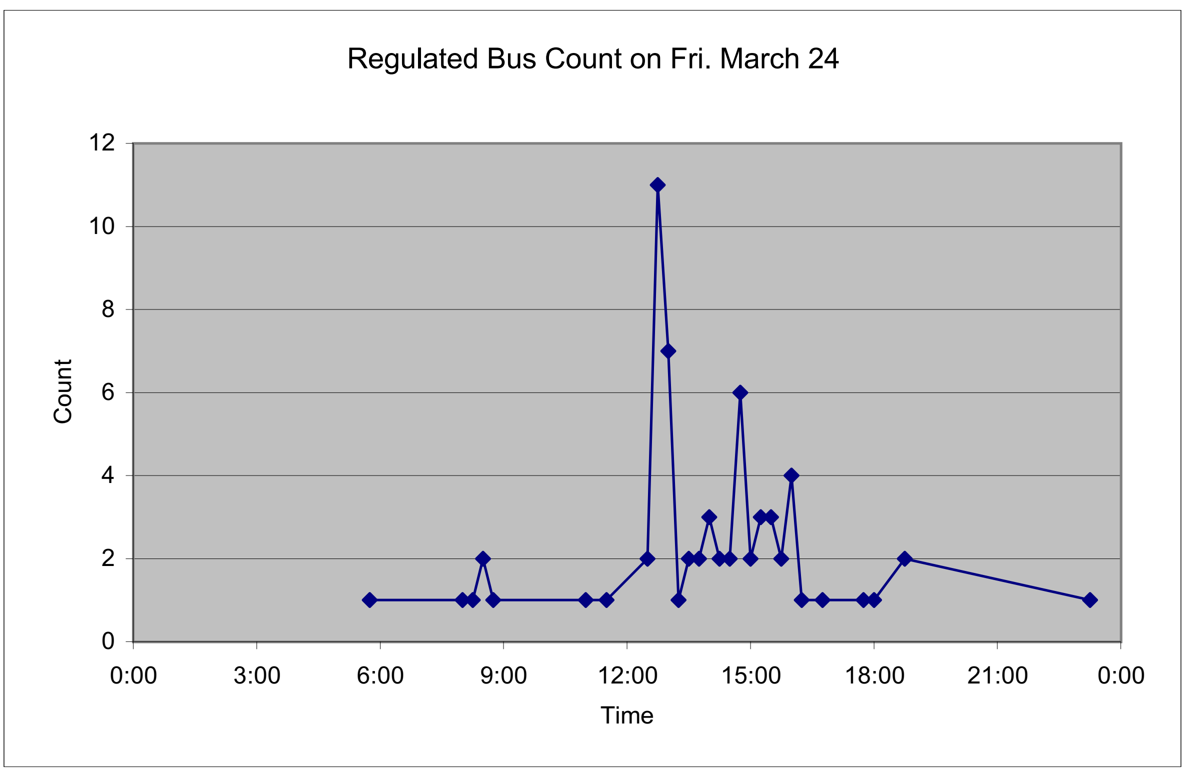

Figure 32: Regulated Bus Count on Fri. March 24

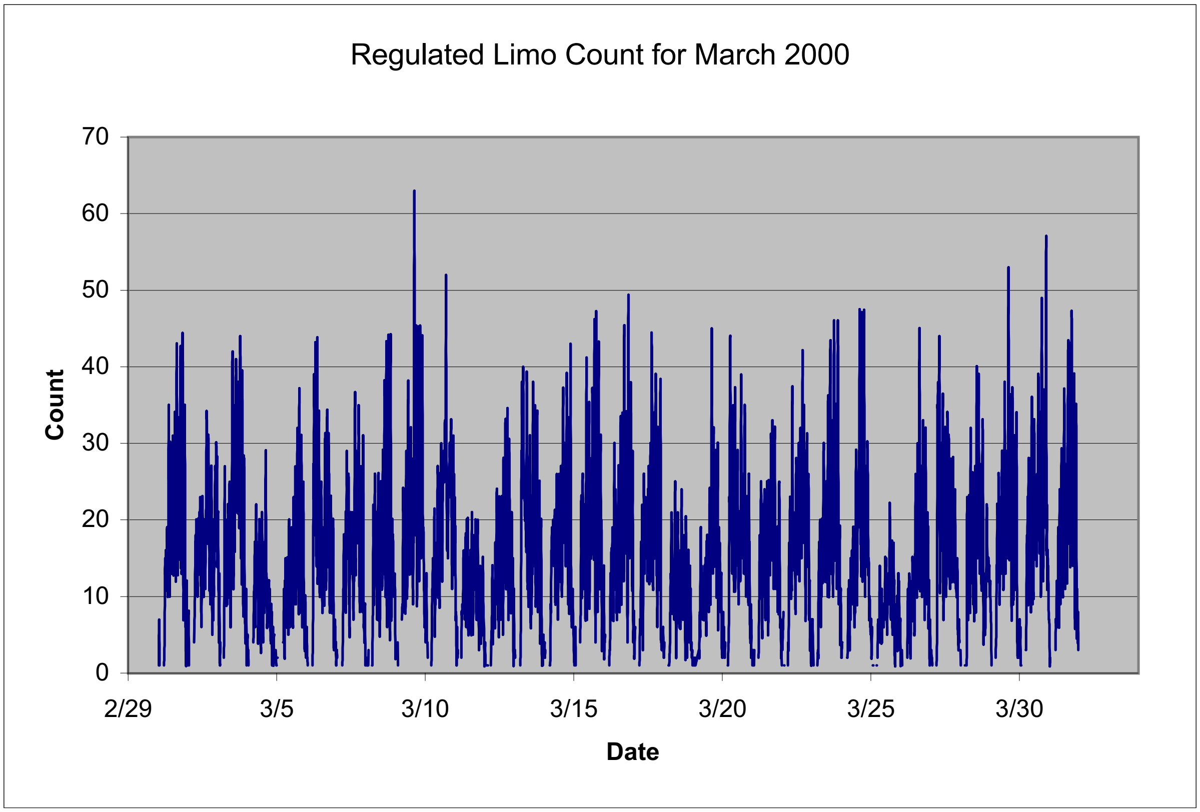

Figure 33: Regulated Limo Count for March 2000

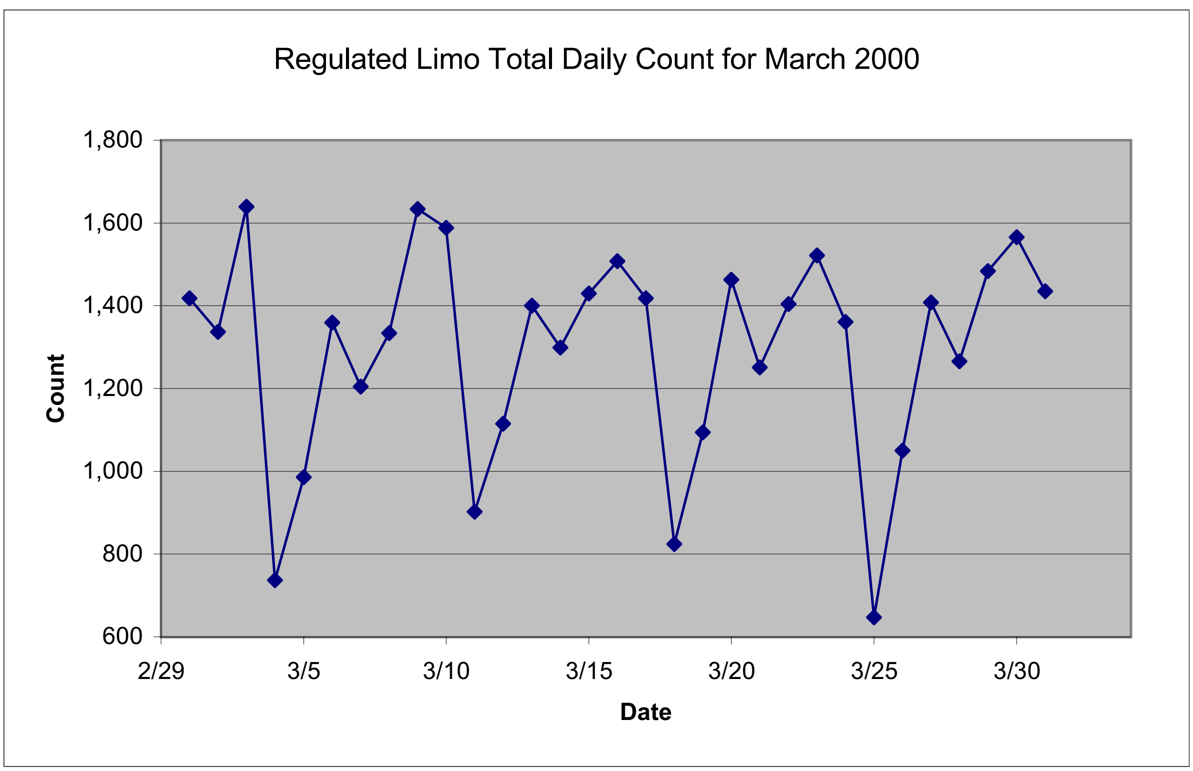

Figure 34: Regulated Limo Total Daily Count for March 2000

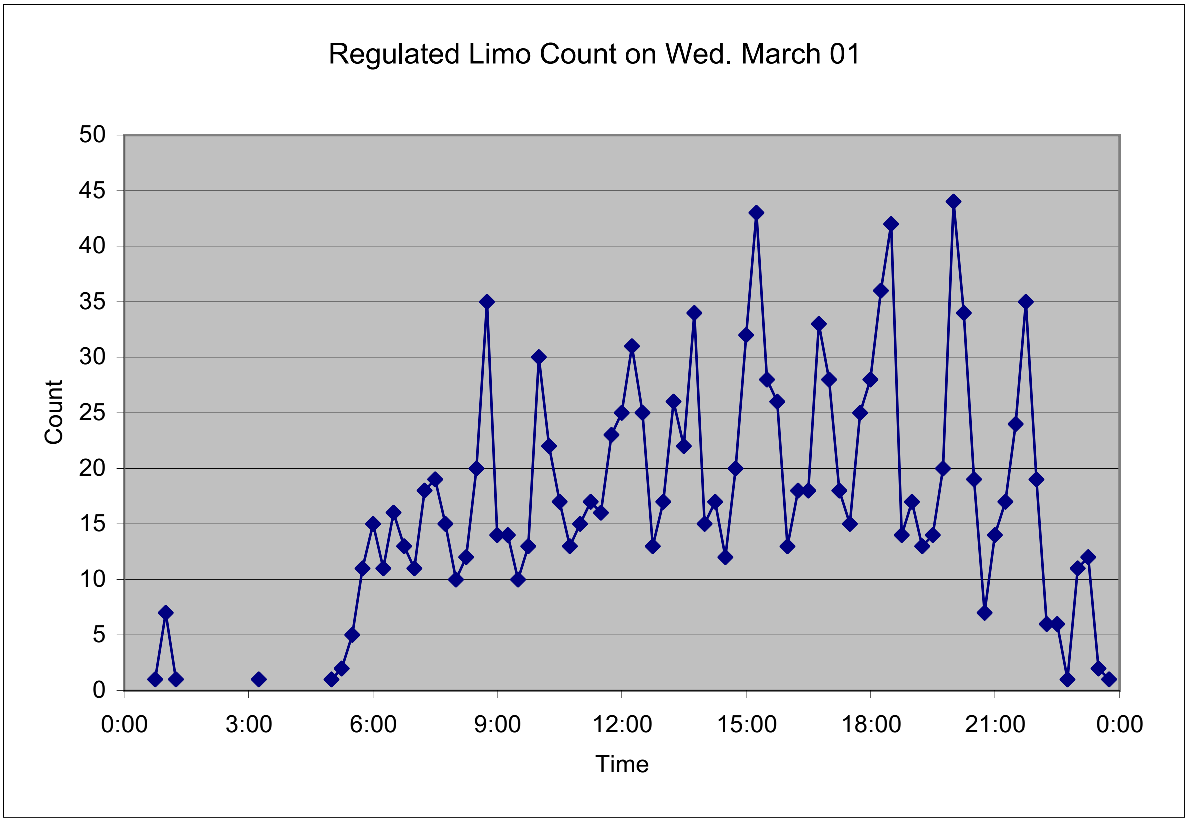

Figure 35: Regulated Limo Count on Wed. March 01

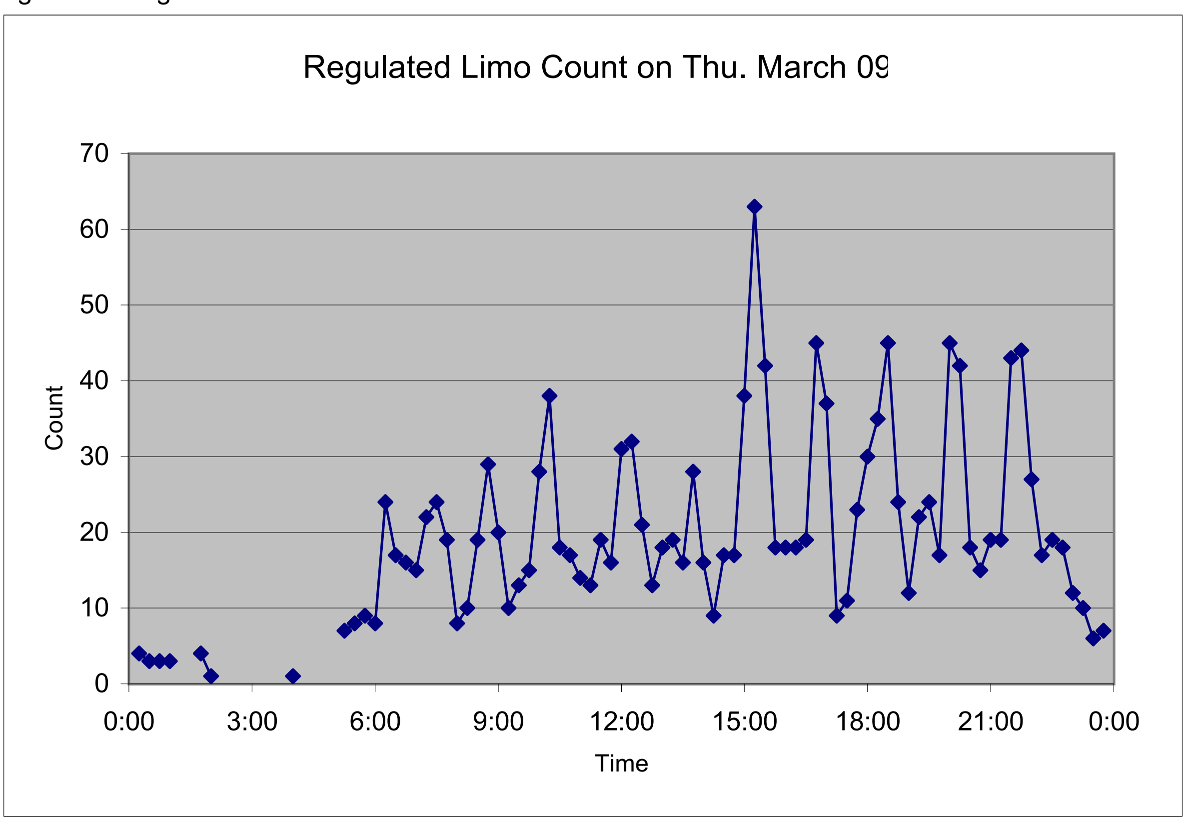

Figure 36: Regulated Limo Count on Thu. March 09

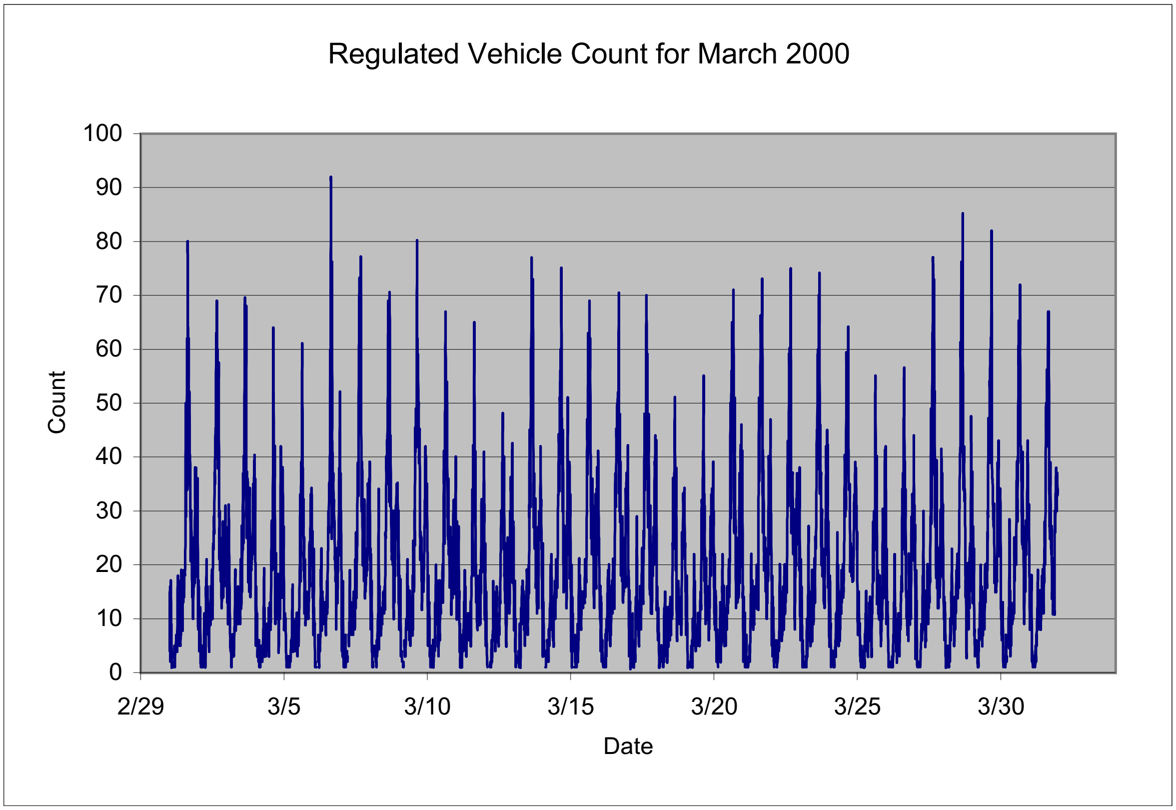

Figure 37: Regulated Vehicle Count for March 2000

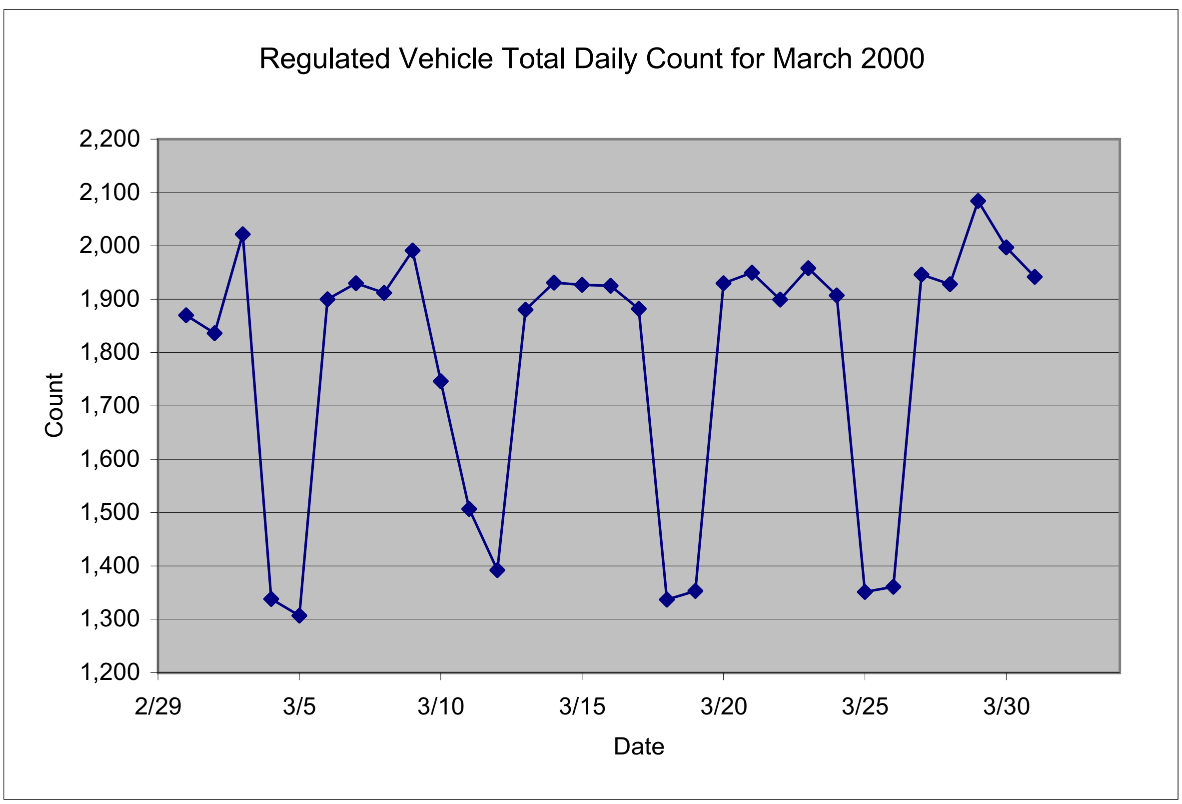

Figure 38: Regulated Vehicle Total Daily Count for March 2000

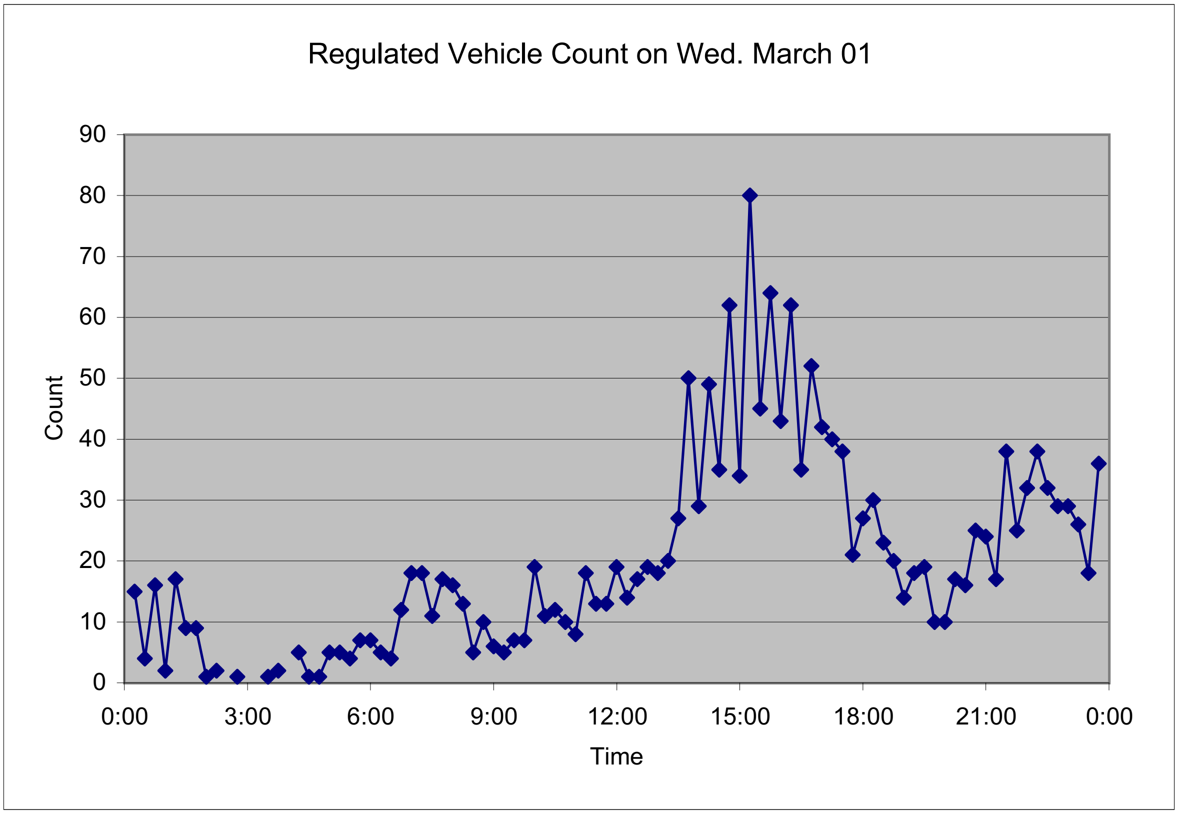

Figure 39: Regulated Vehicle Count on Wed. March 01

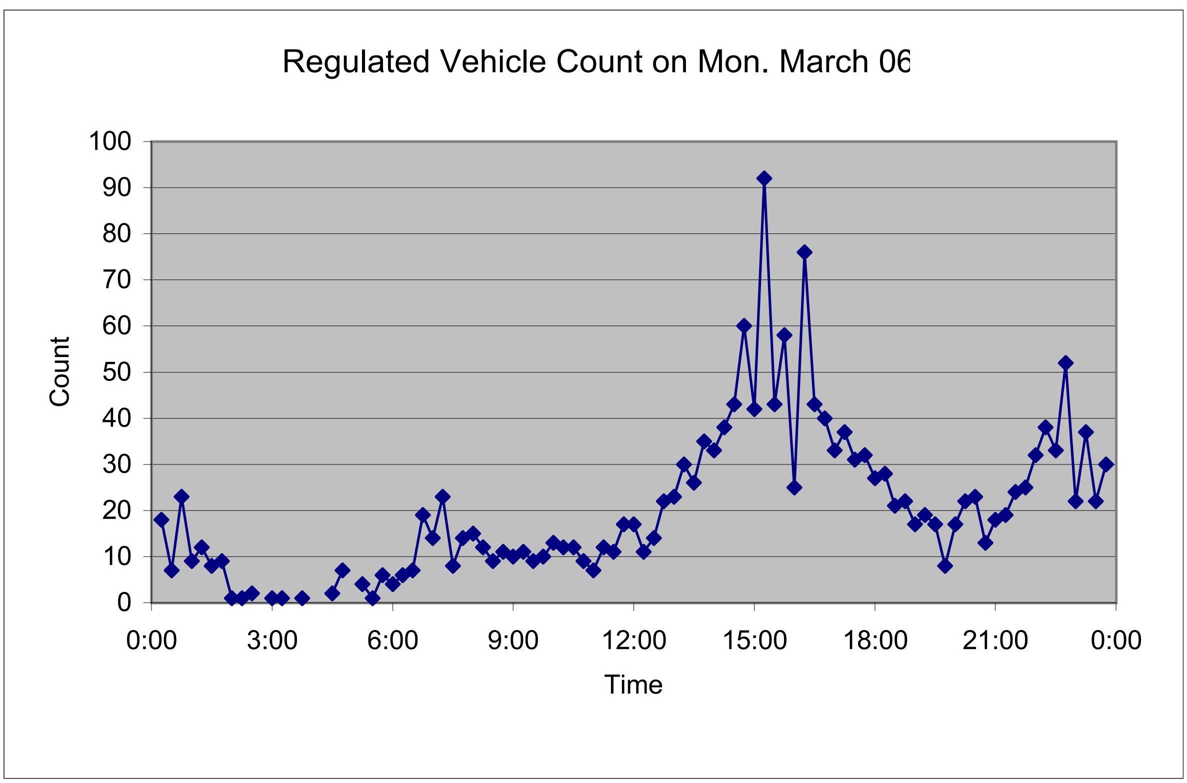

Figure 40: Regulated Vehicle Count on Wed. March 06

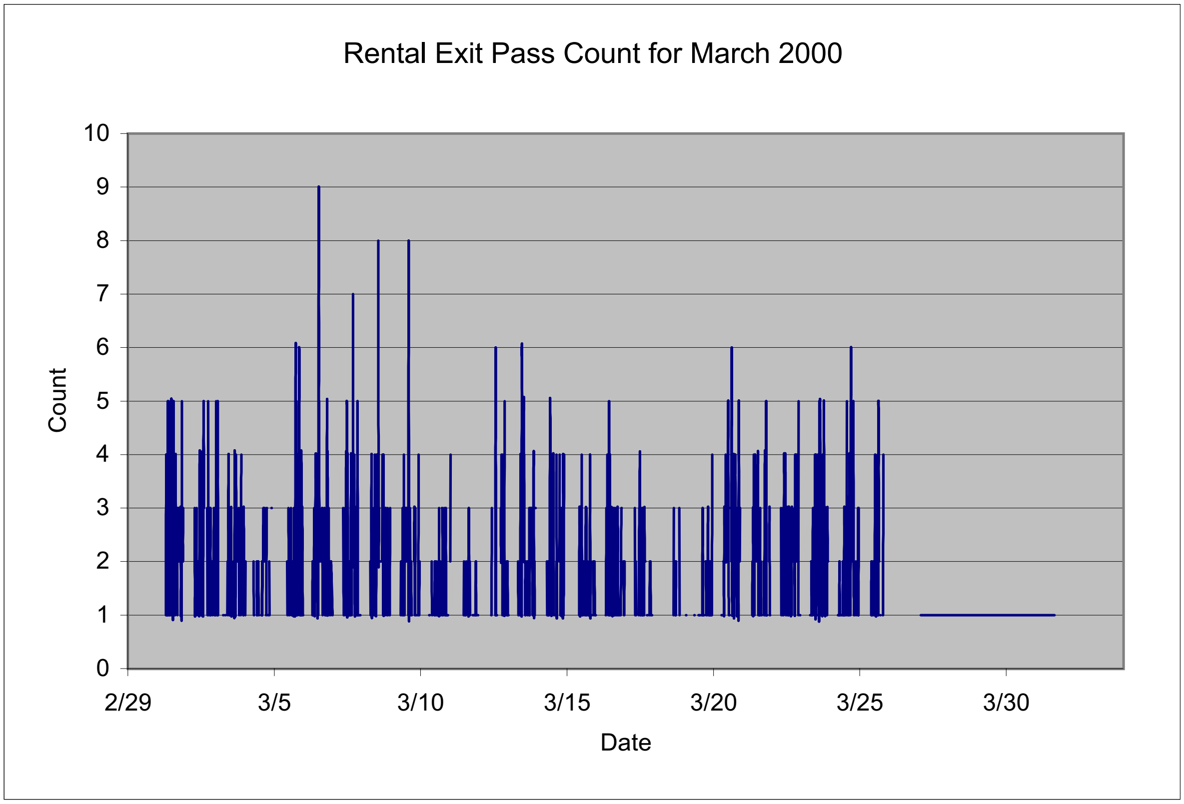

Figure 41: Rental Exit Pass Count for March 2000

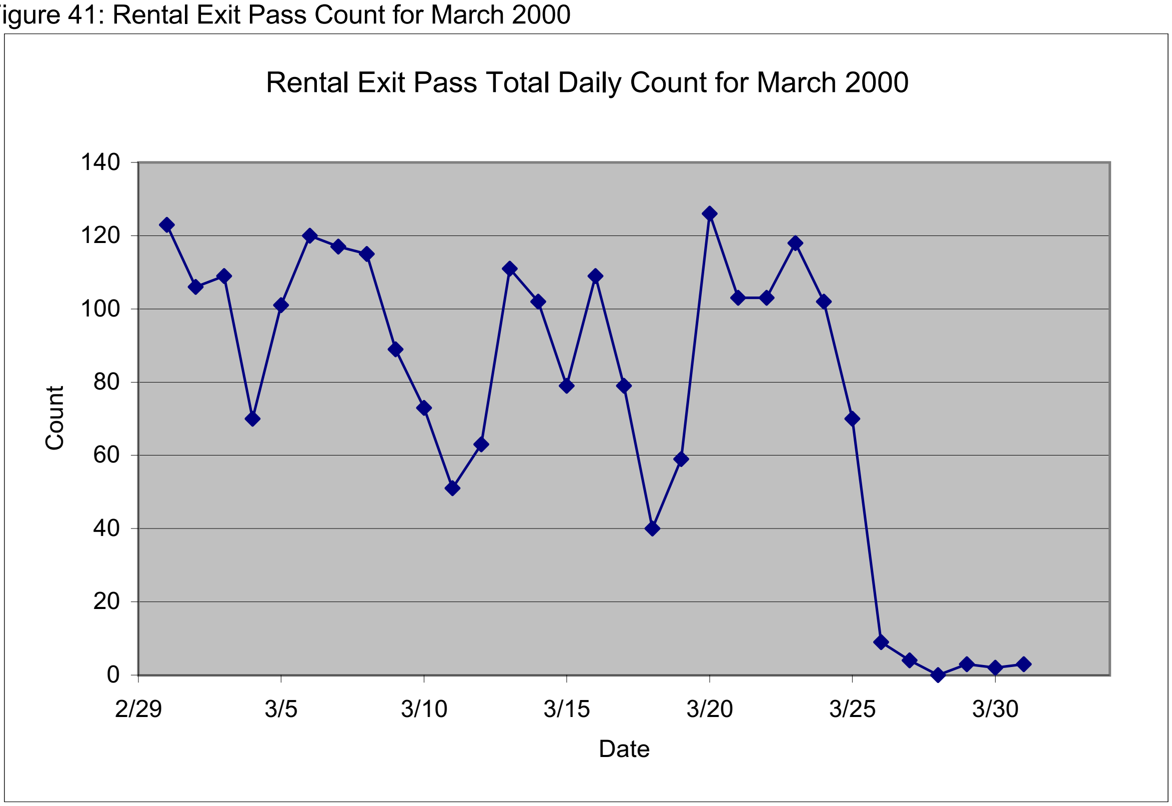

Figure 42: Rental Exit Pass Total Daily Count for March 2000

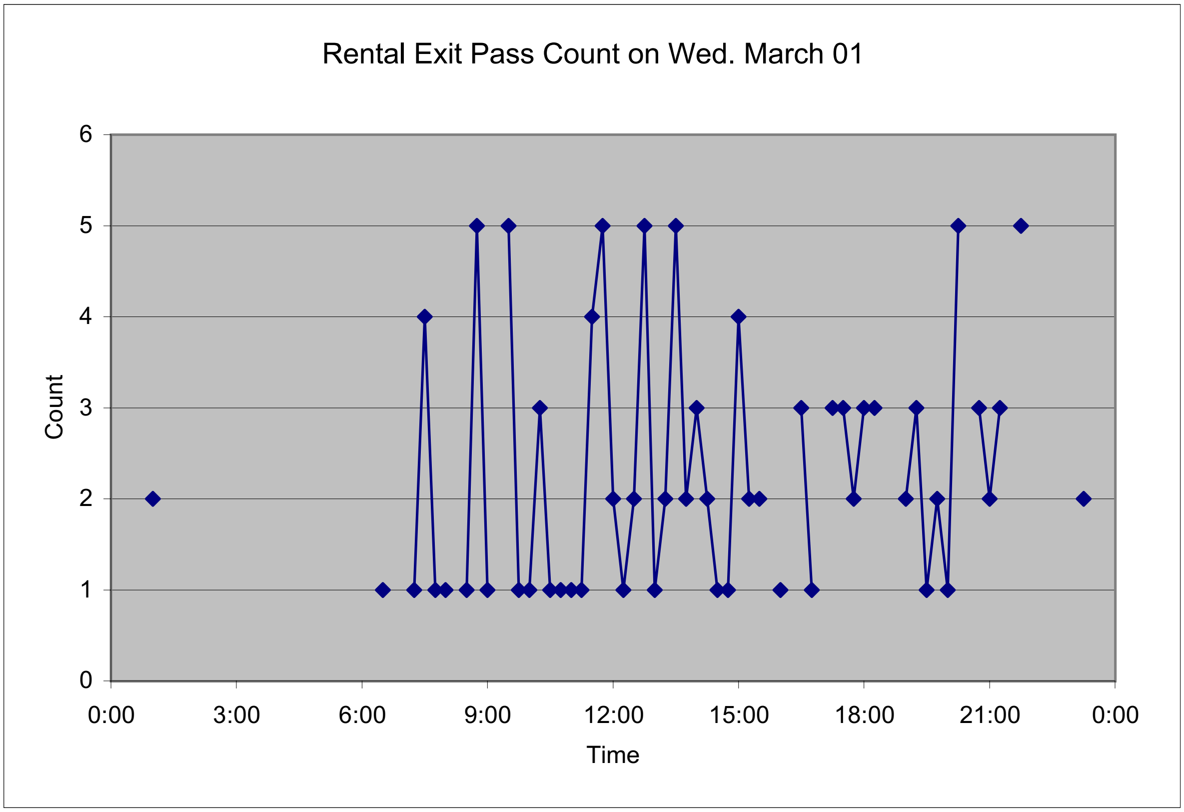

Figure 43: Rental Exit Pass Count on Wed. March 01

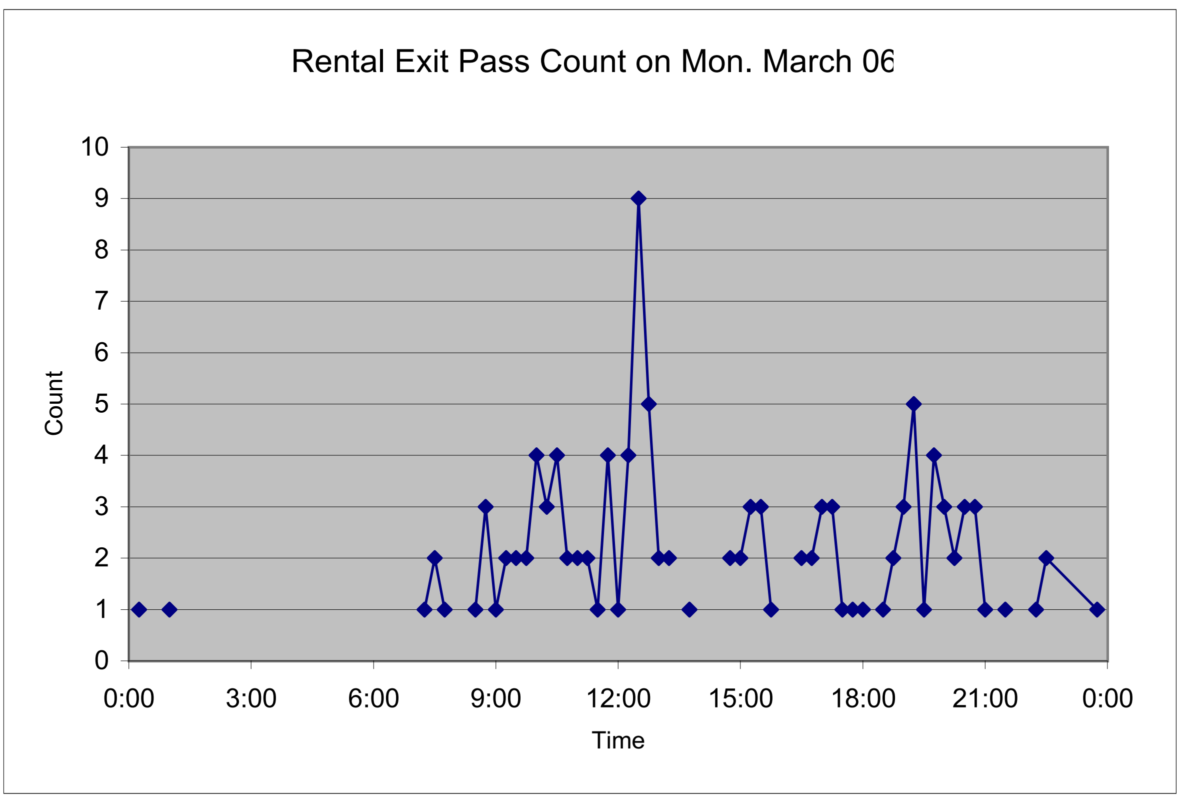

Figure 44: Rental Exit Pass Count on Mon. March 06

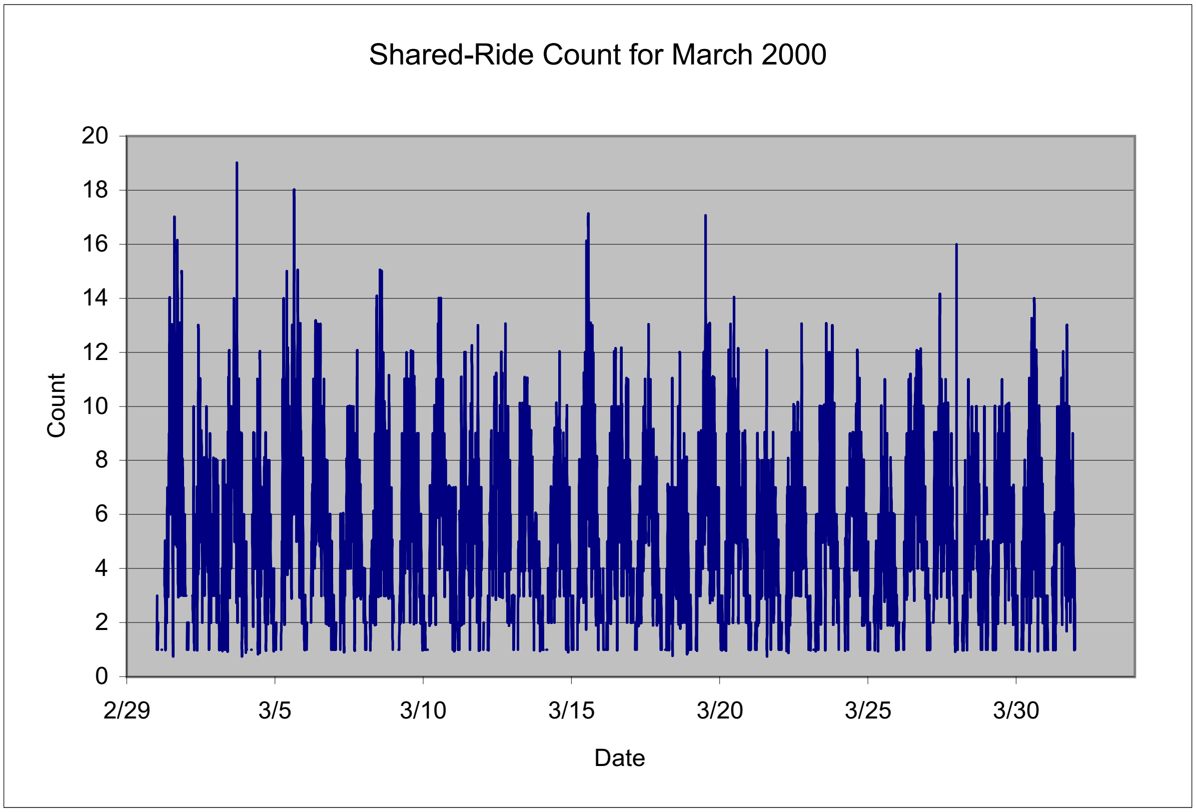

Figure 45: Shared-Ride Count for March 2000

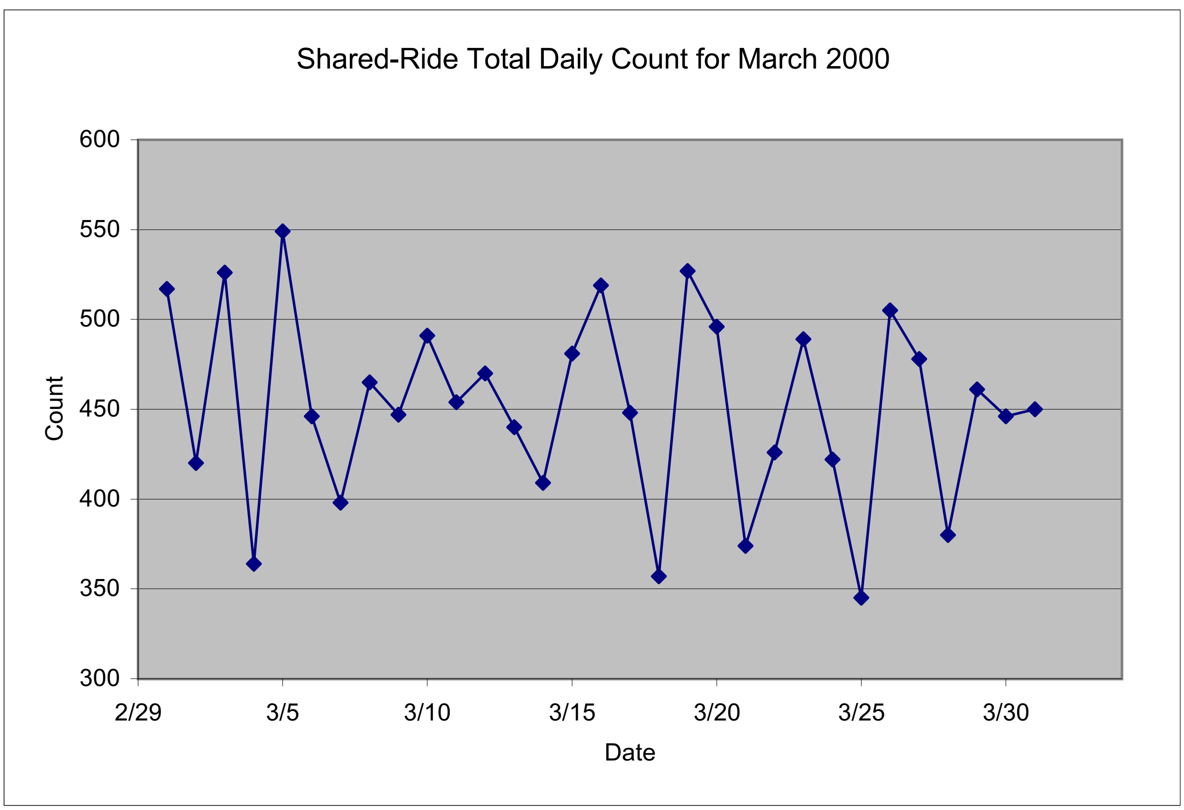

Figure 46: Shared-Ride Total Daily Count for March 2000

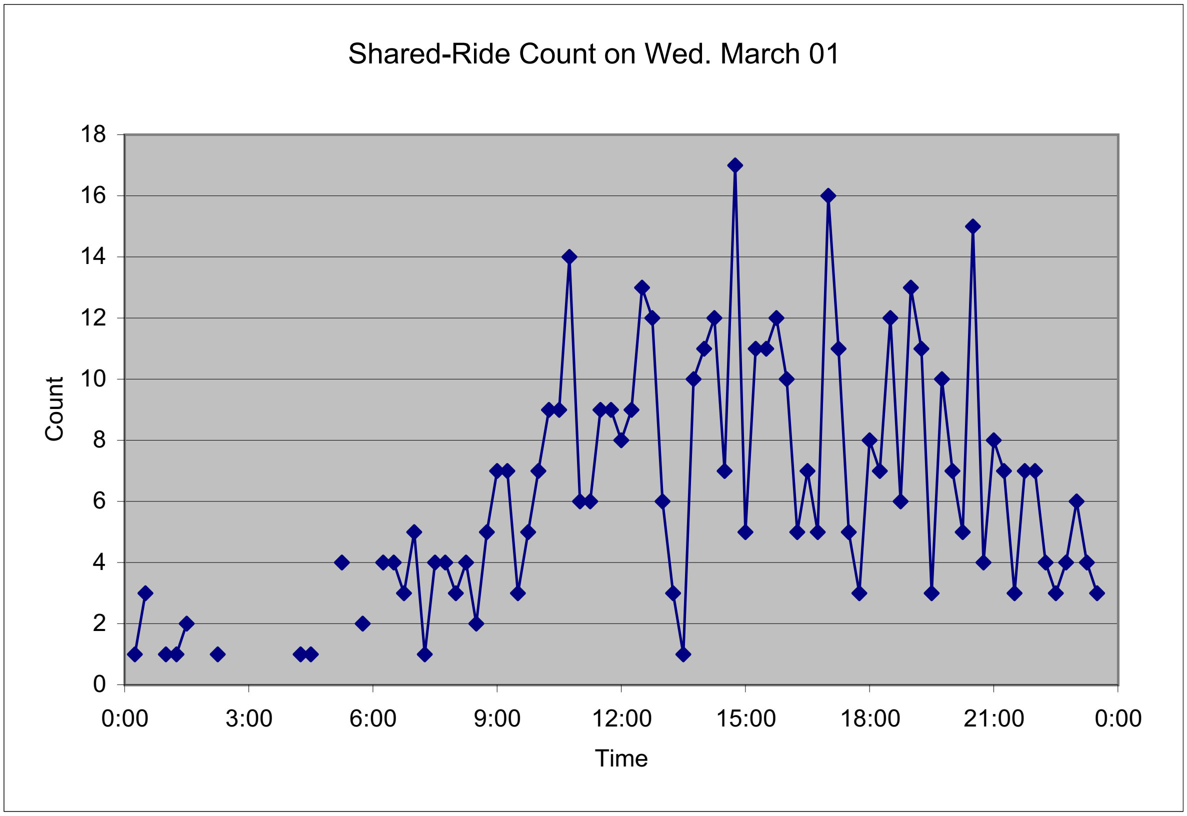

Figure 47: Shared-Ride Count on Wed. March 01

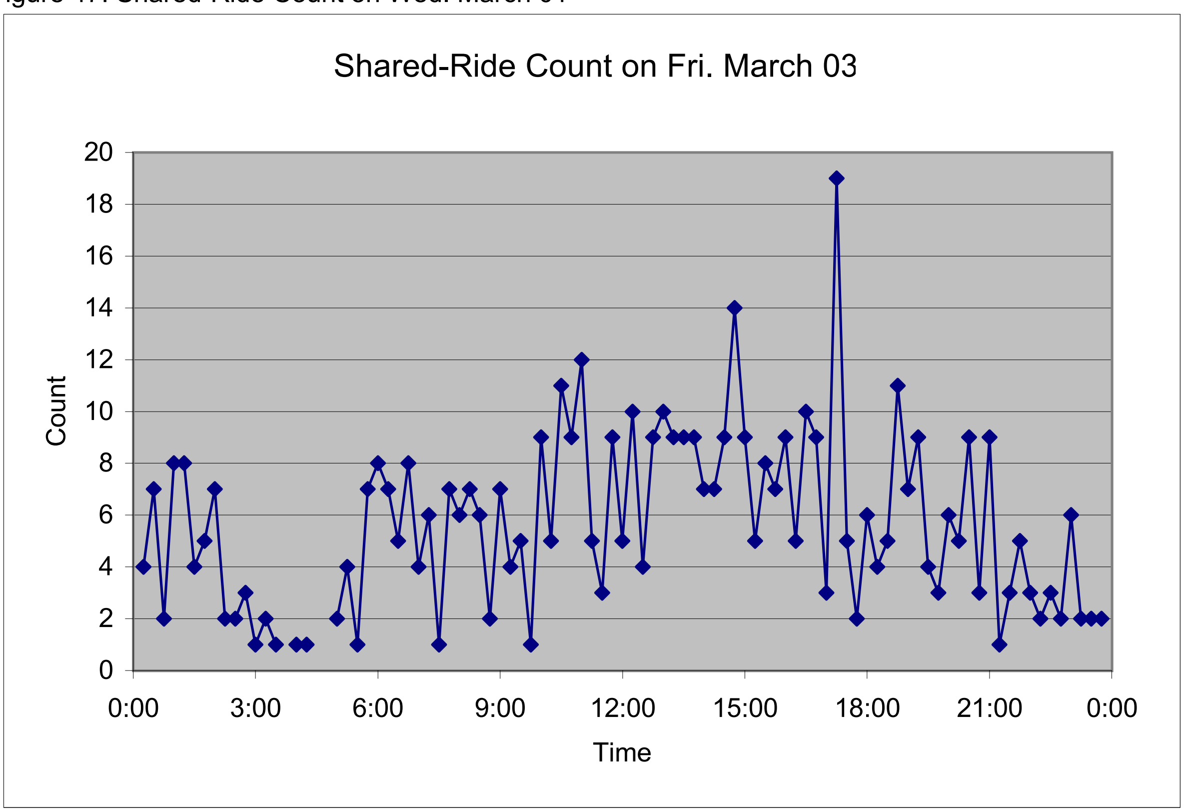

Figure 48: Shared-Ride Count on Fri. March 03

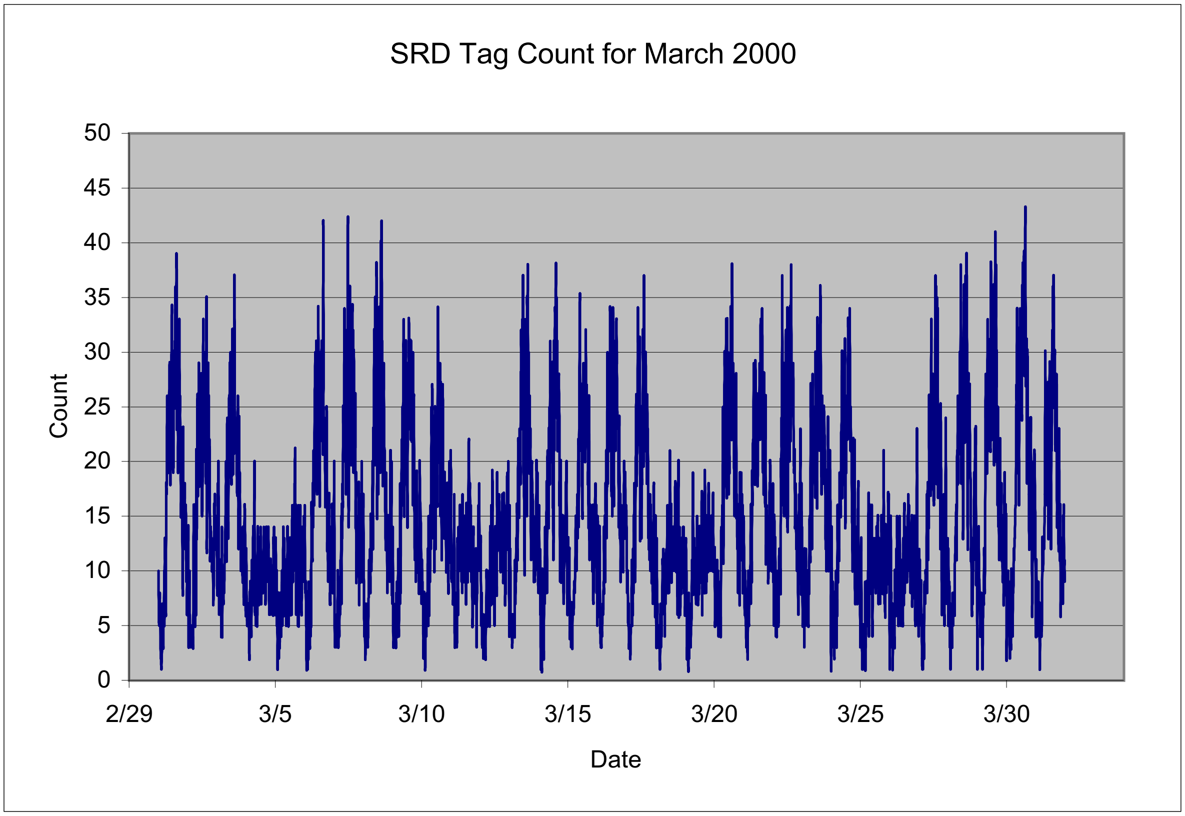

Figure 49: SRD Tag Count for March 2000

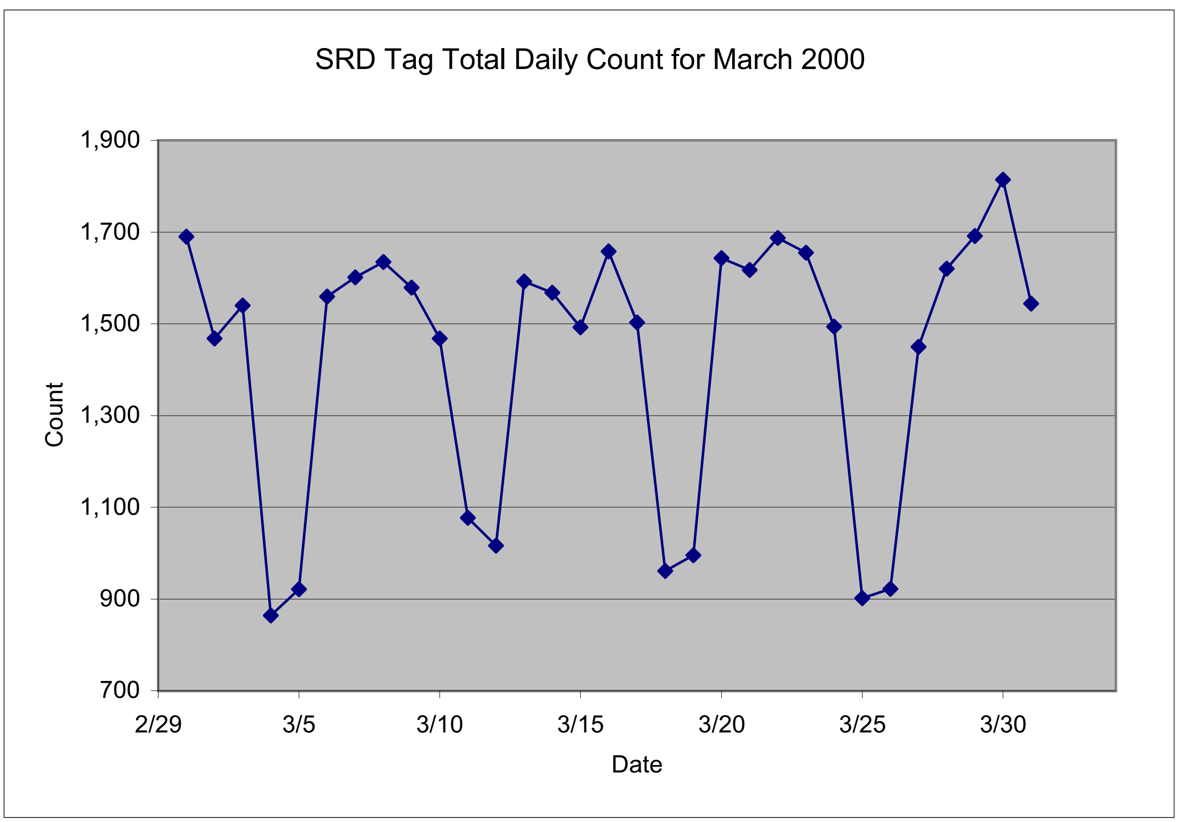

Figure 50: SRD Tag Total Daily Count for March 2000

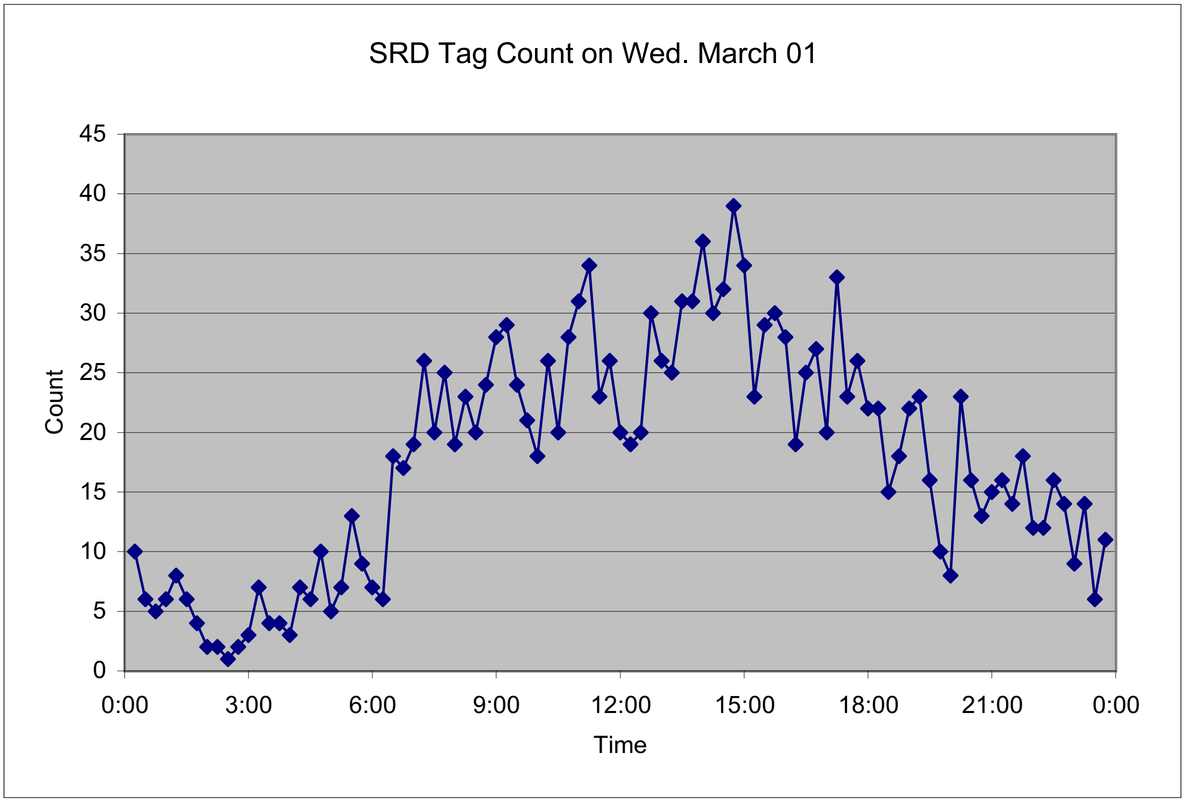

Figure 51: SRD Tag Count on Wed. March 01

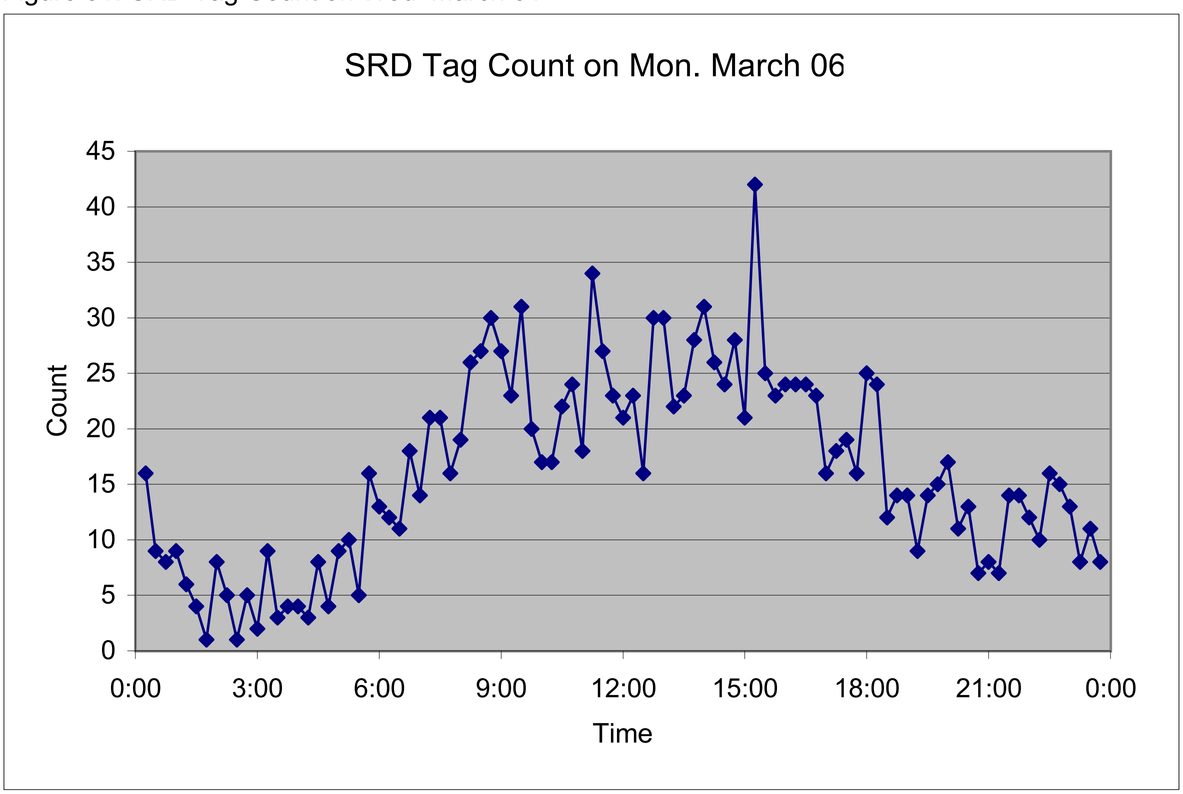

Figure 52: SRD Tag Count on Mon. March 06

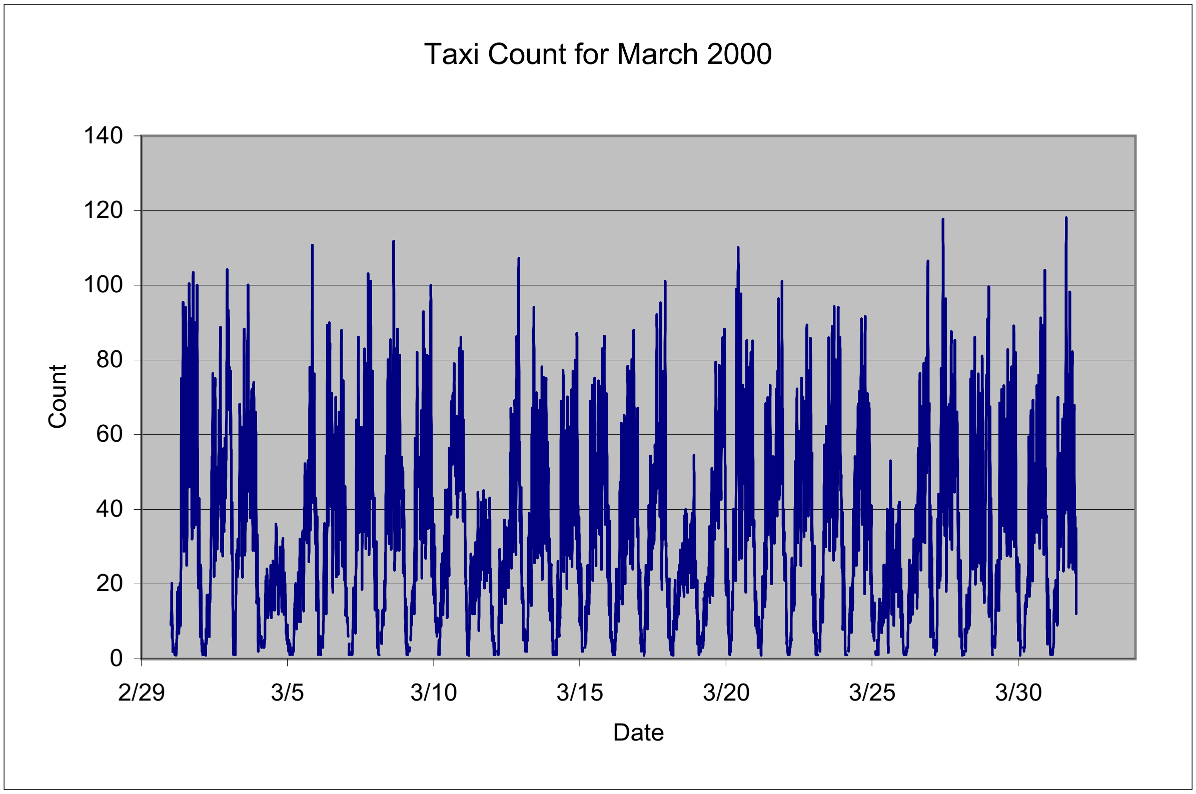

Figure 53: Taxi Count for March 2000

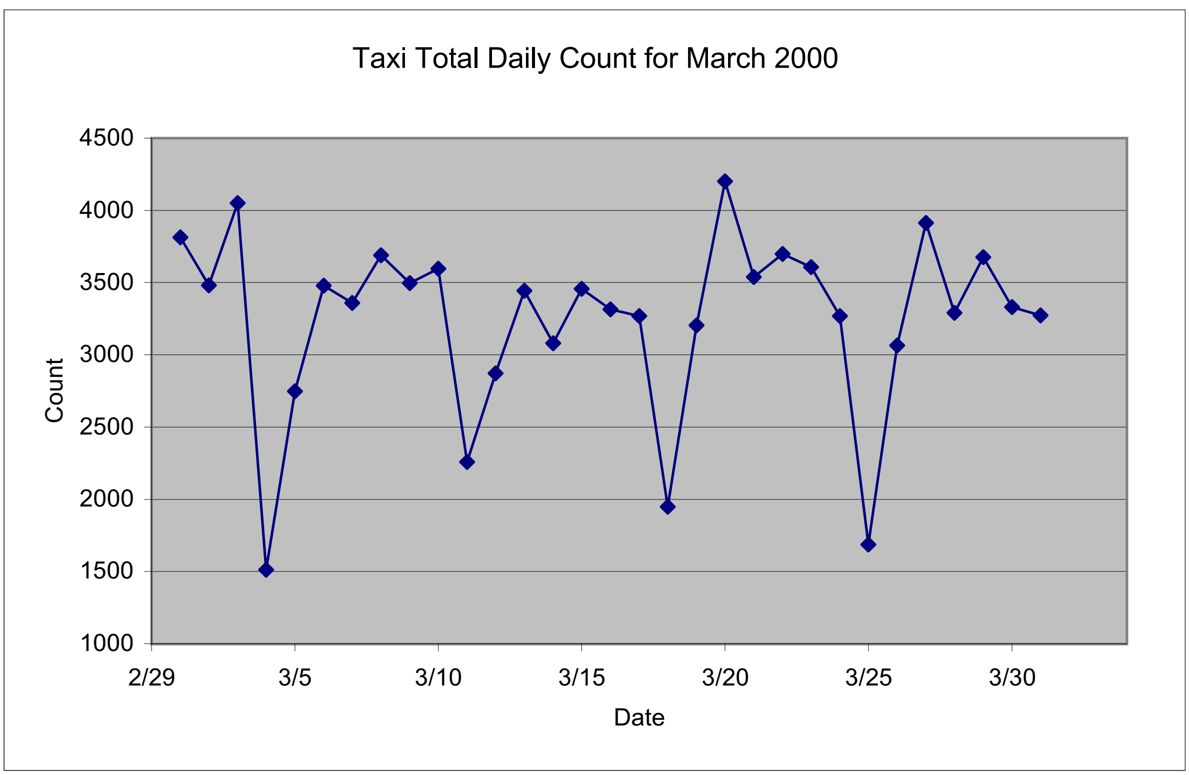

Figure 54: Taxi Total Daily Count for March 2000

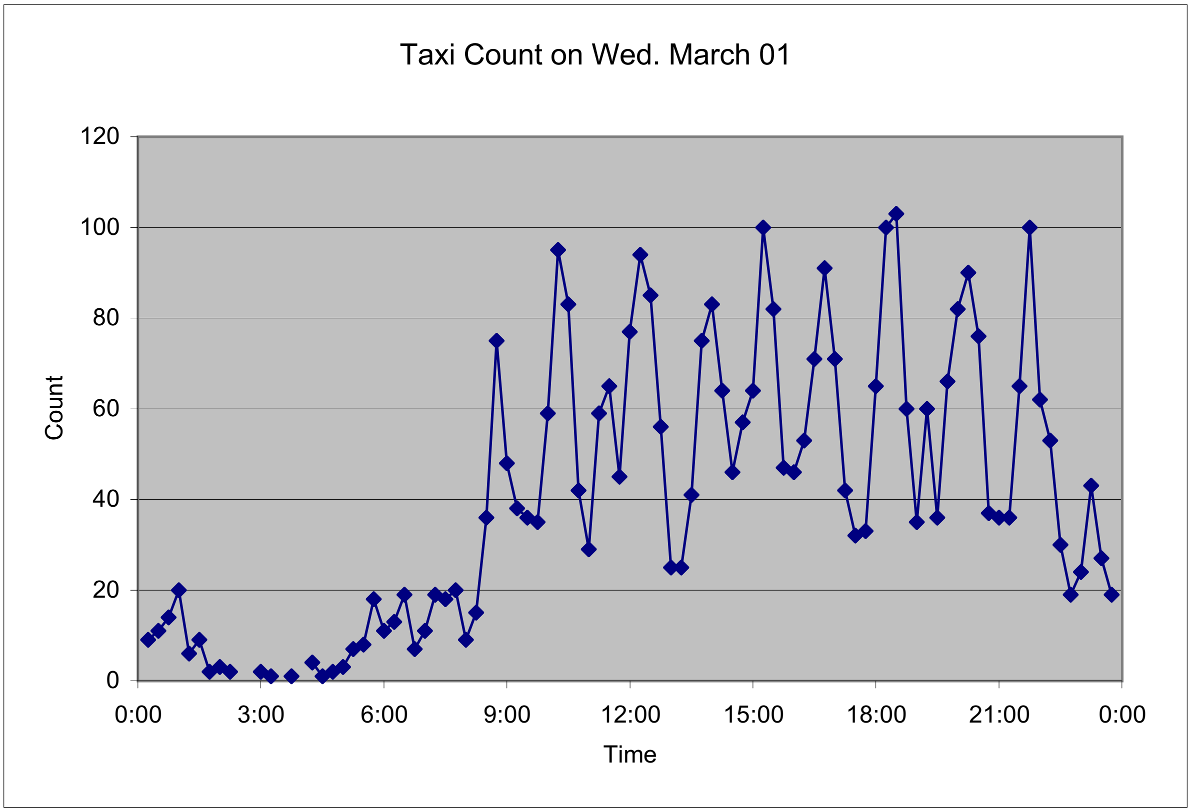

Figure 55: Taxi Count on Wed. March 01

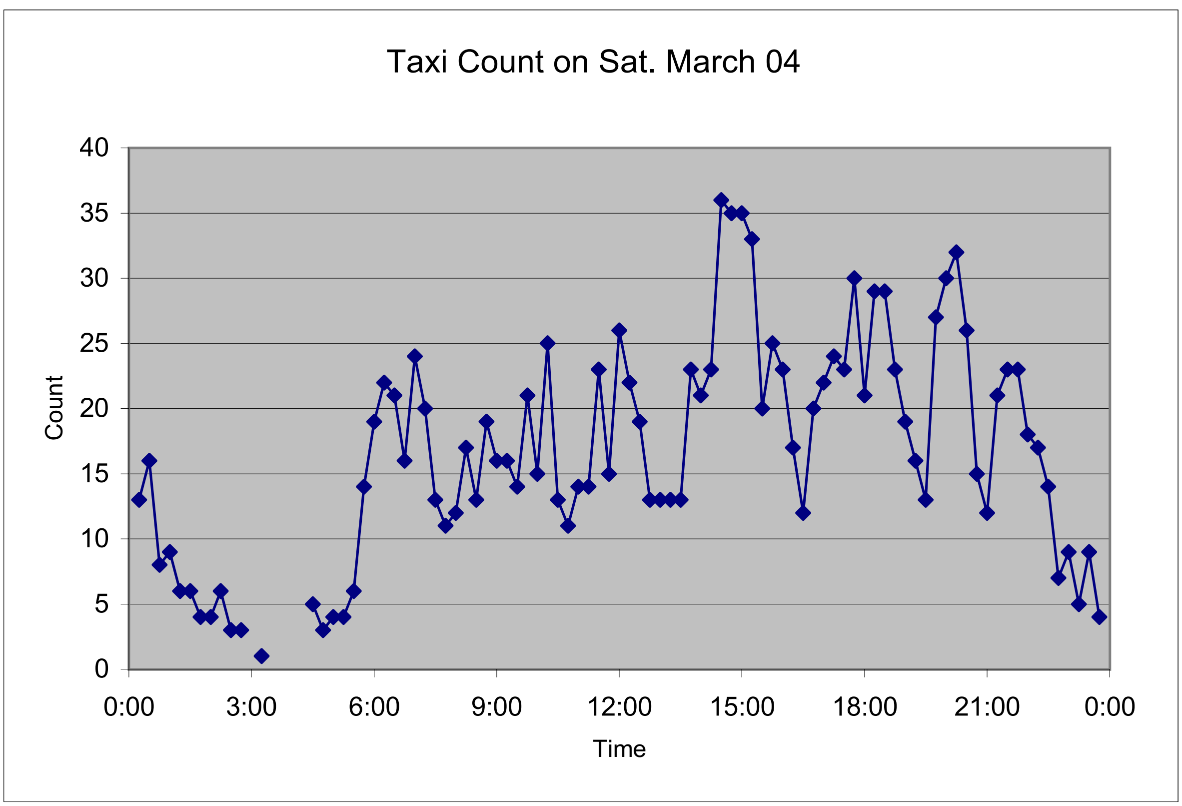

Figure 56: Taxi Count on Sat. March 04

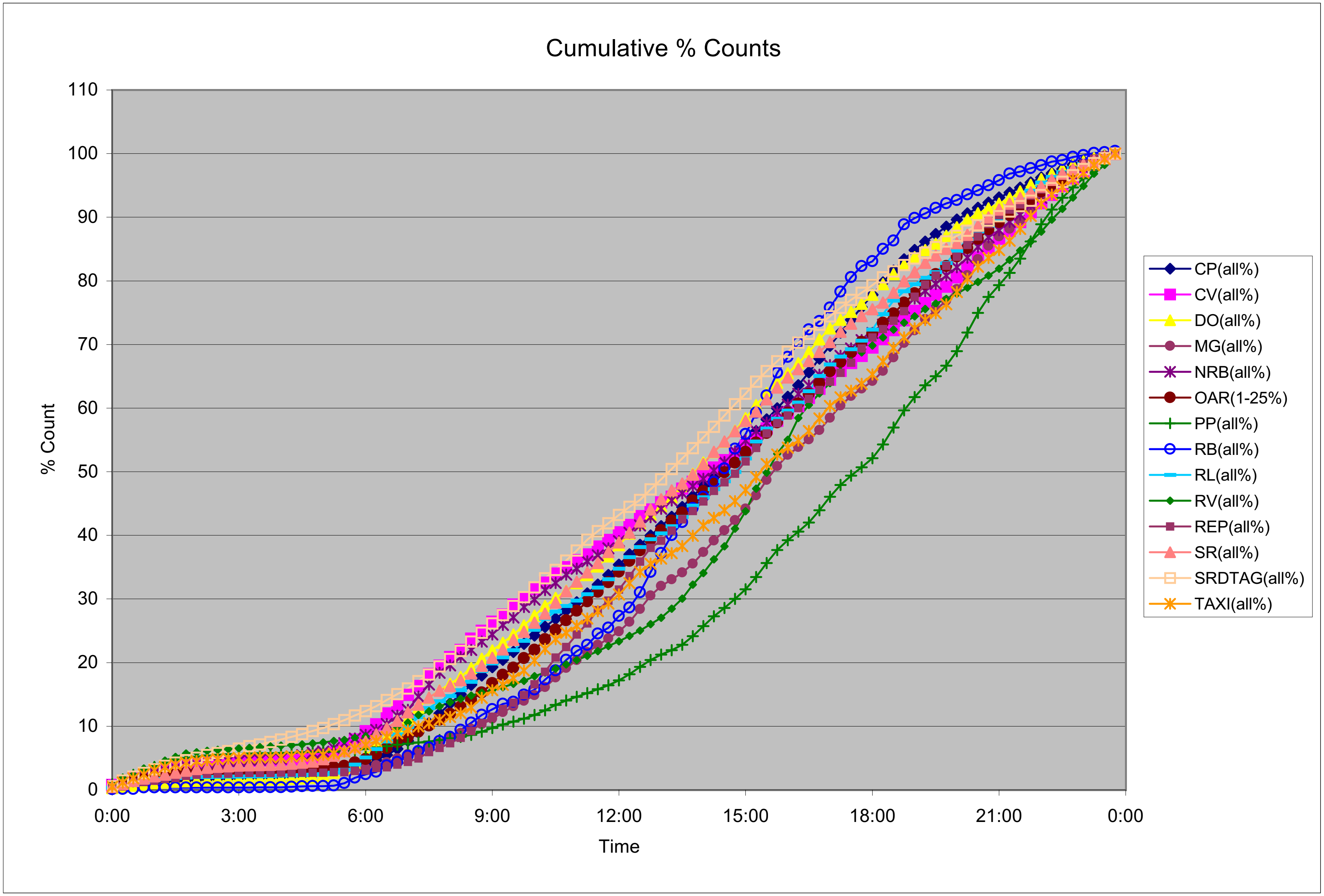

Figure 57: Cumulative Percentage Counts

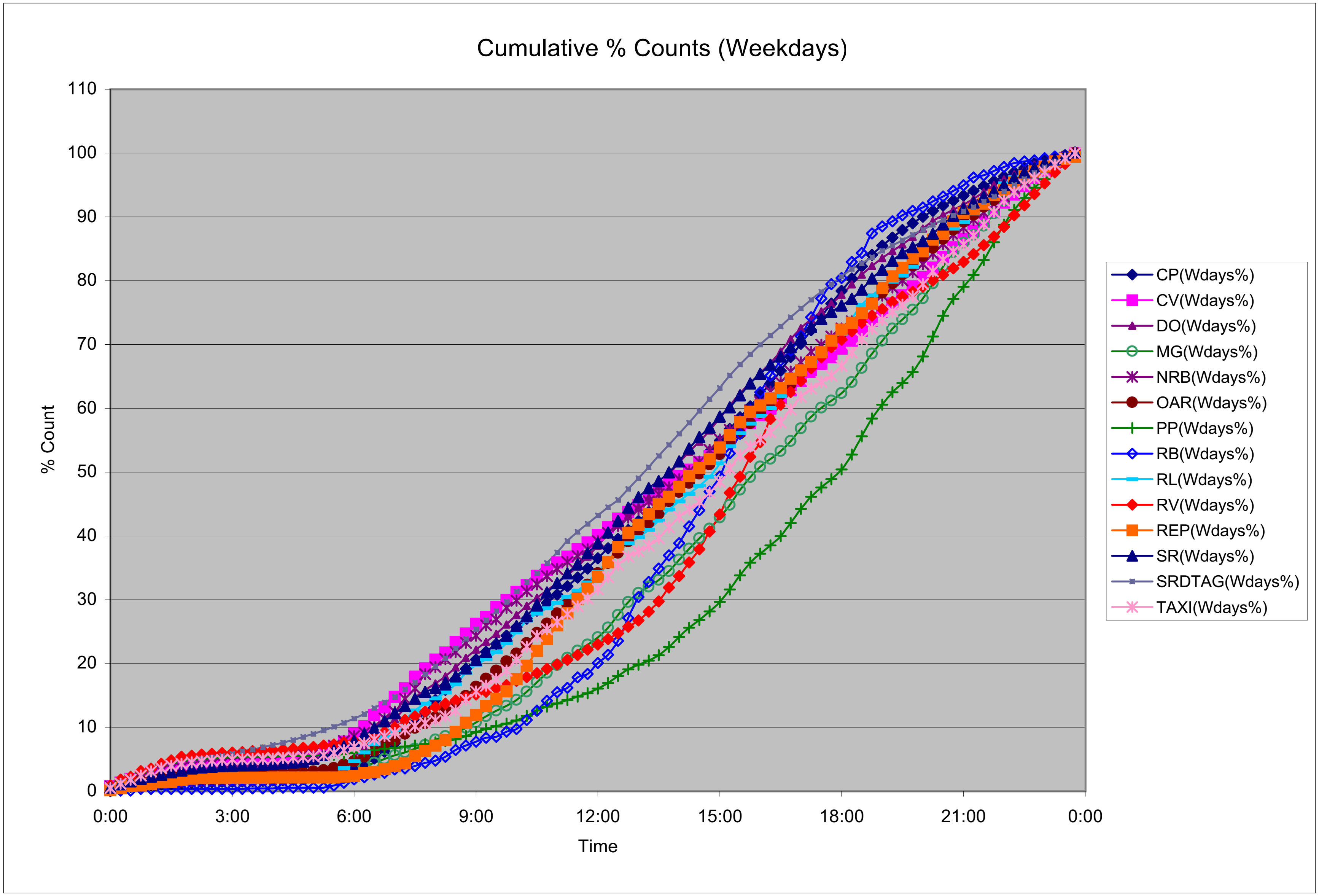

Figure 58: Cumulative Percentage Counts (Weekdays)

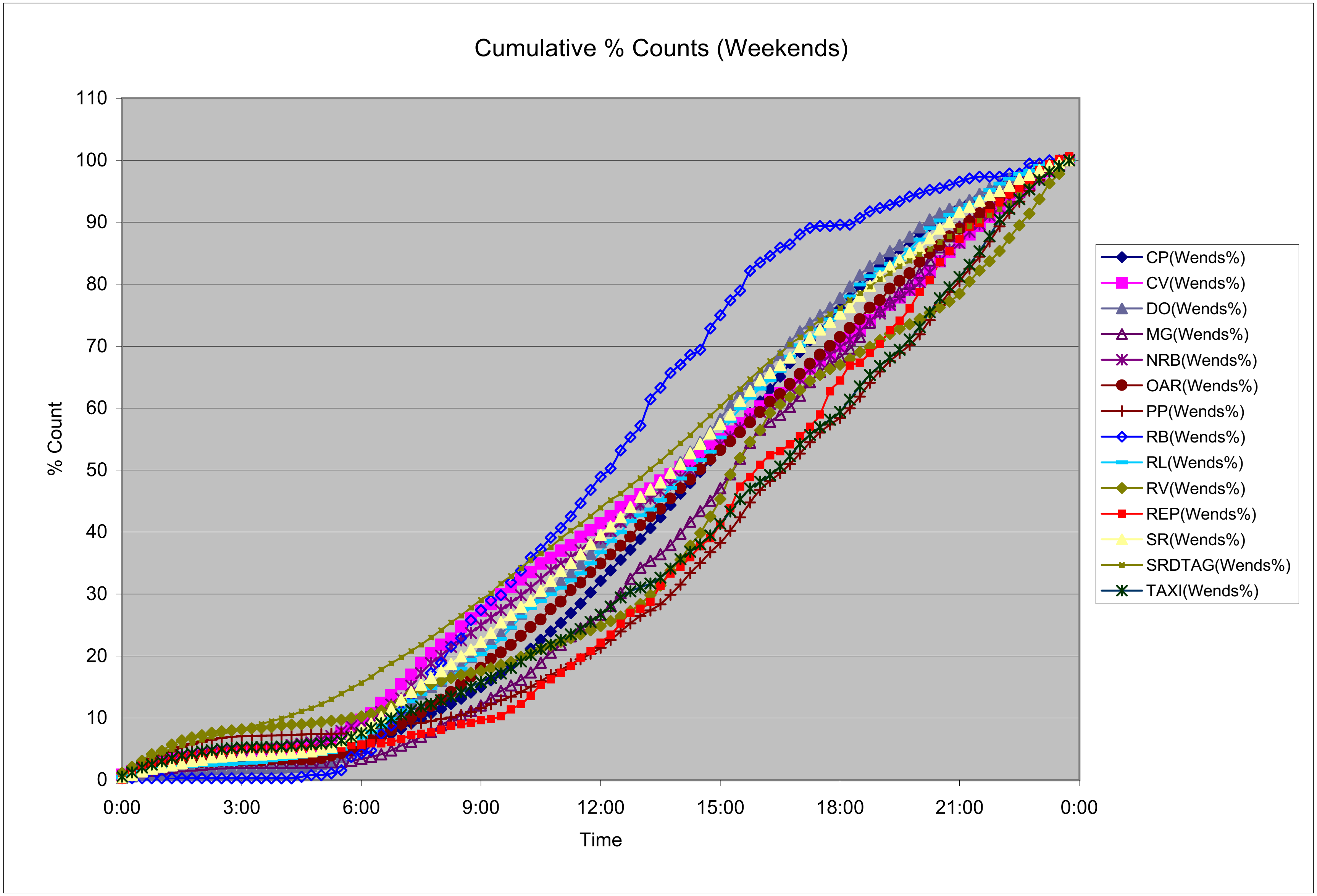

Figure 59: Cumulative Percentage Counts (Weekends)

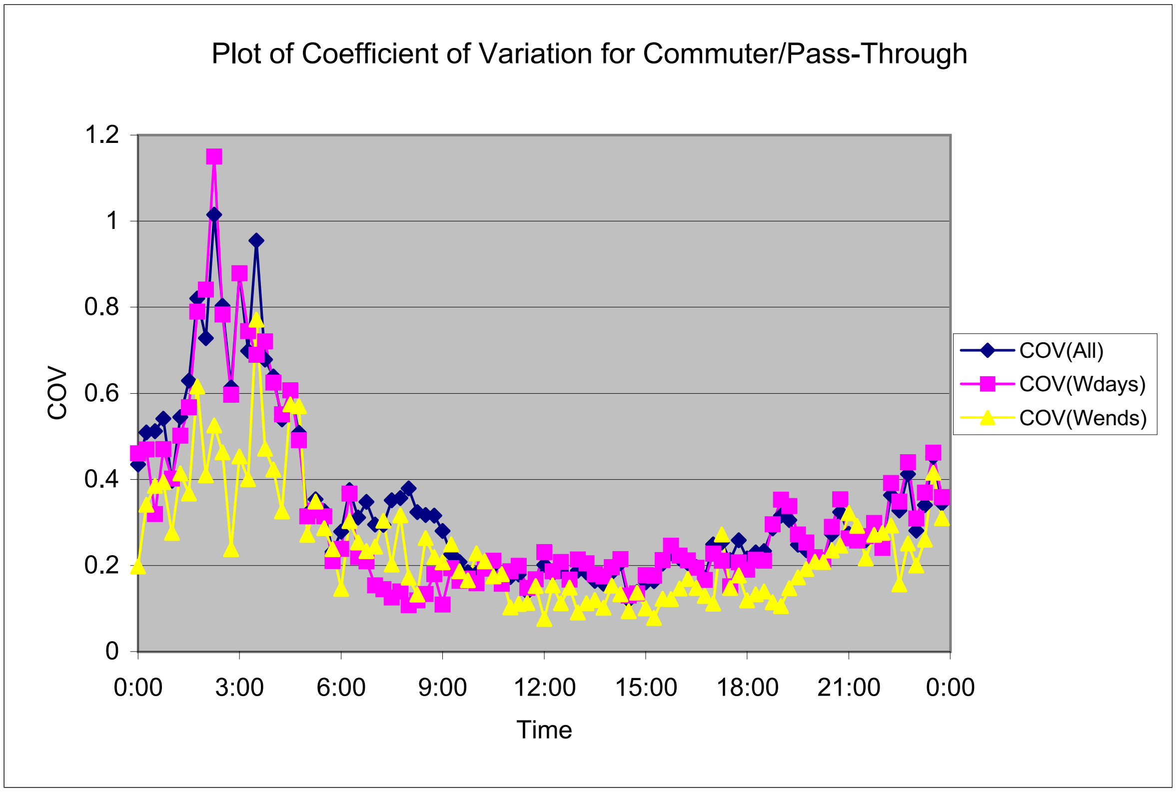

Figure 60: Plot of Coefficient of Variation for Commuter/Pass-Through

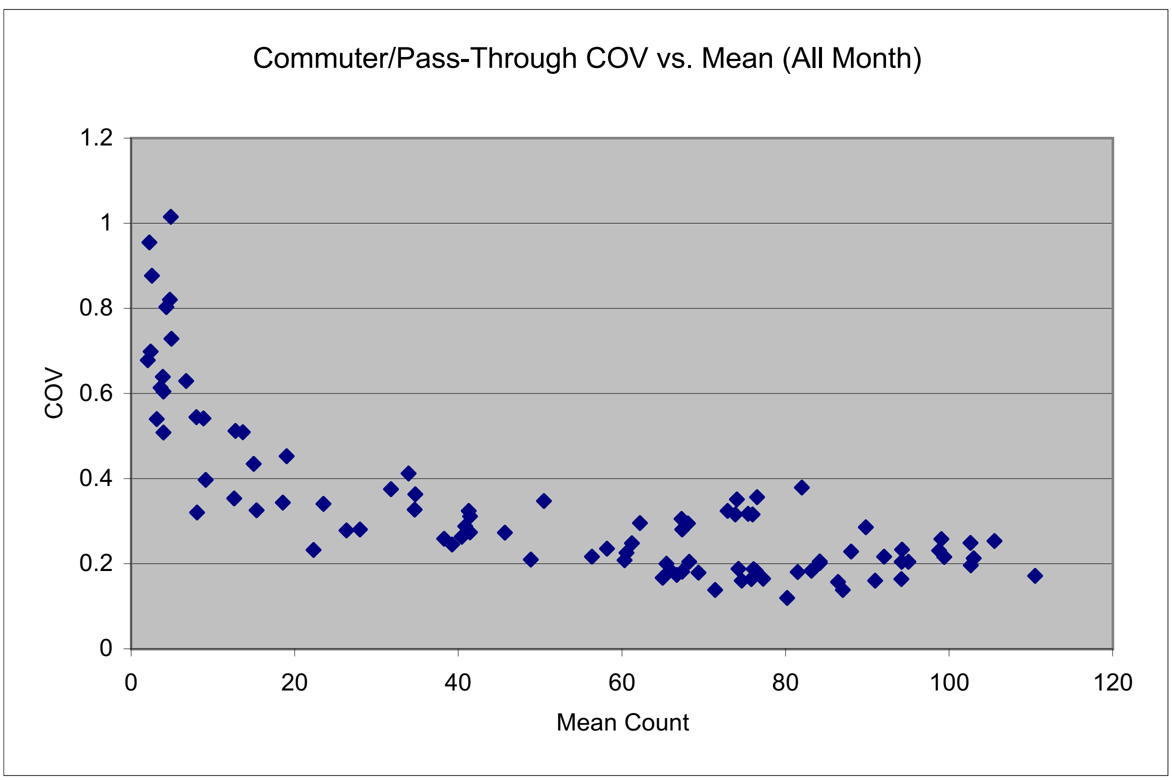

Figure 61: Commuter/Pass-Through COV vs. Mean (All Month)

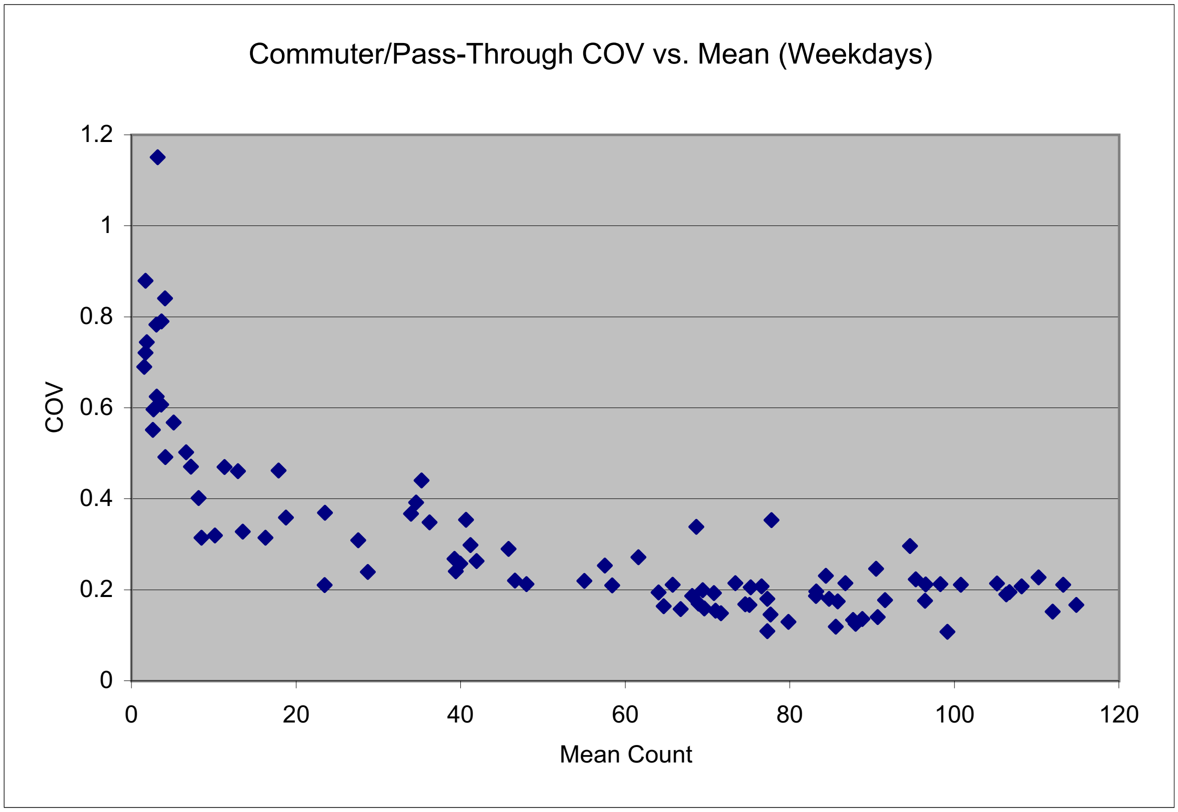

Figure 62: Commuter/Pass-Through COV vs. Mean (Weekdays)

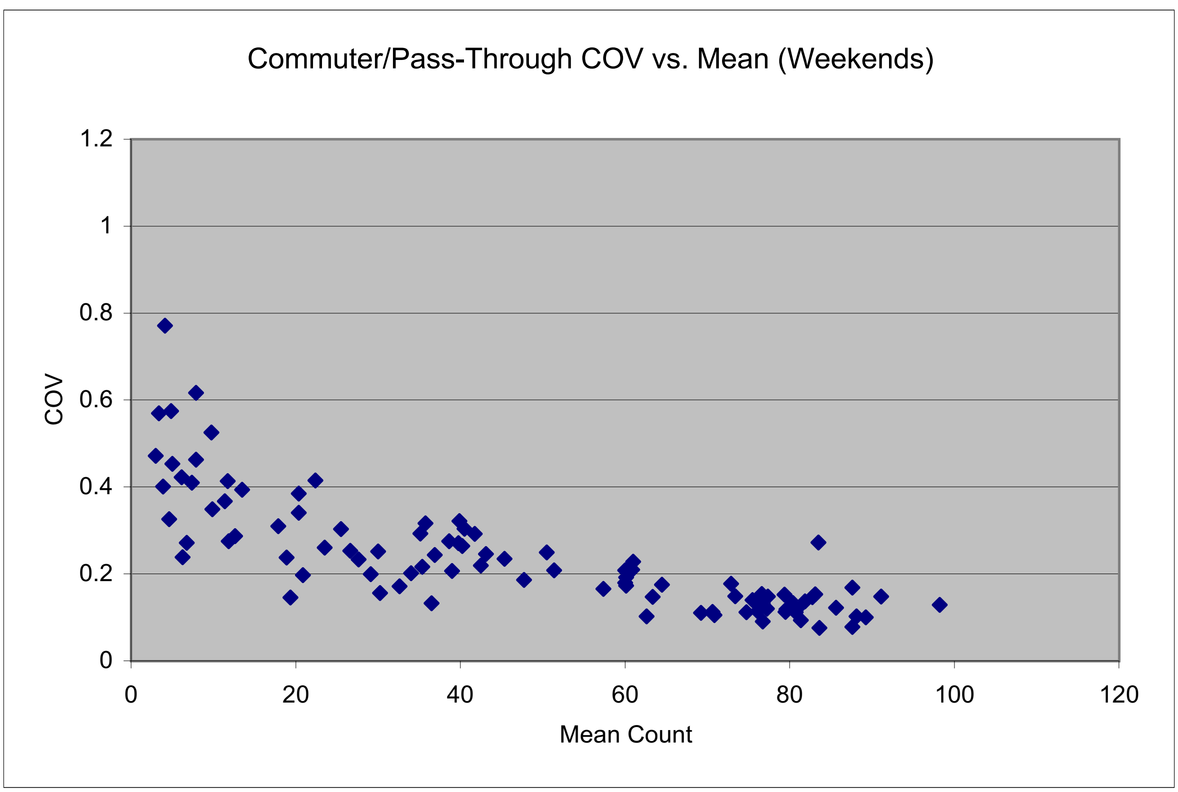

Figure 63: Commuter/Pass-Through COV vs. Mean (Weekends)

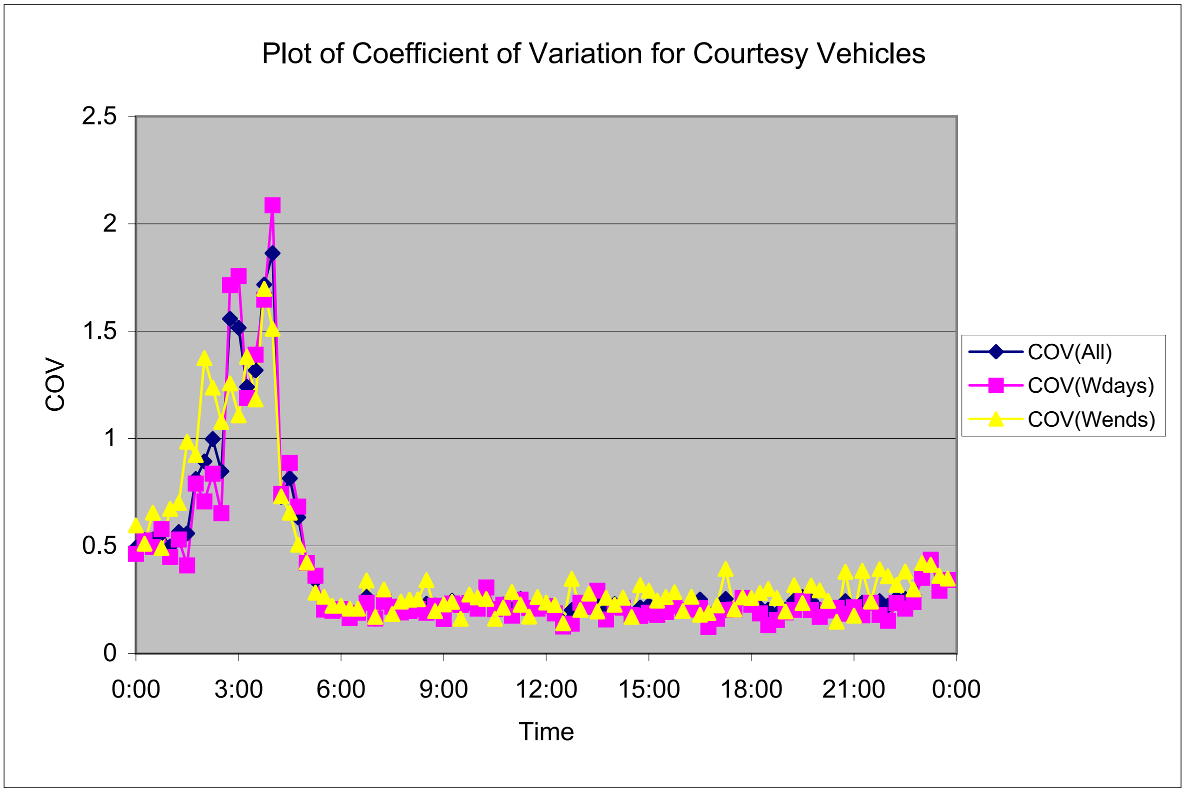

Figure 64: Plot of Coefficient of Variation for Courtesy Vehicles

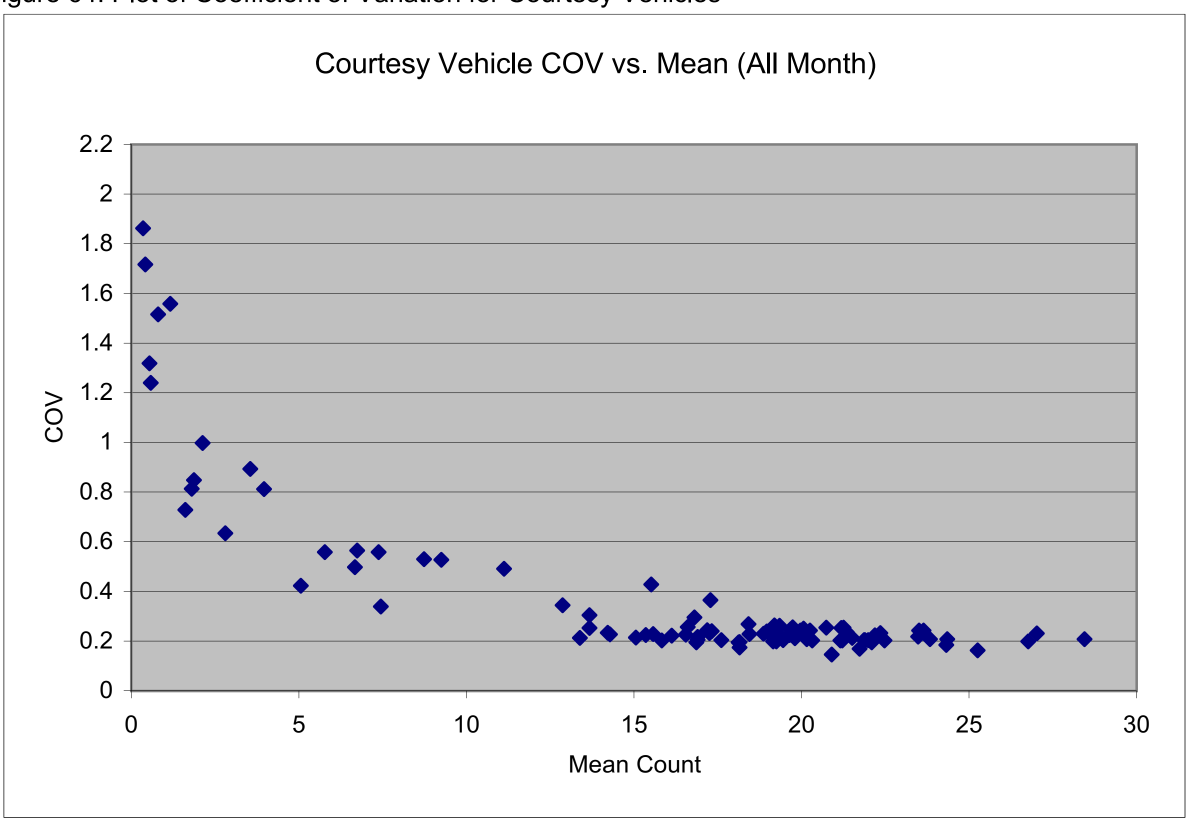

Figure 65: Courtesy Vehicle COV vs. Mean (All Month)

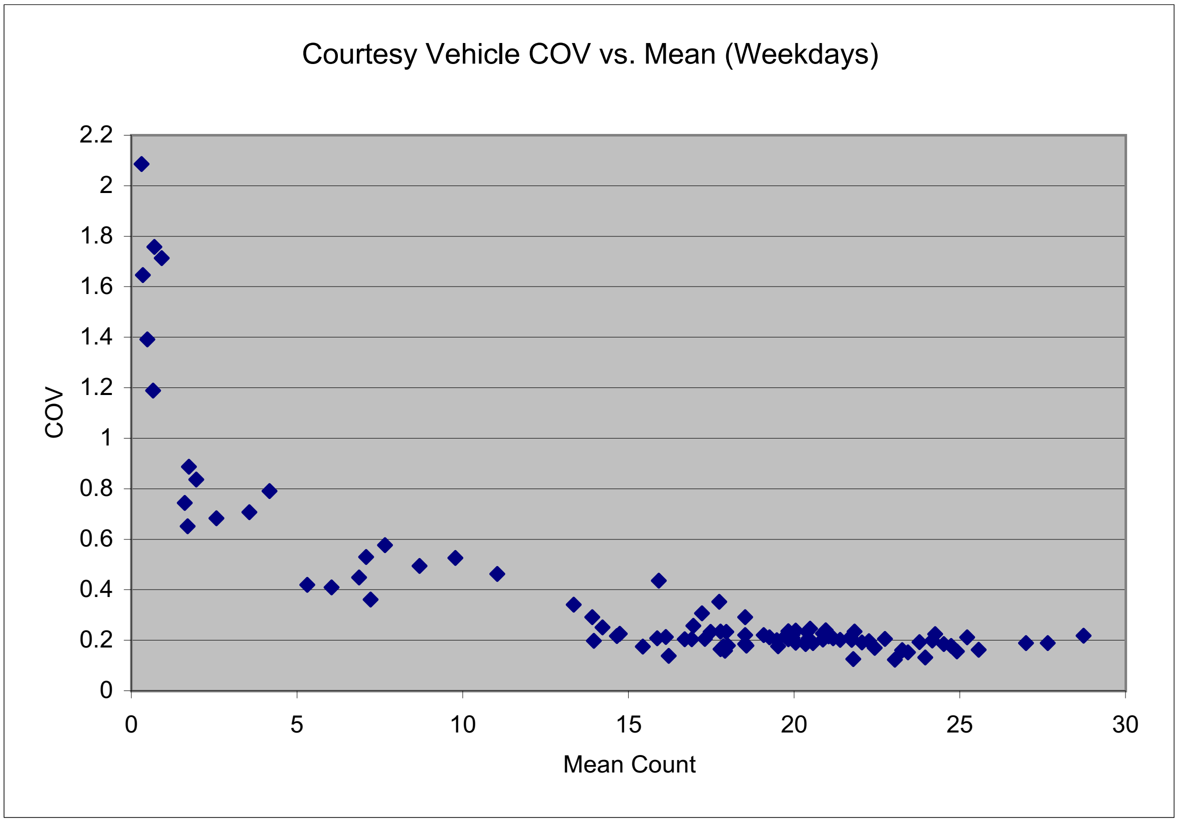

Figure 66: Courtesy Vehicle COV vs. Mean (Weekdays)

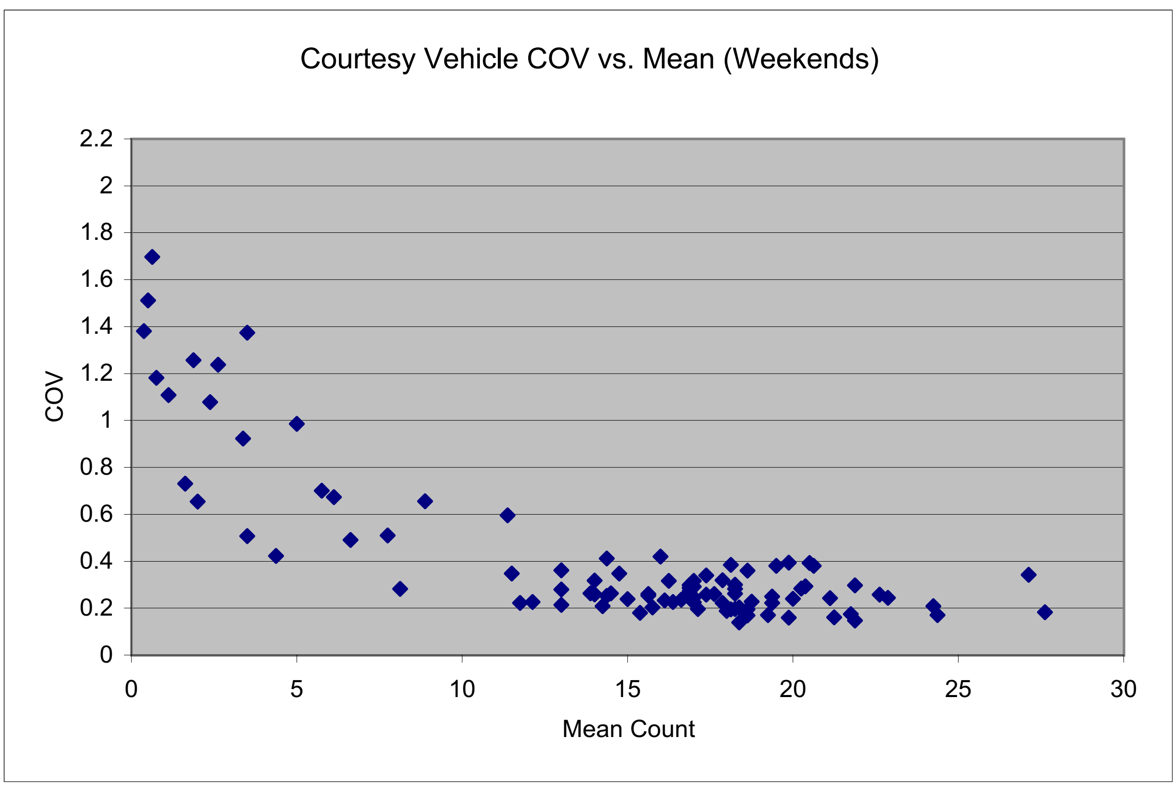

Figure 67: Courtesy Vehicle COV vs. Mean (Weekends)

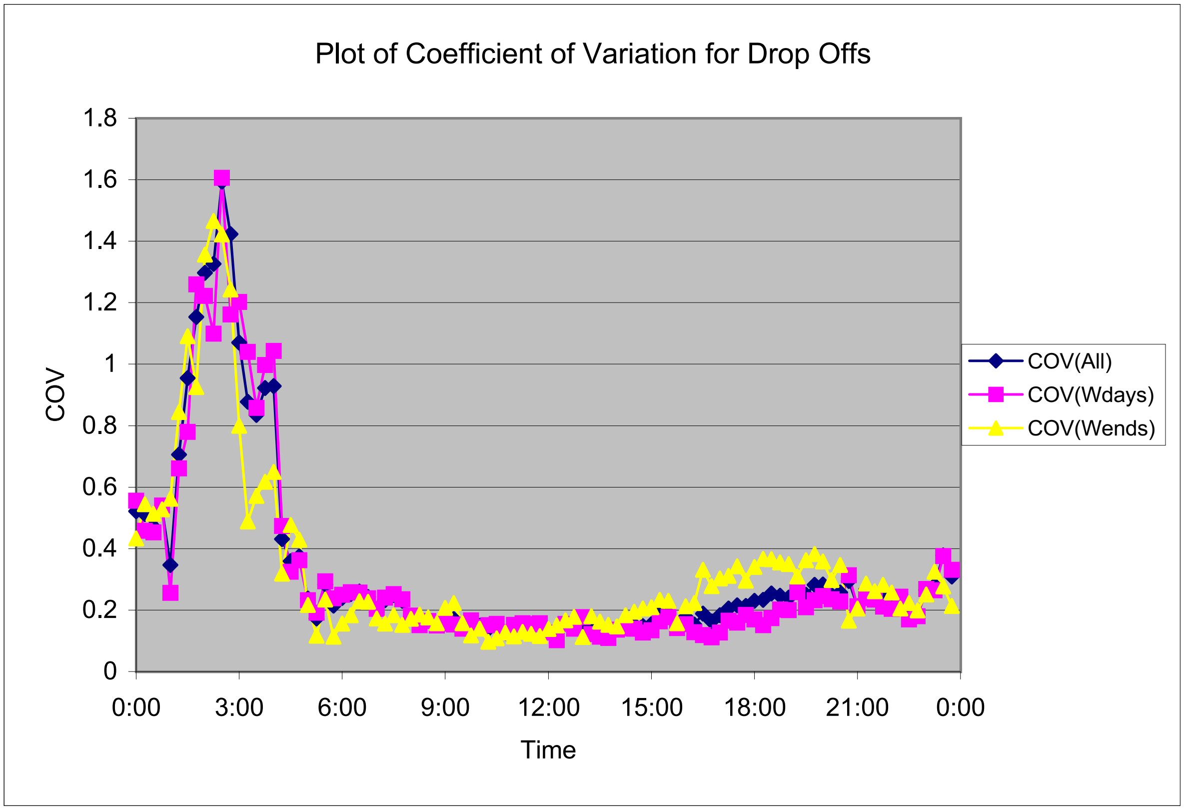

Figure 68: Plot of Coefficient of Variation for Drop Offs

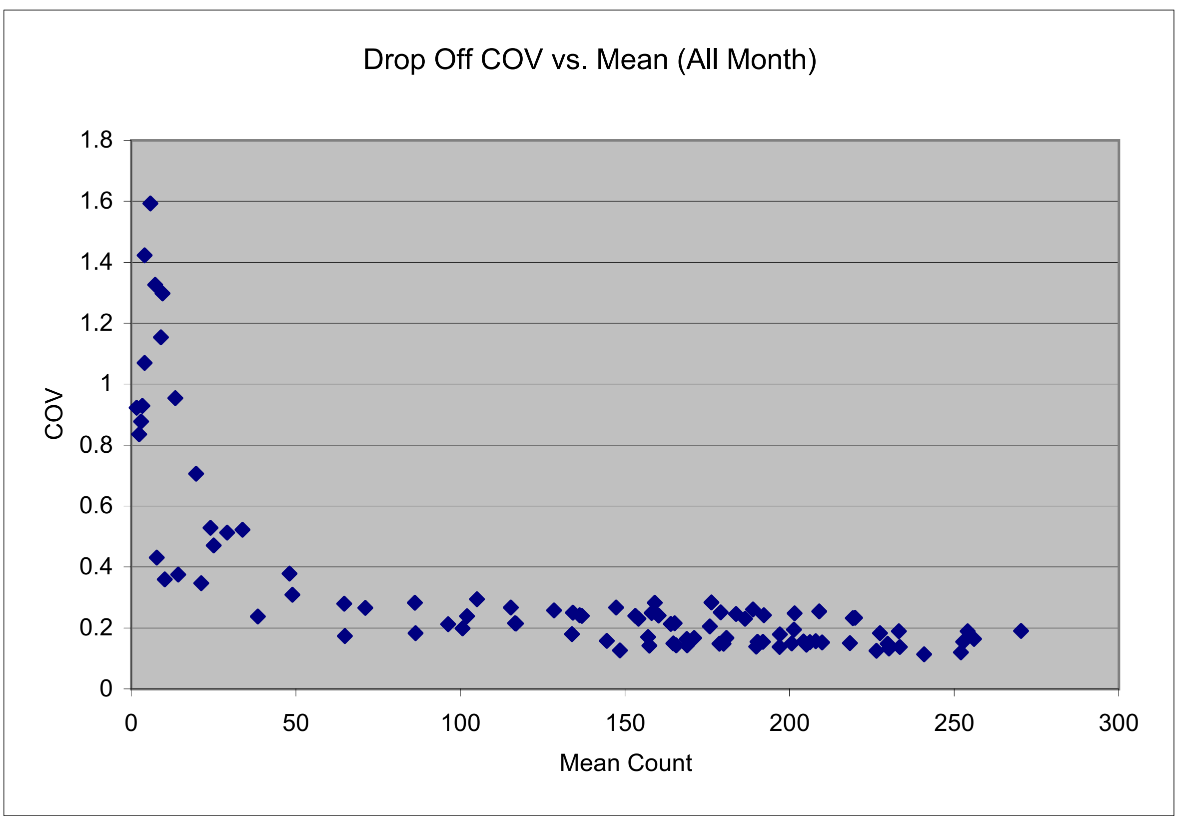

Figure 69: Drop Off COV vs. Mean (All Month)

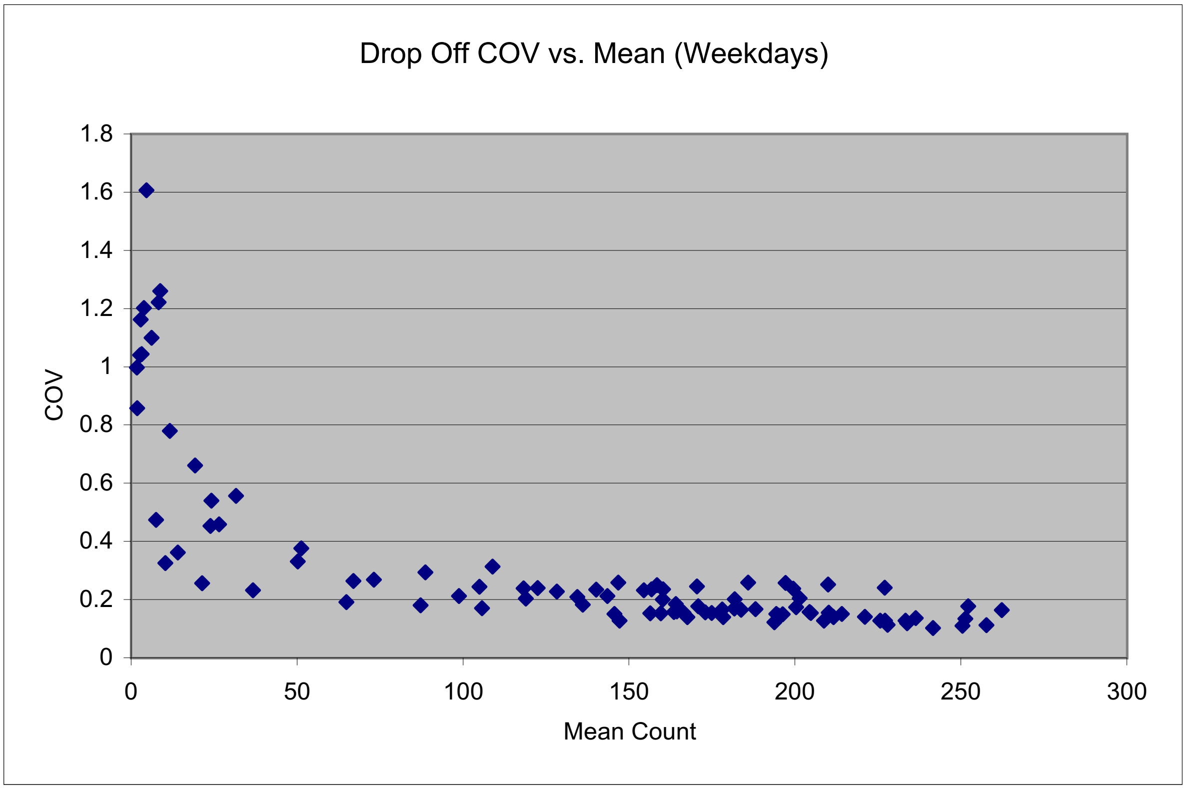

Figure 70: Drop Off COV vs. Mean (Weekdays)

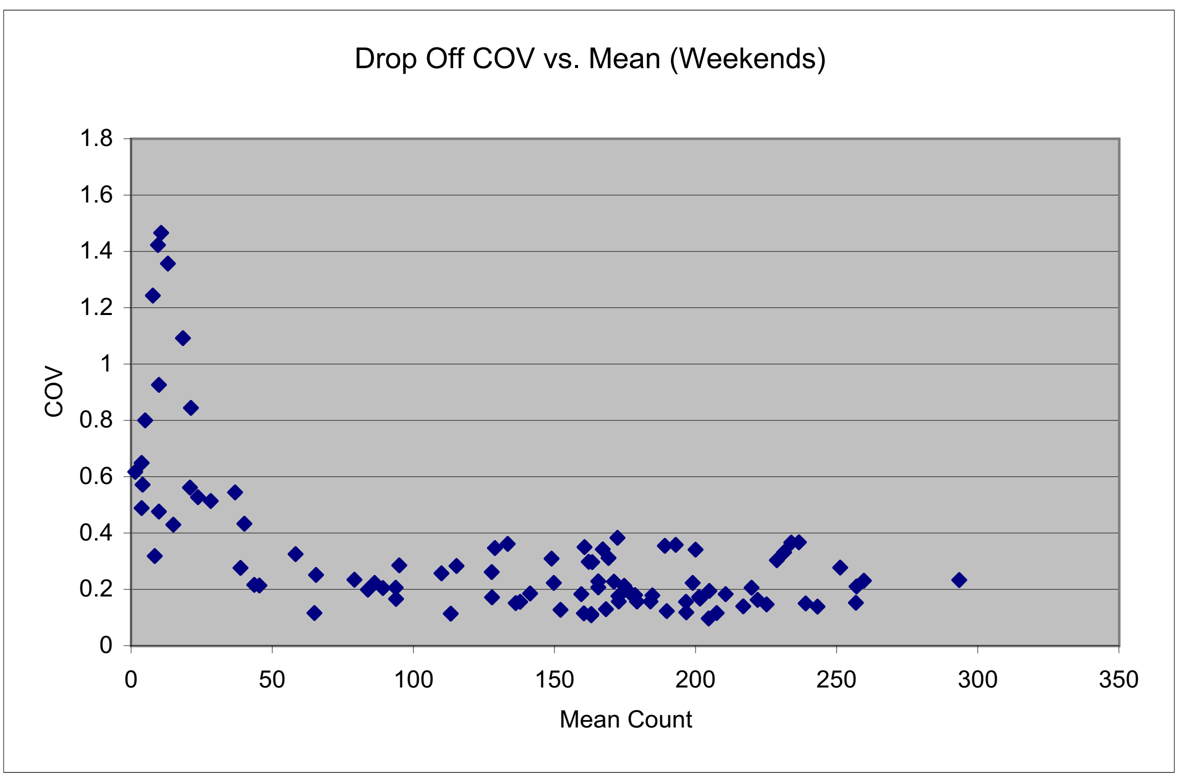

Figure 71: Drop Off COV vs. Mean (Weekends)

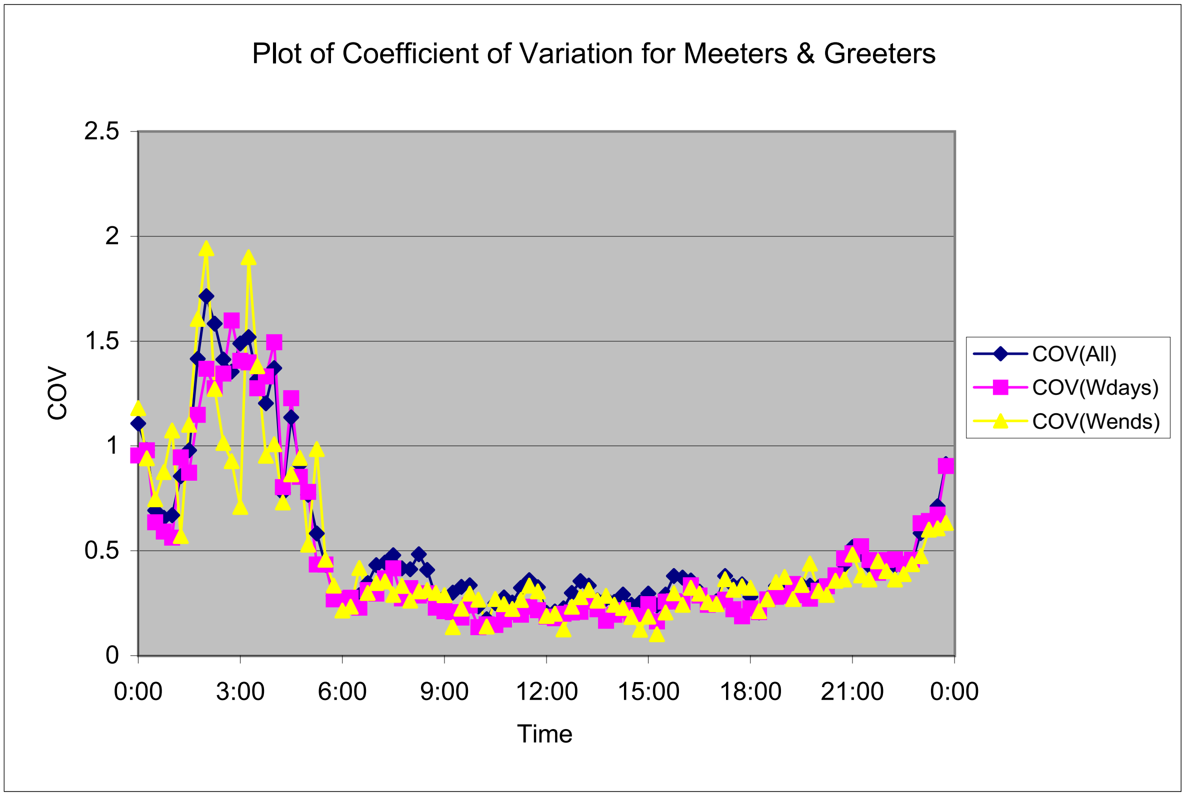

Figure 72: Plot of Coefficient of Variation for Meeters & Greeters

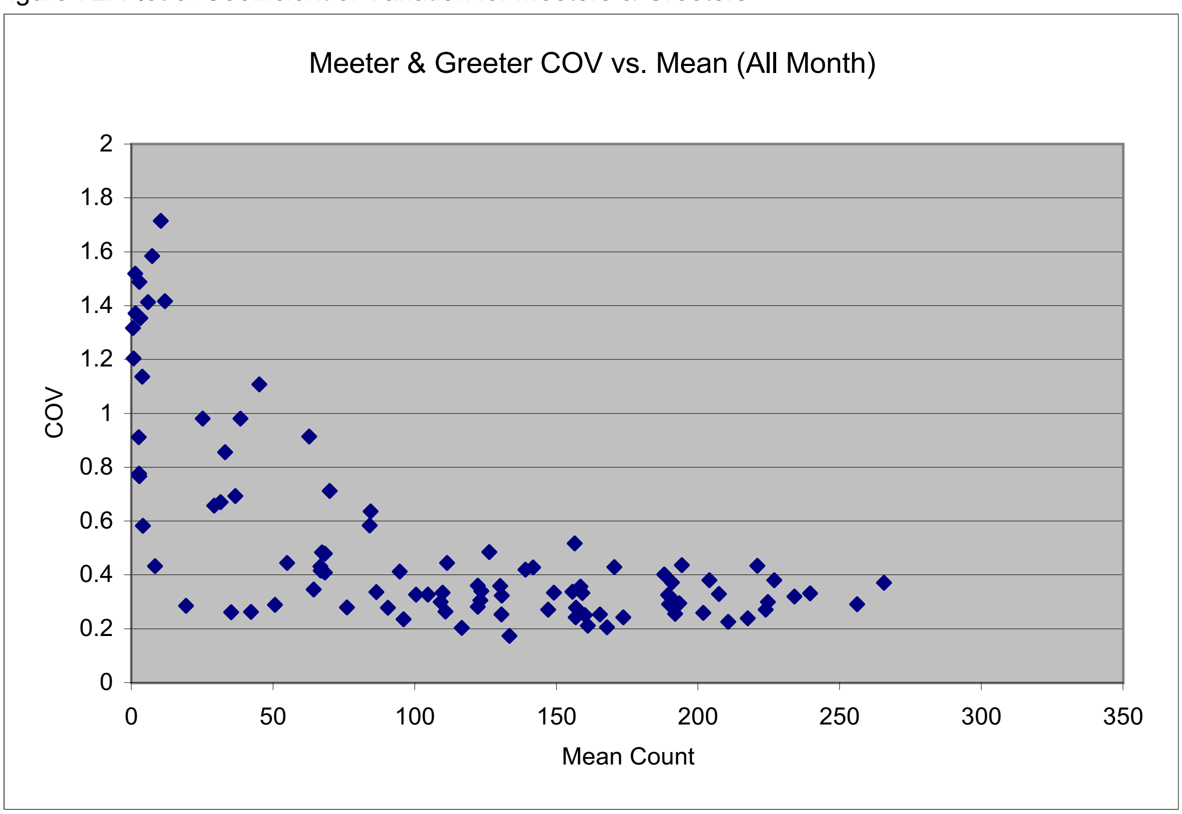

Figure 73: Meeter & Greeter COV vs. Mean (All Month)

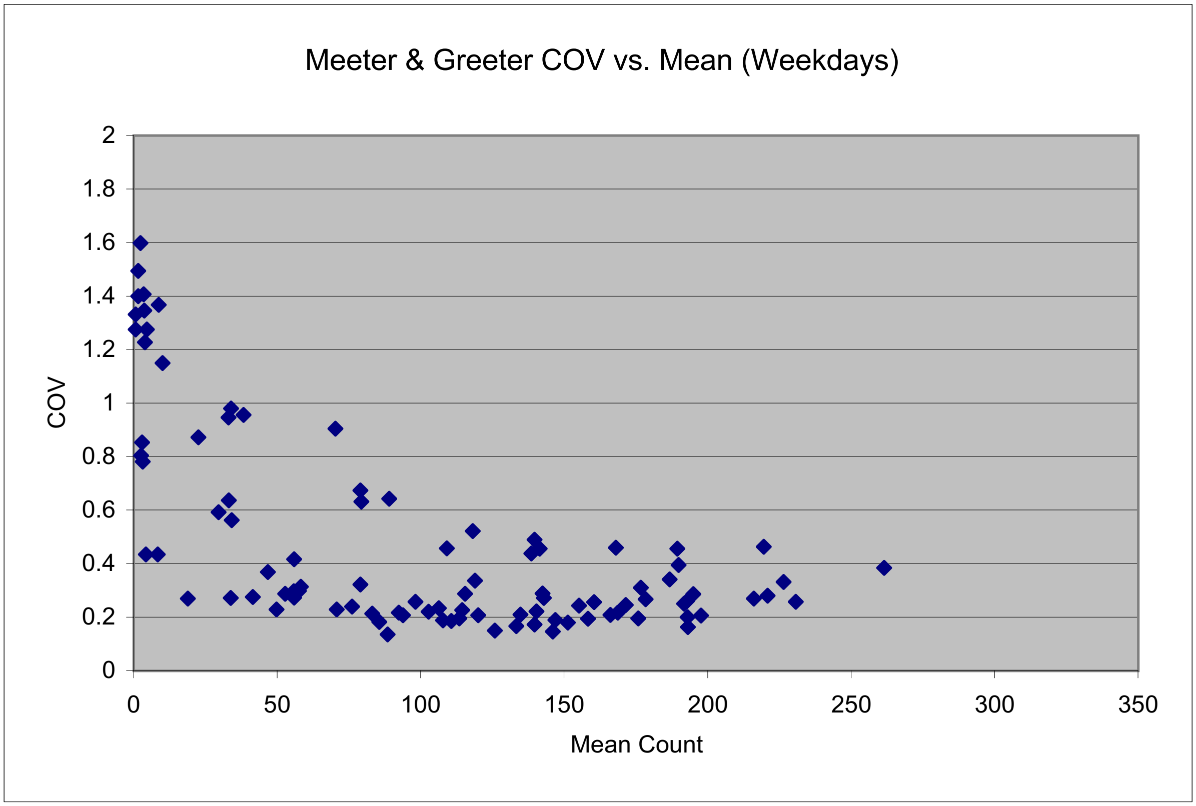

Figure 74: Meeter & Greeter COV vs. Mean (Weekdays)

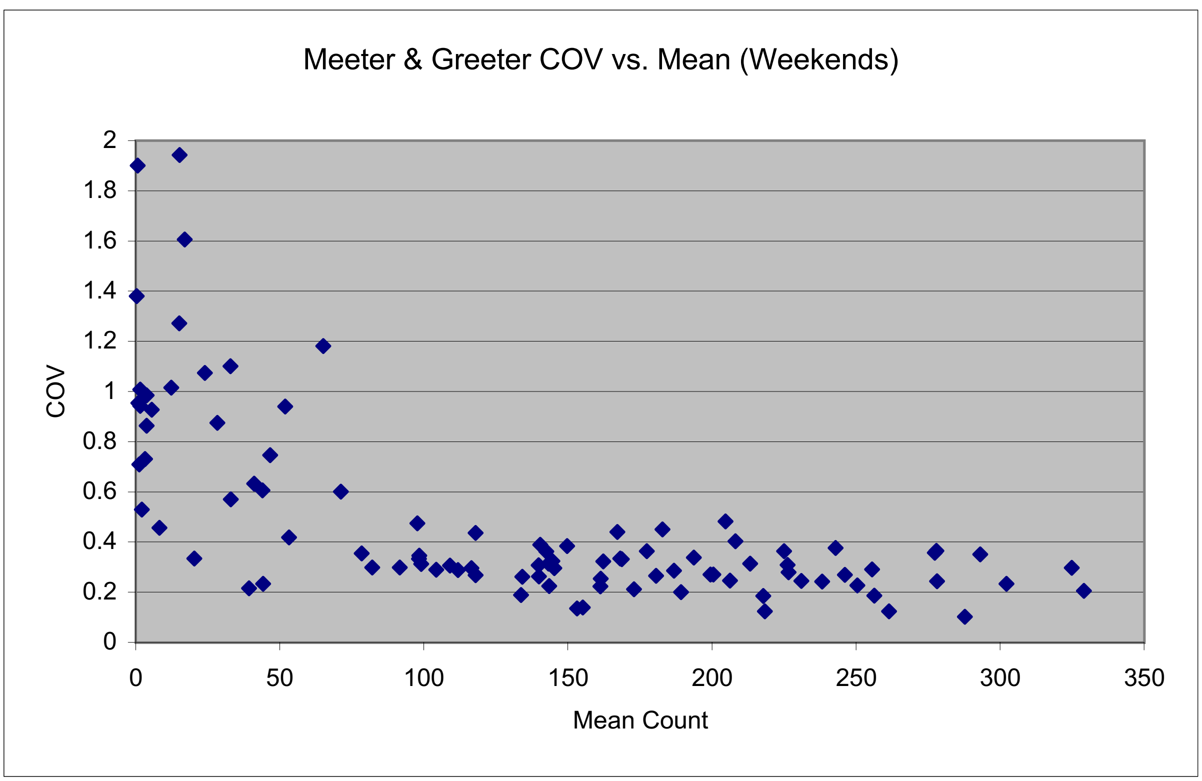

Figure 75: Meeter & Greeter COV vs. Mean (Weekends)

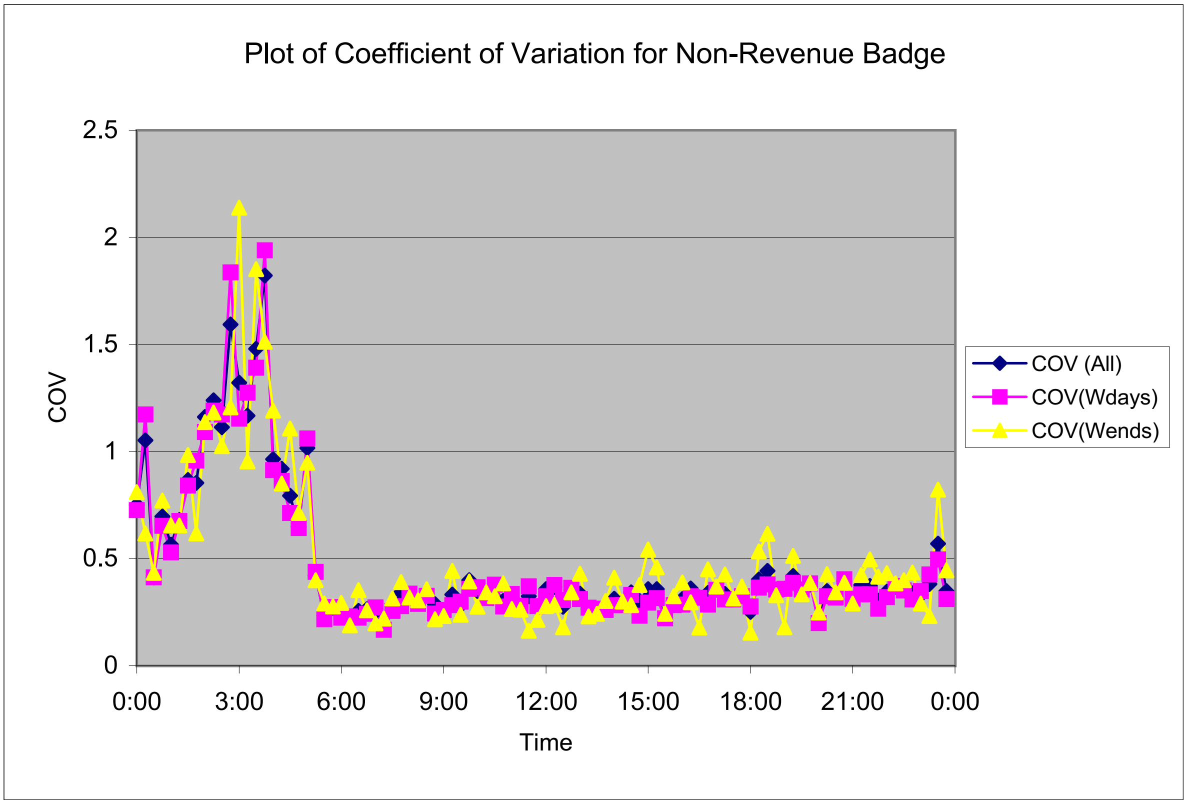

Figure 76: Plot of Coefficient of Variation for Non-Revenue Badge

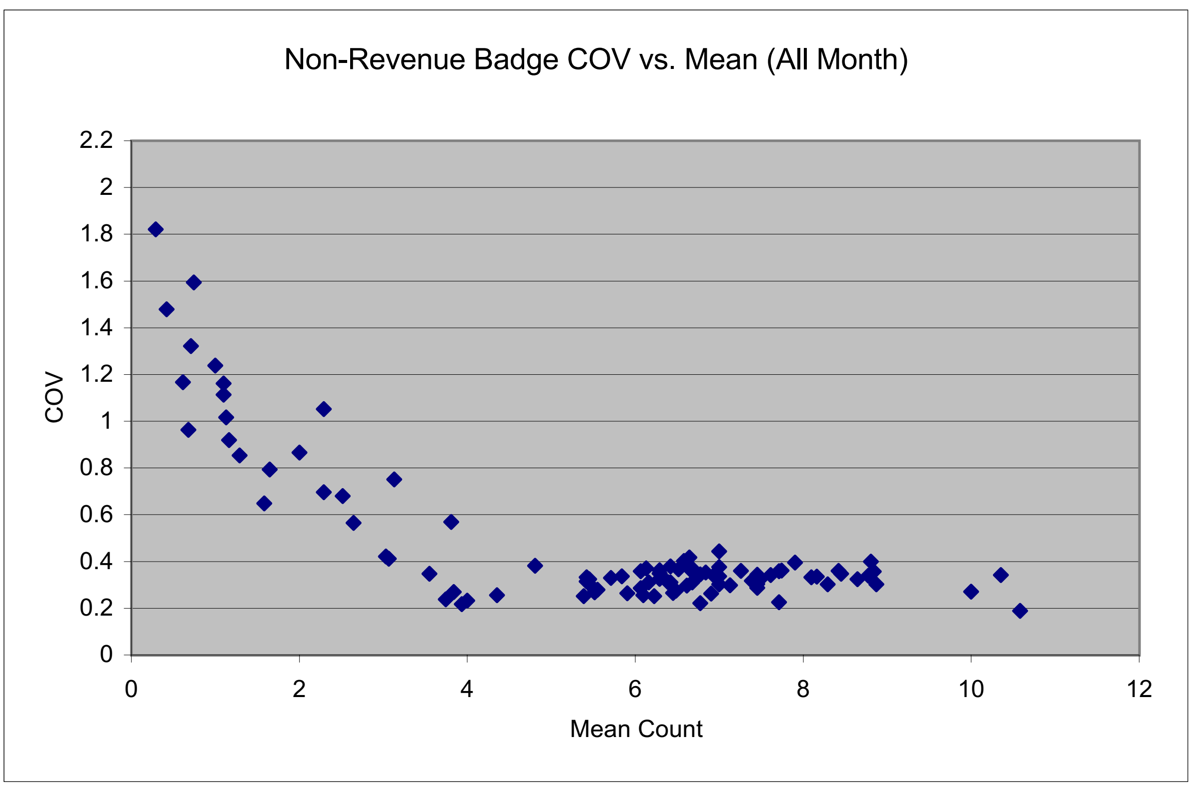

Figure 77: Non-Revenue Badge COV vs. Mean (All Month)

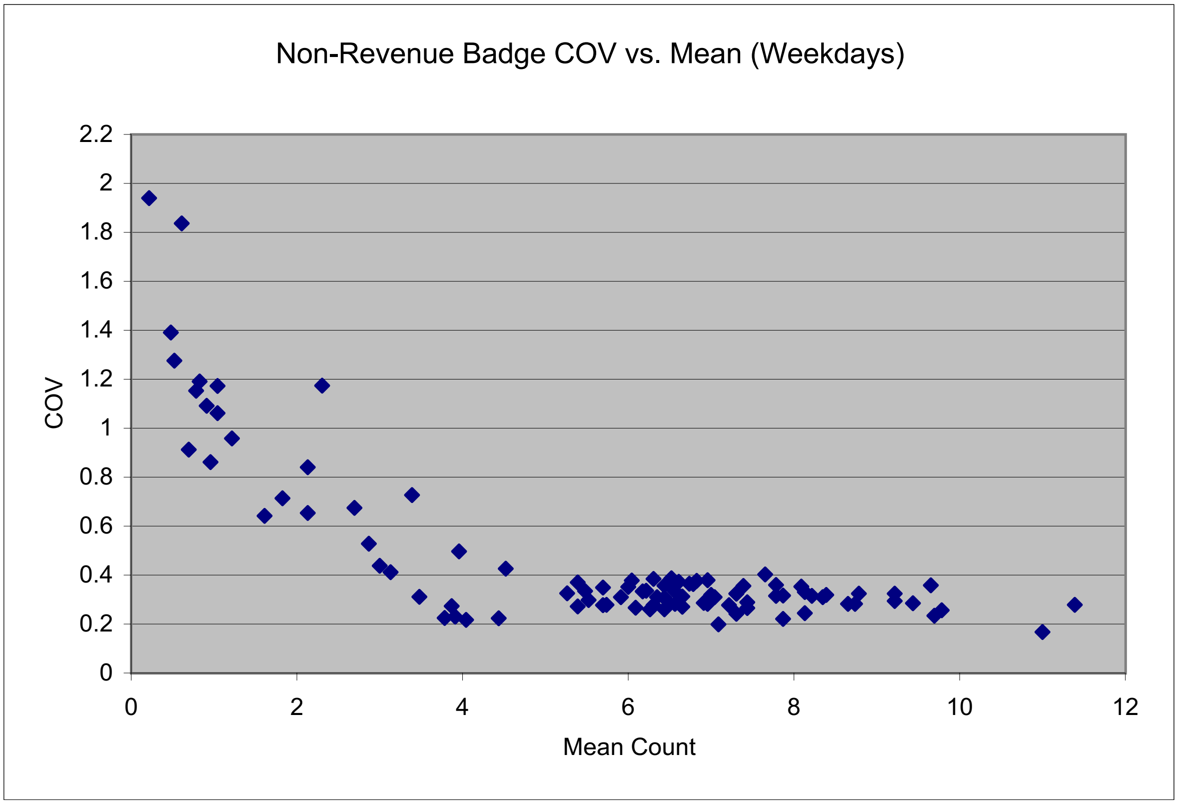

Figure 78: Non-Revenue Badge COV vs. Mean (Weekdays)

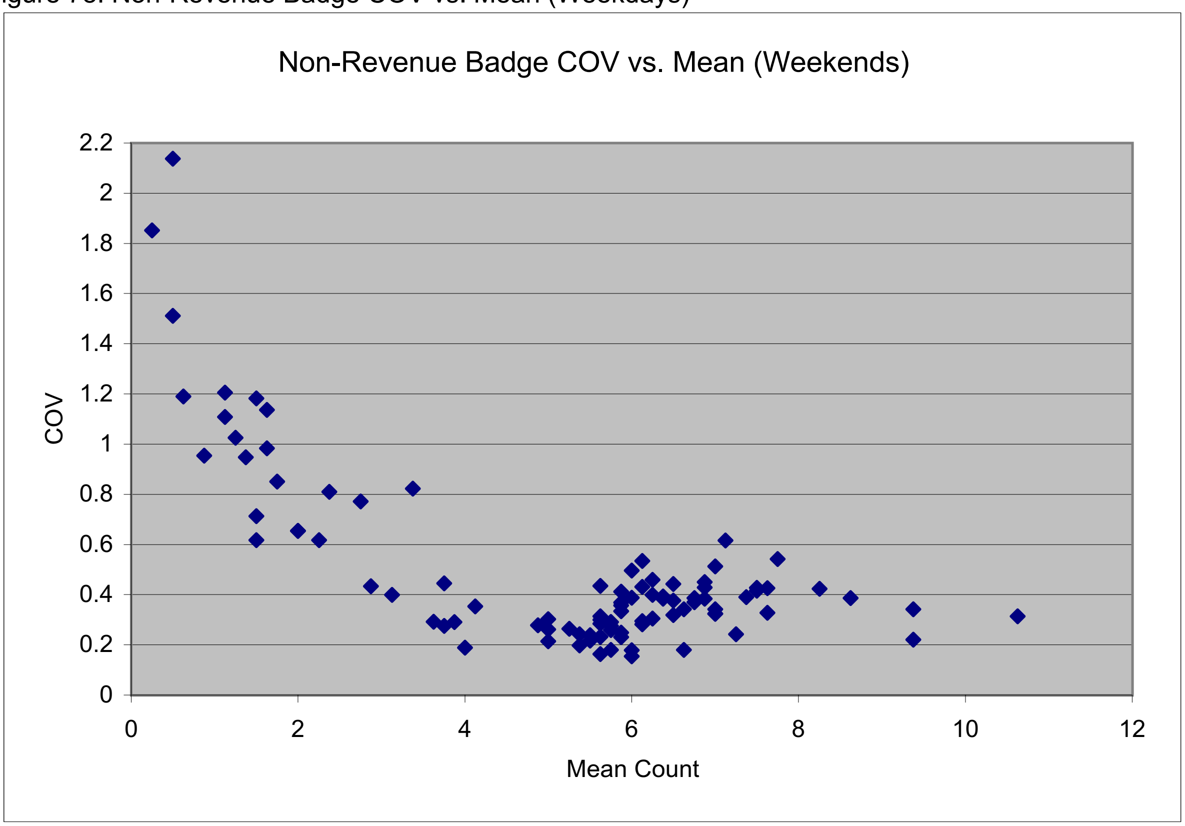

Figure 79: Non-Revenue Badge COV vs. Mean (Weekends)

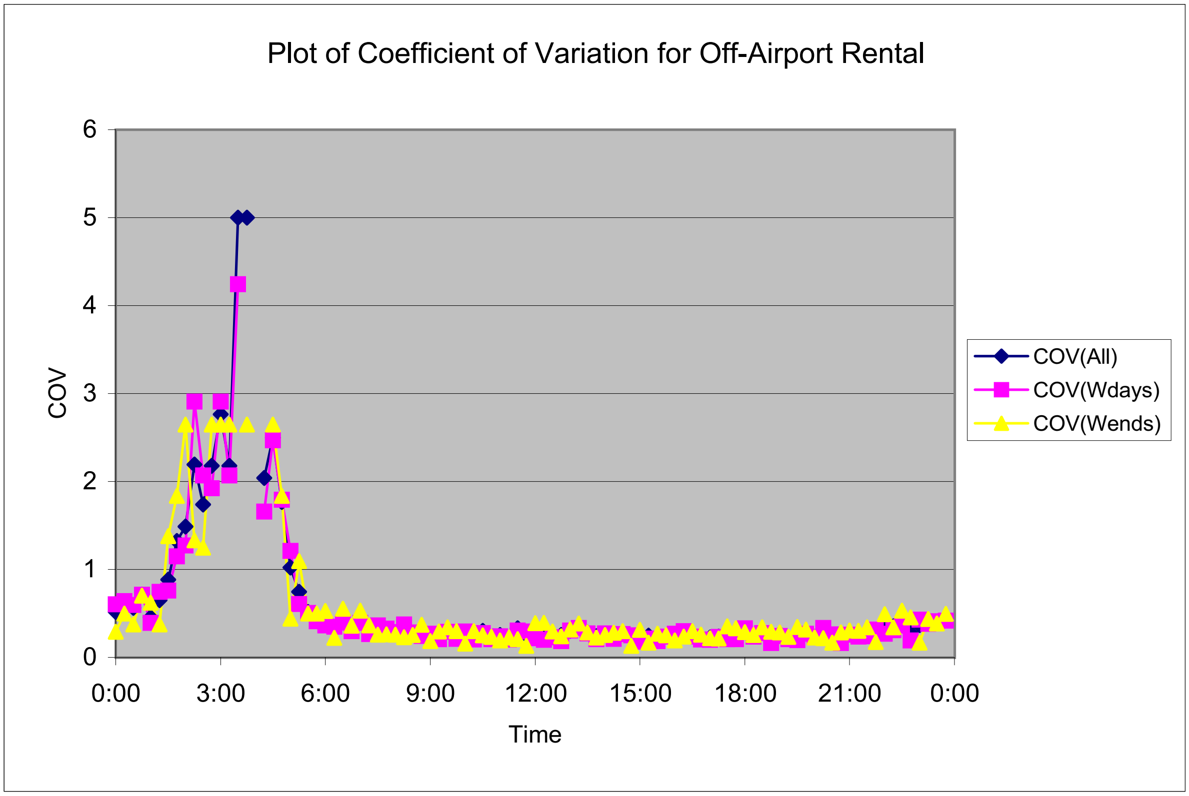

Figure 80: Plot of Coefficient of Variation for Off-Airport Rental

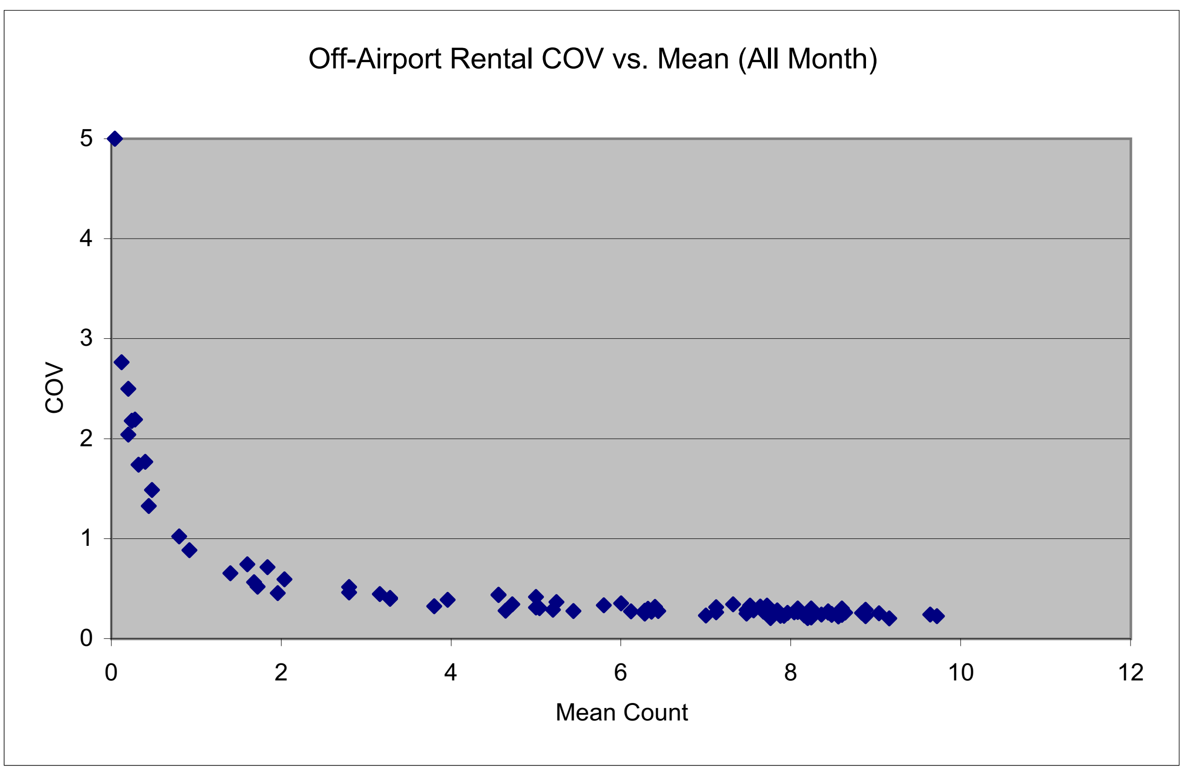

Figure 81: Off-Airport Rental COV vs. Mean (All Month)

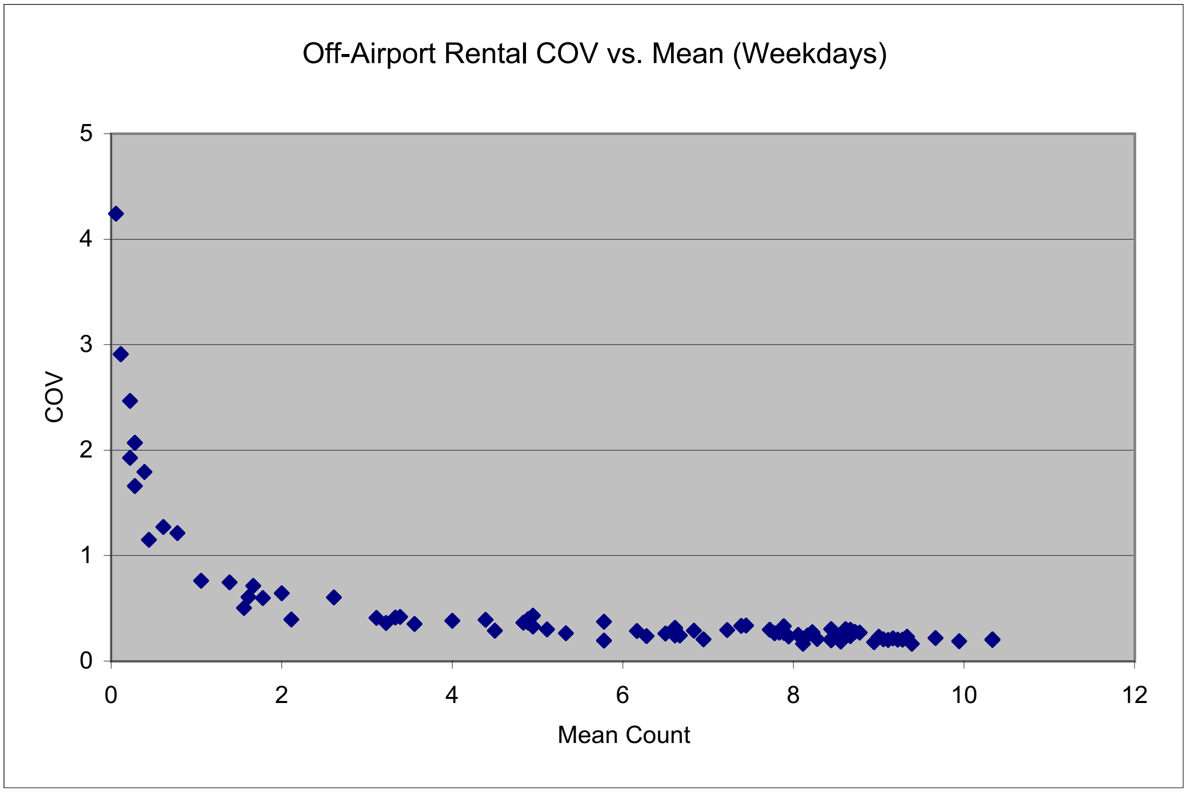

Figure 82: Off-Airport Rental COV vs. Mean (Weekdays)

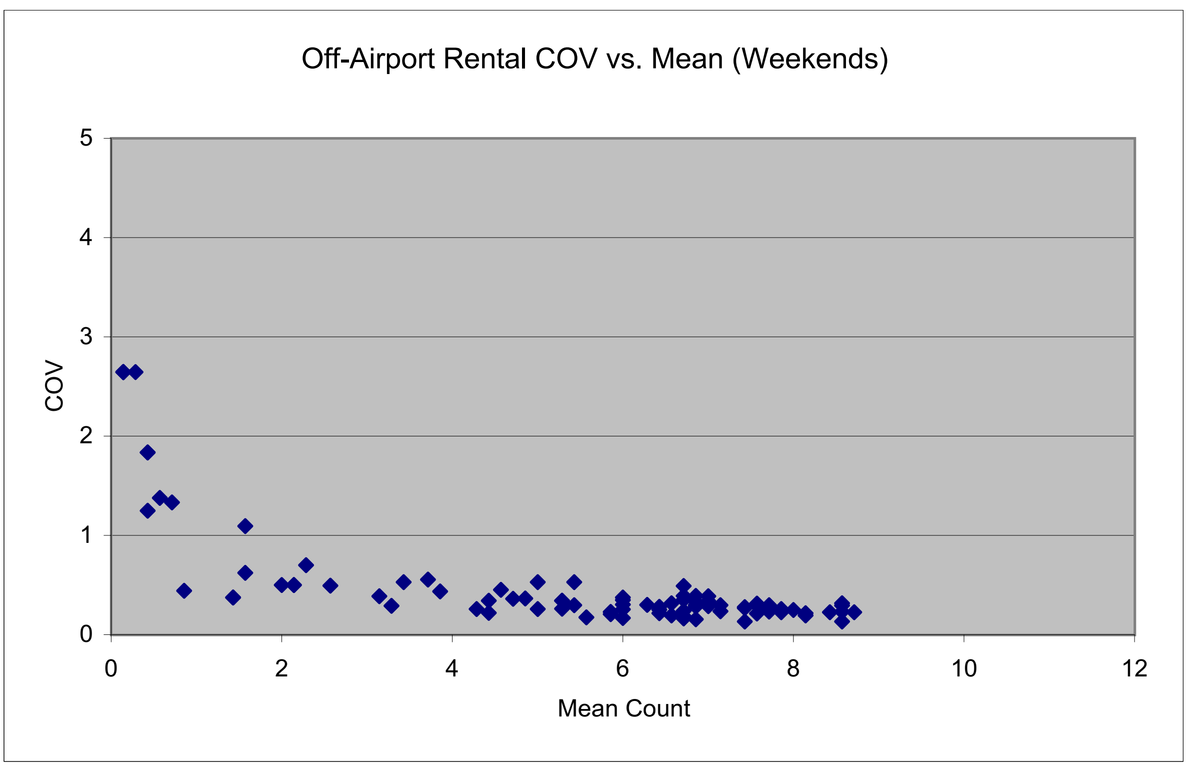

Figure 83: Off-Airport Rental COV vs. Mean (Weekends)

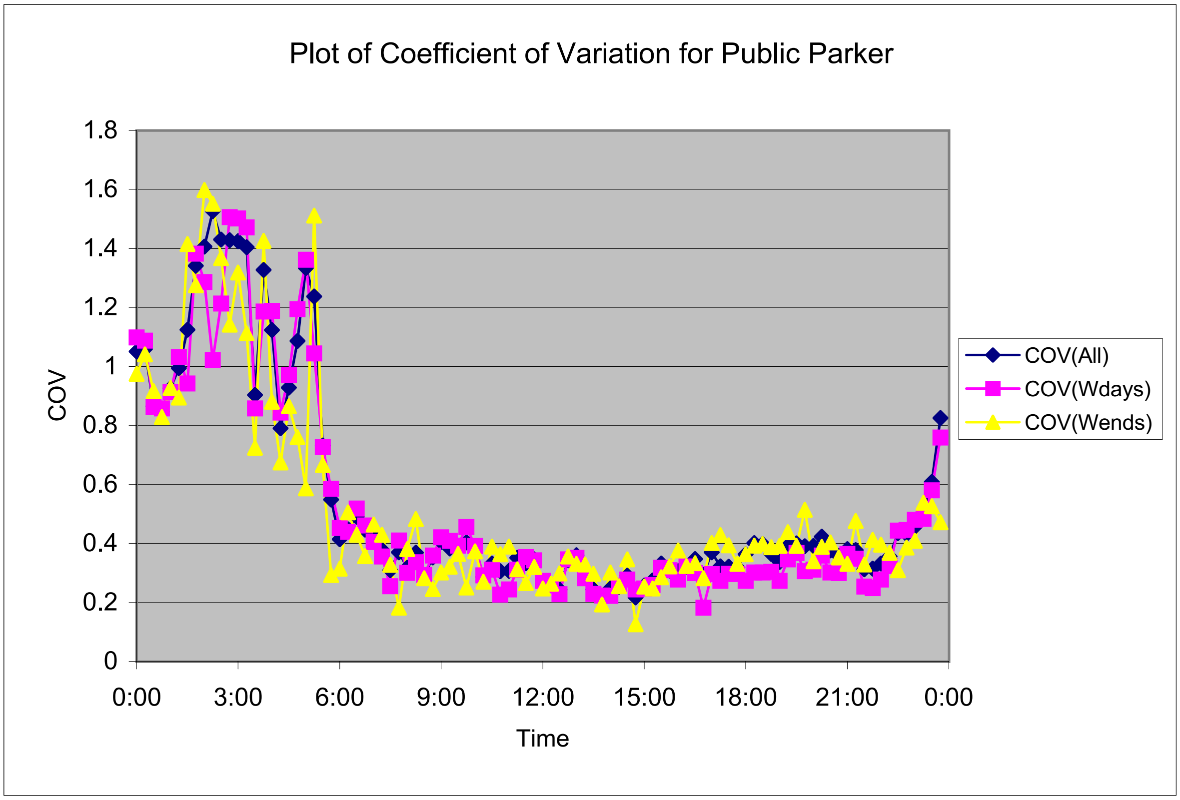

Figure 84:Plot of Coefficient of Variation for Public Parker

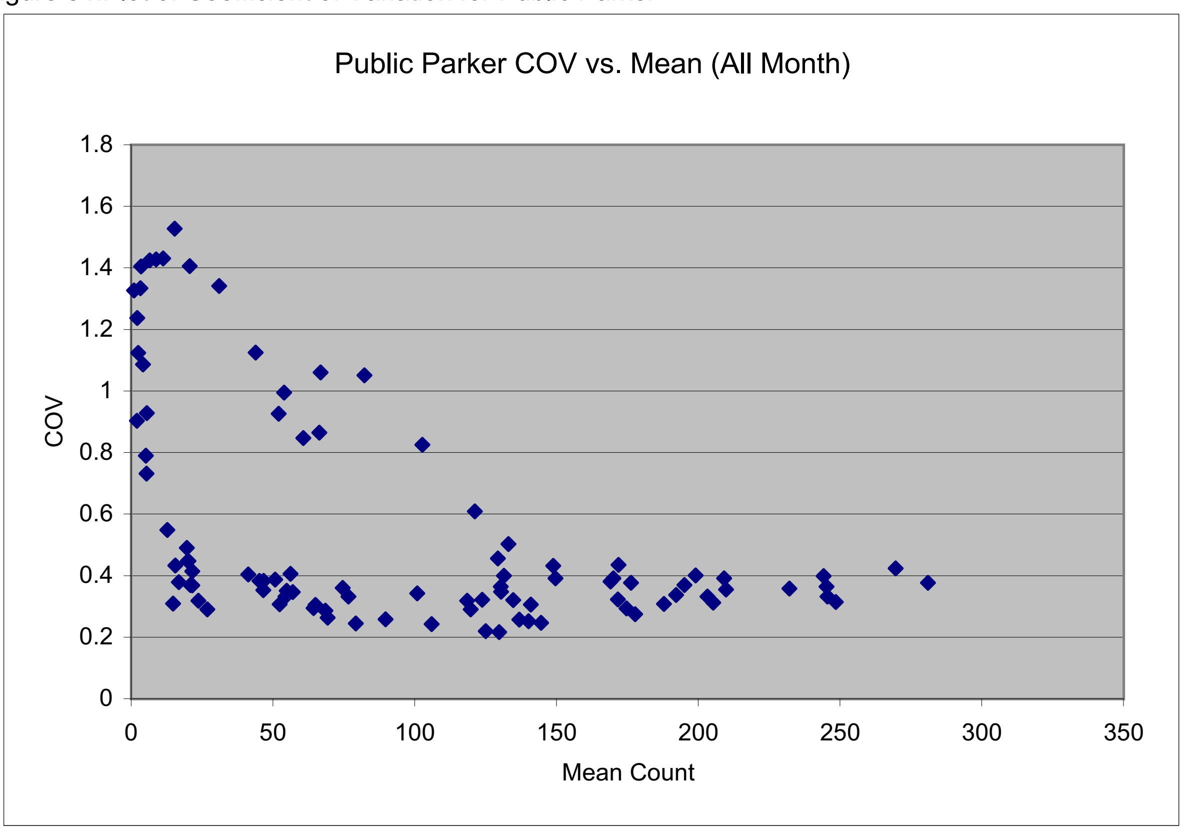

Figure 85: Public Parker COV vs. Mean (All Month)

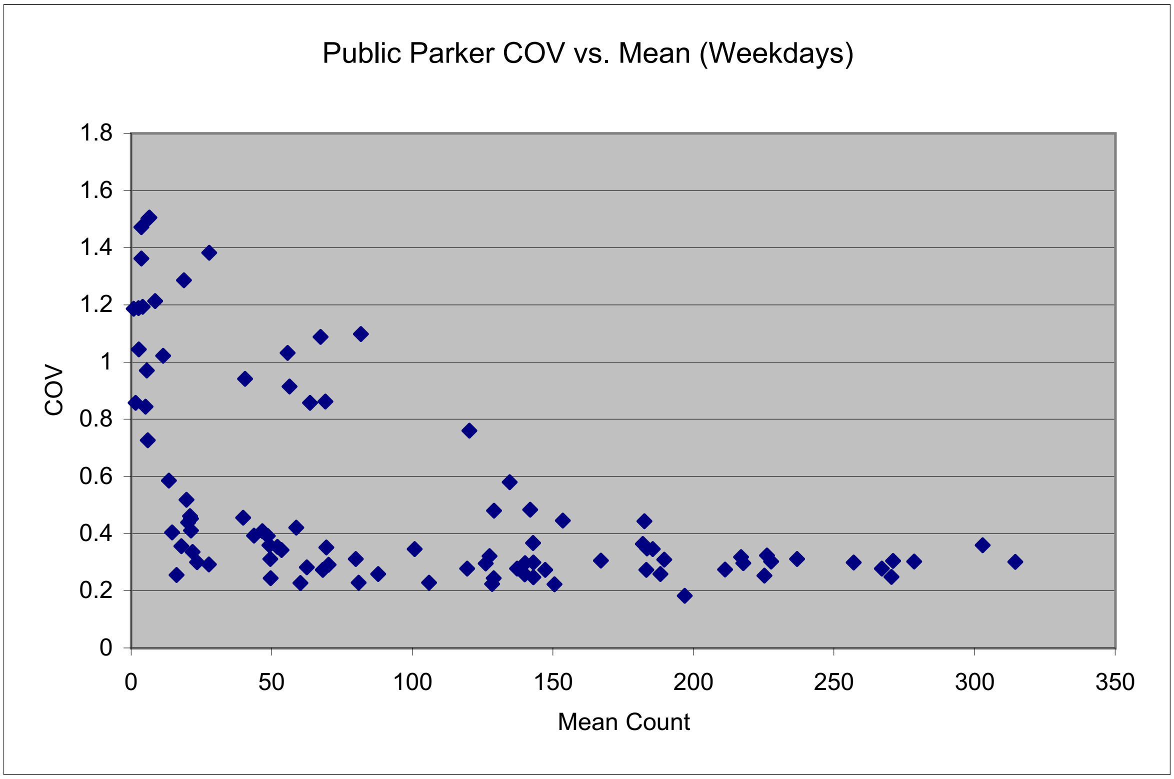

Figure 86: Public Parker COV vs. Mean (Weekdays)

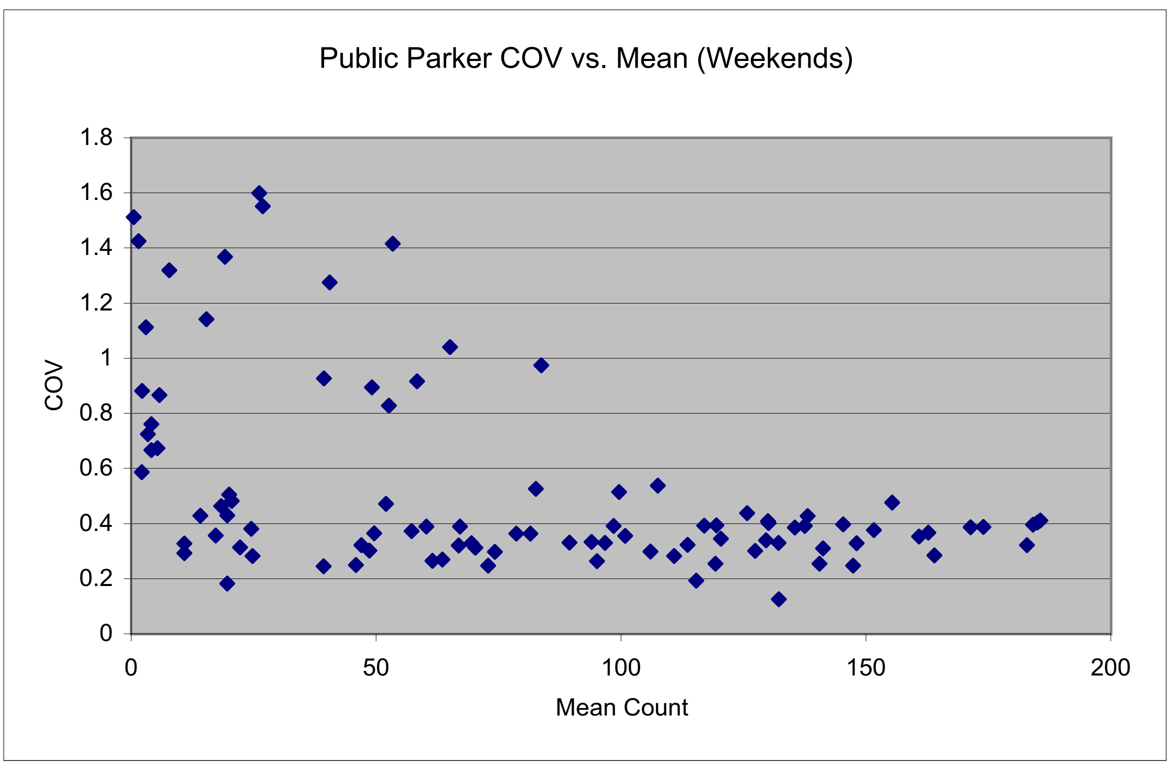

Figure 87: Public Parker COV vs. Mean (Weekends)

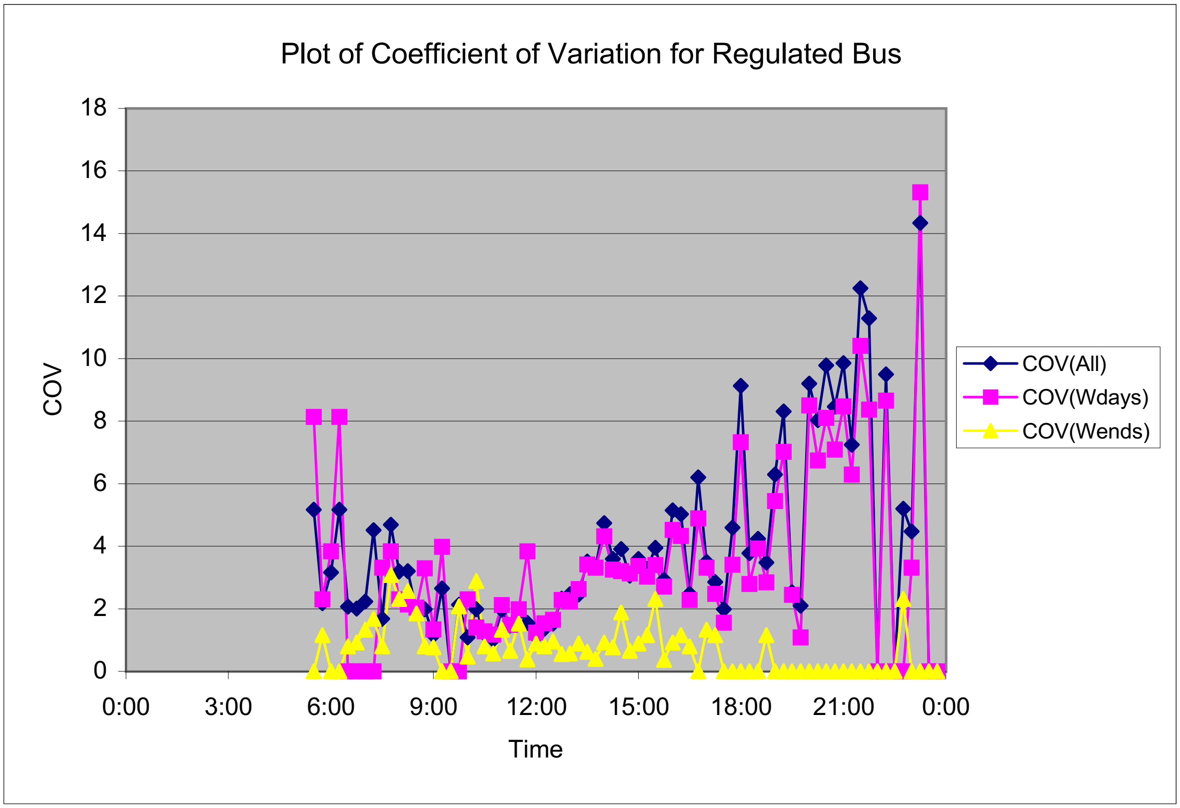

Figure 88: Plot of Coefficient of Variation for Regulated Bus

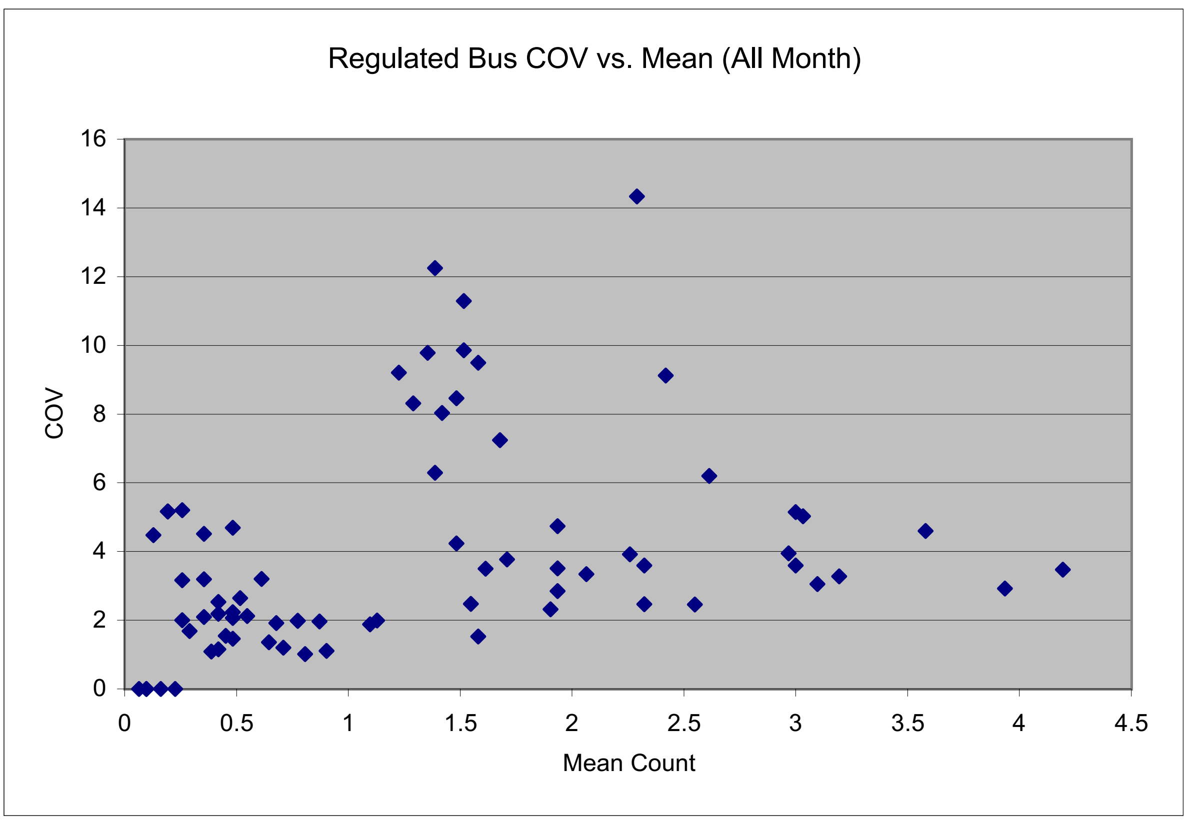

Figure 89: Regulated Bus COV vs. Mean (All Month)

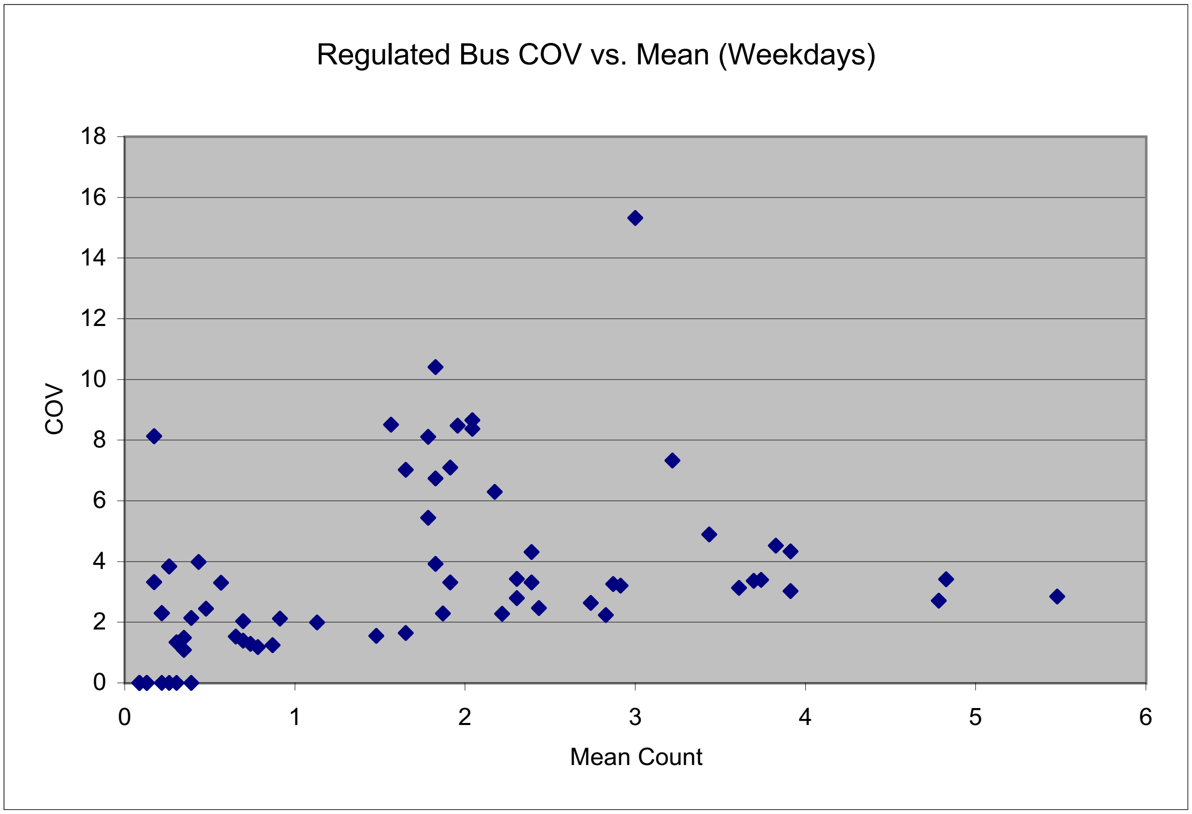

Figure 90: Regulated Bus COV vs. Mean (Weekdays)

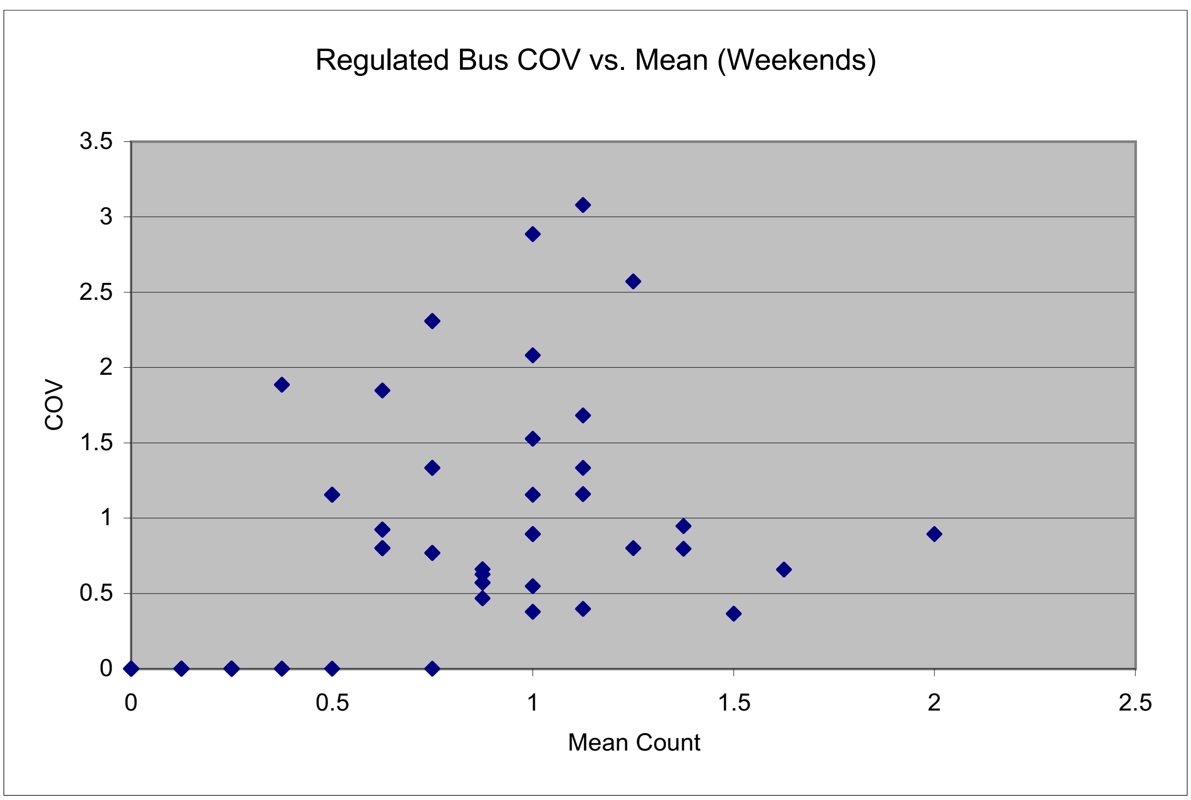

Figure 91: Regulated Bus COV vs. Mean (Weekends)

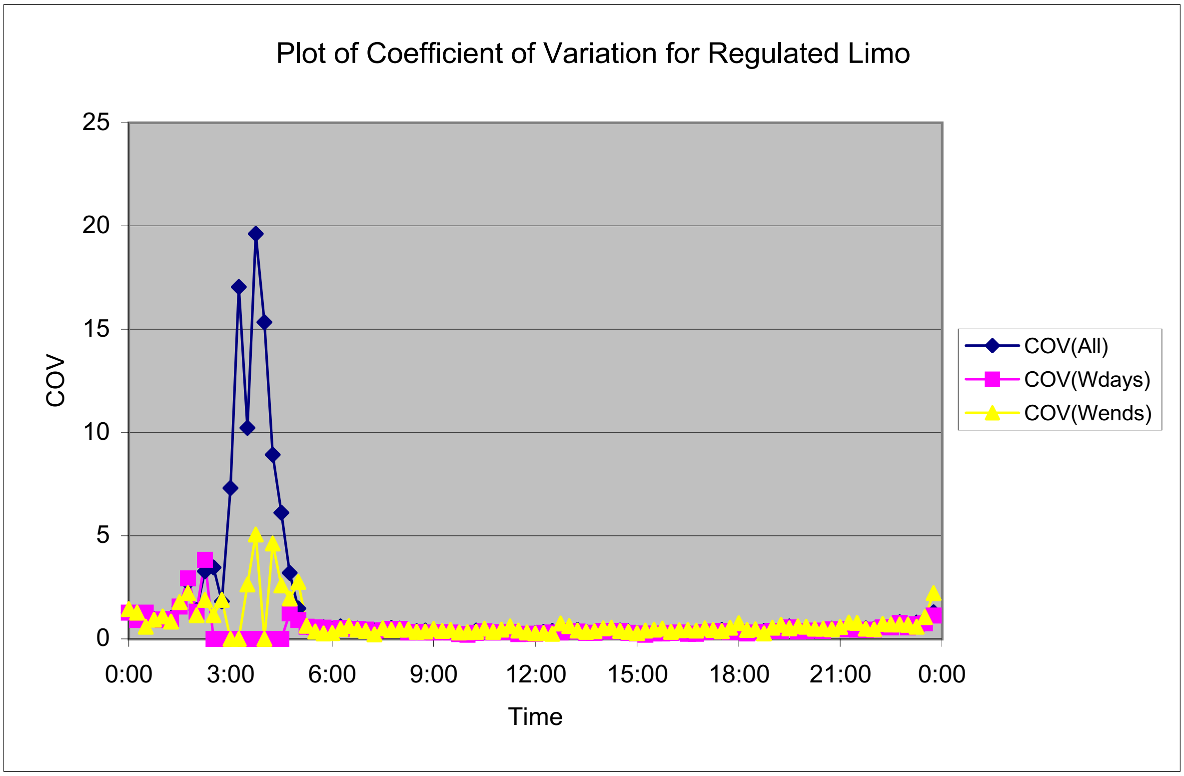

Figure 92: Plot of Coefficient of Variation for Regulated Limo

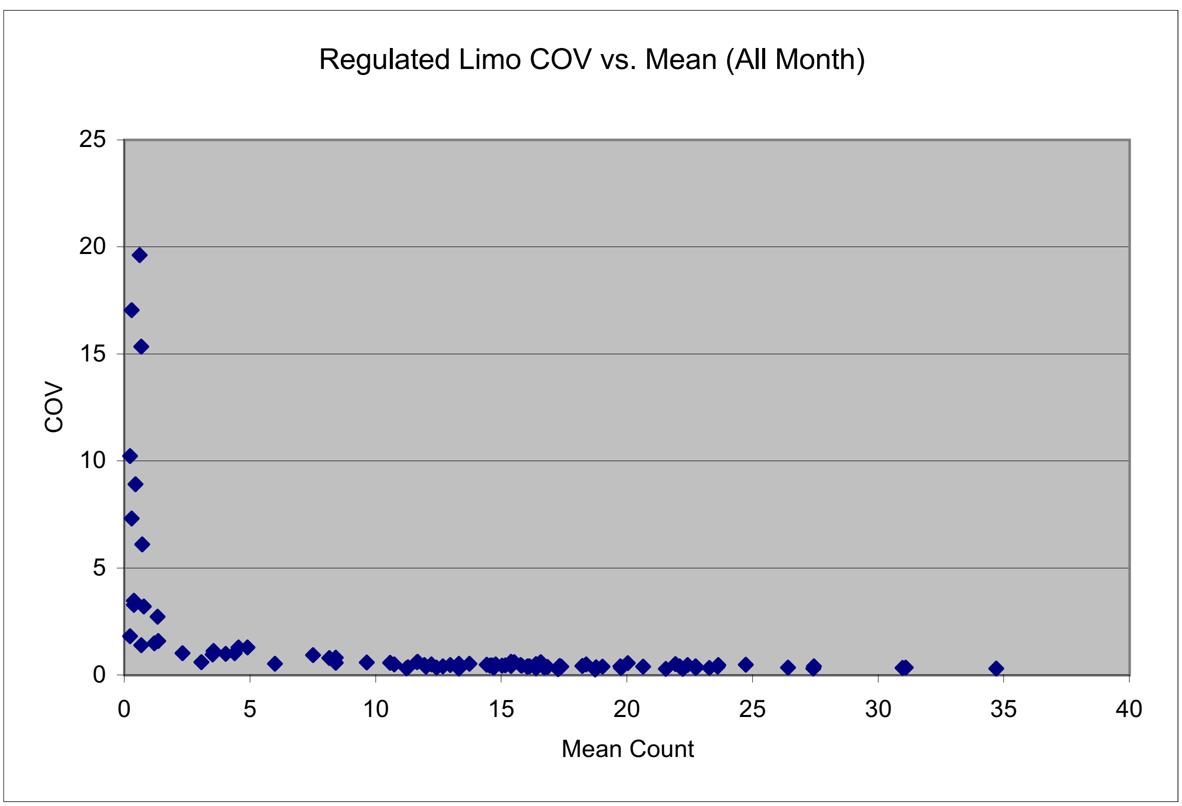

Figure 93: Regulated Limo COV vs. Mean (All Month)

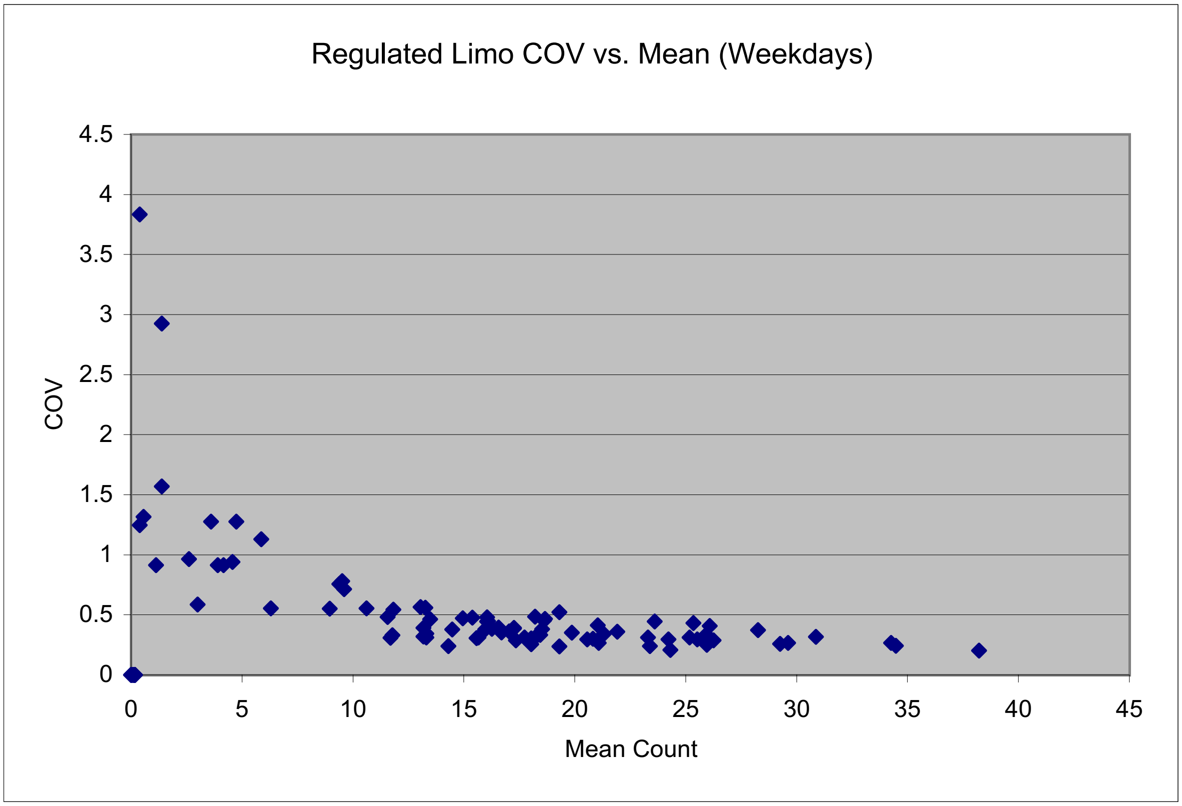

Figure 94: Regulated Limo COV vs. Mean (Weekdays)

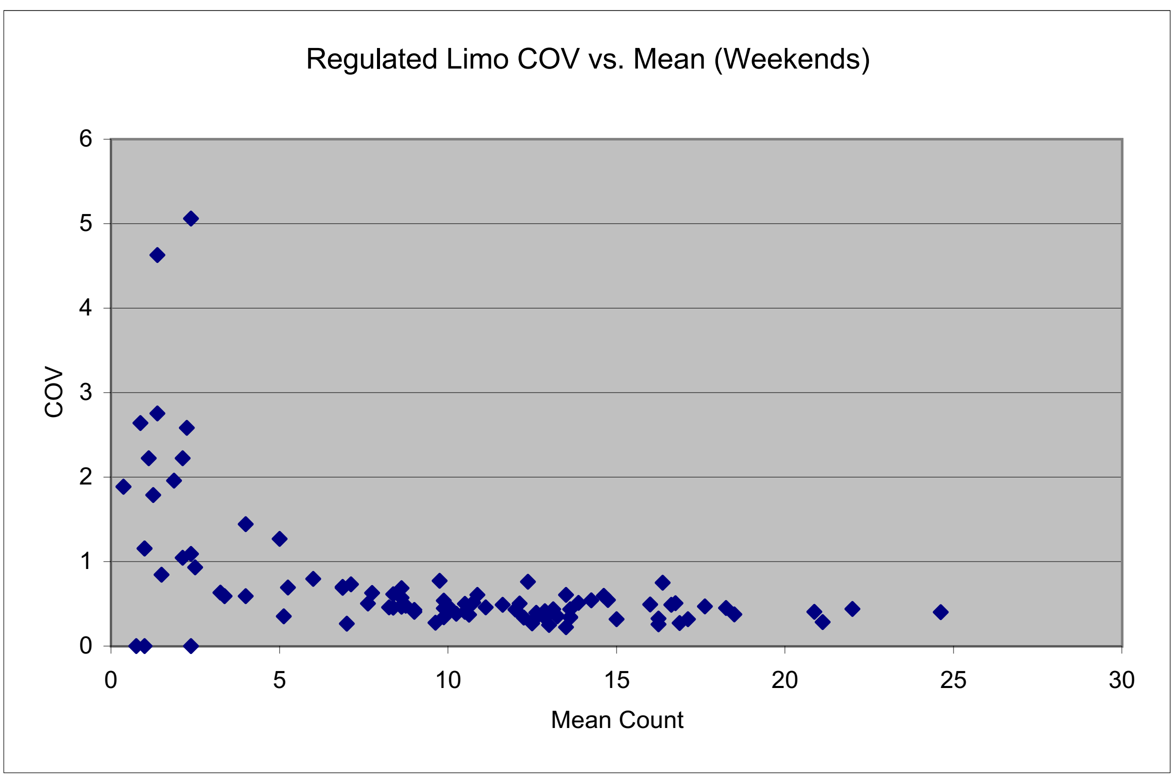

Figure 95: Regulated Limo COV vs. Mean (Weekends)

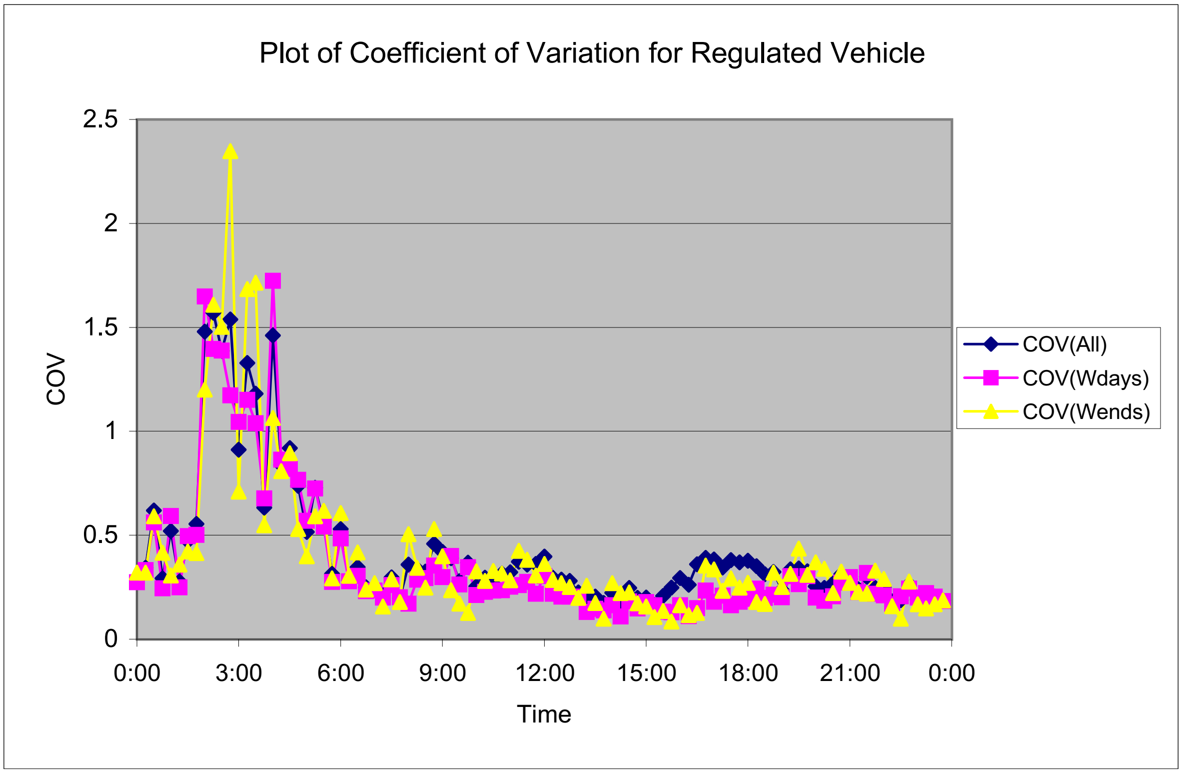

Figure 96: Plot of Coefficient of Variation for Regulated Vehicle

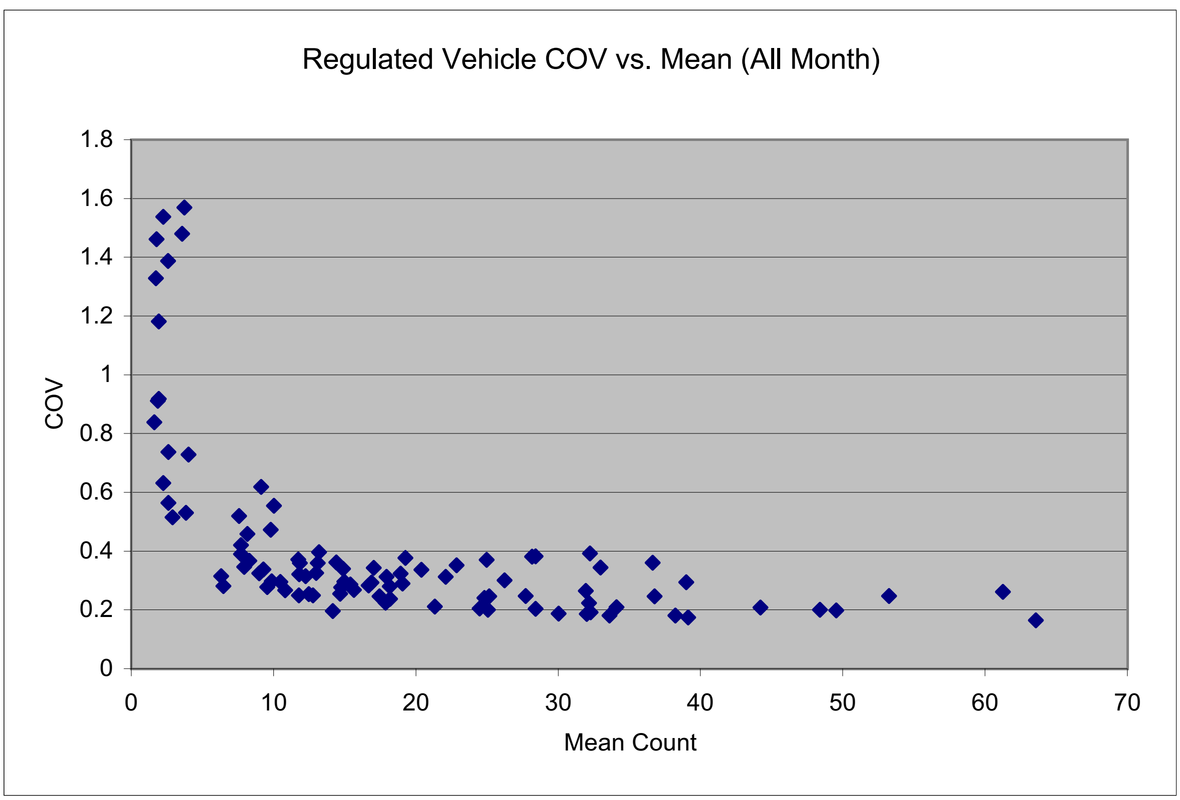

Figure 97: Regulated Vehicle COV vs. Mean (All Month)

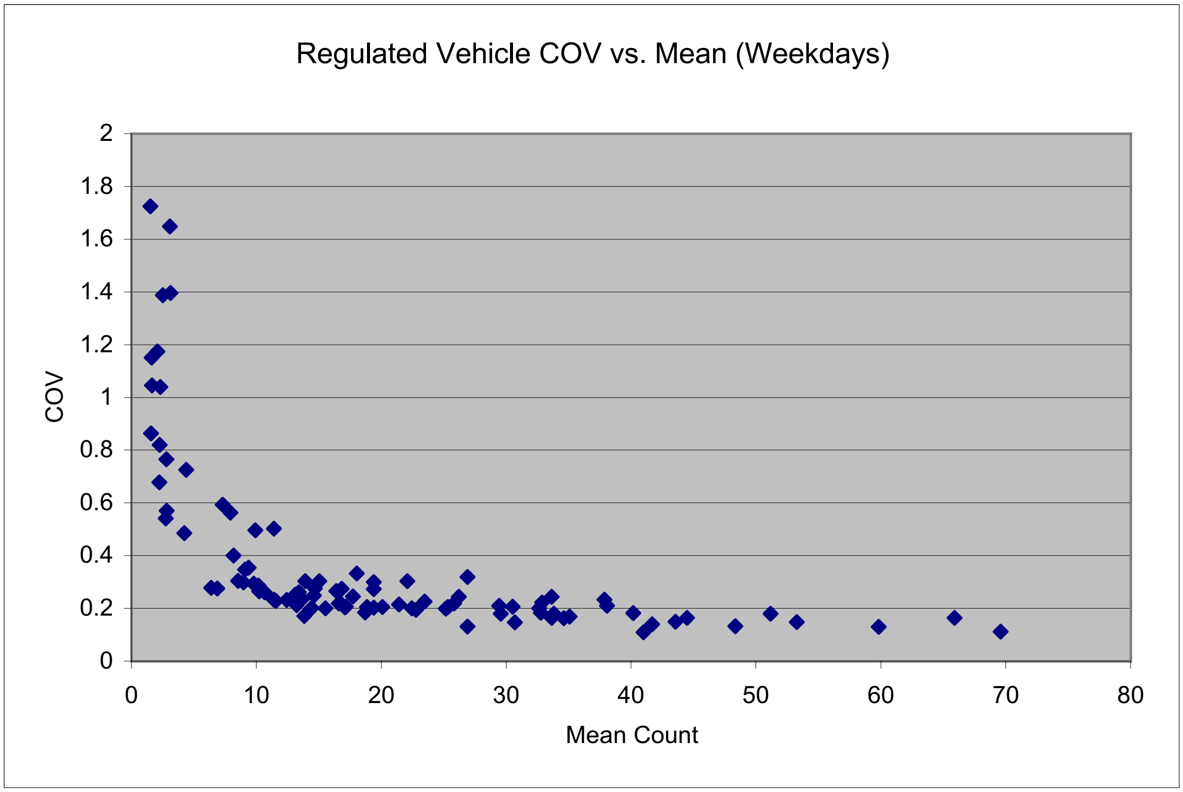

Figure 98: Regulated Vehicle COV vs. Mean (Weekdays)

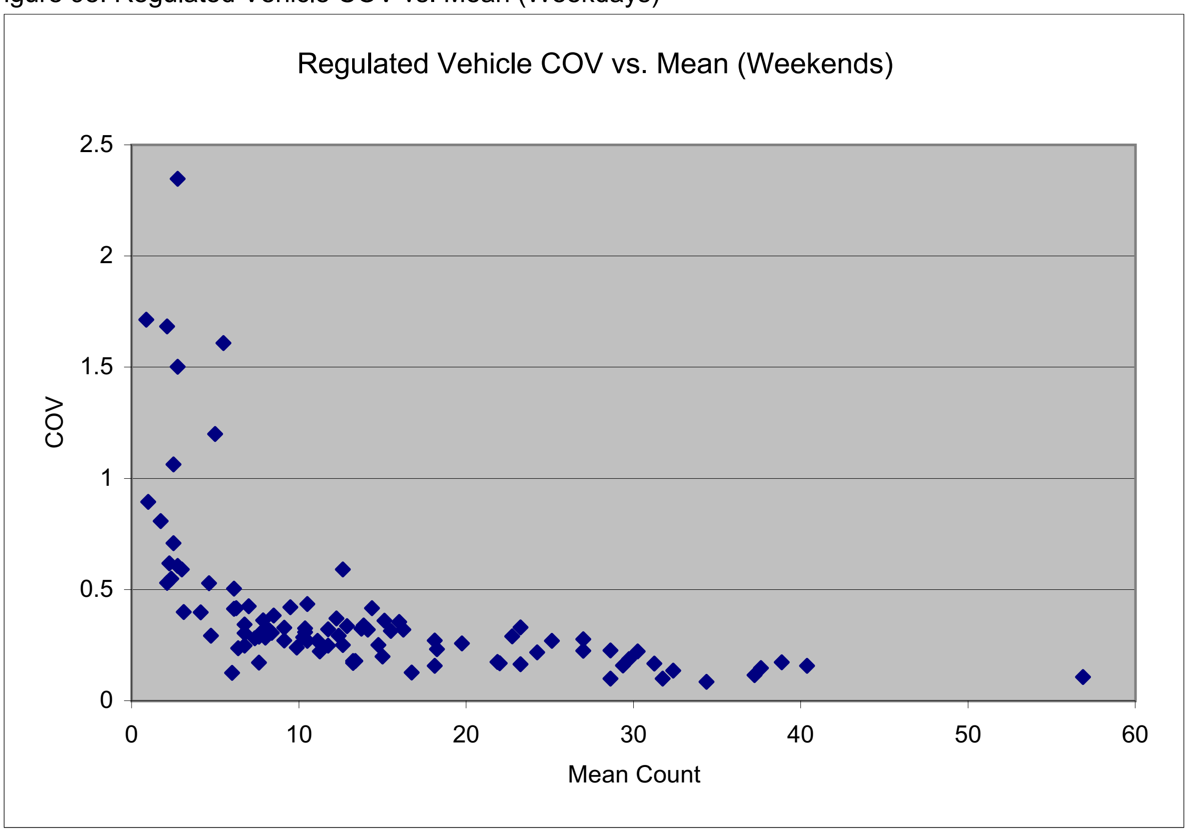

Figure 99: Regulated Vehicle COV vs. Mean (Weekends)

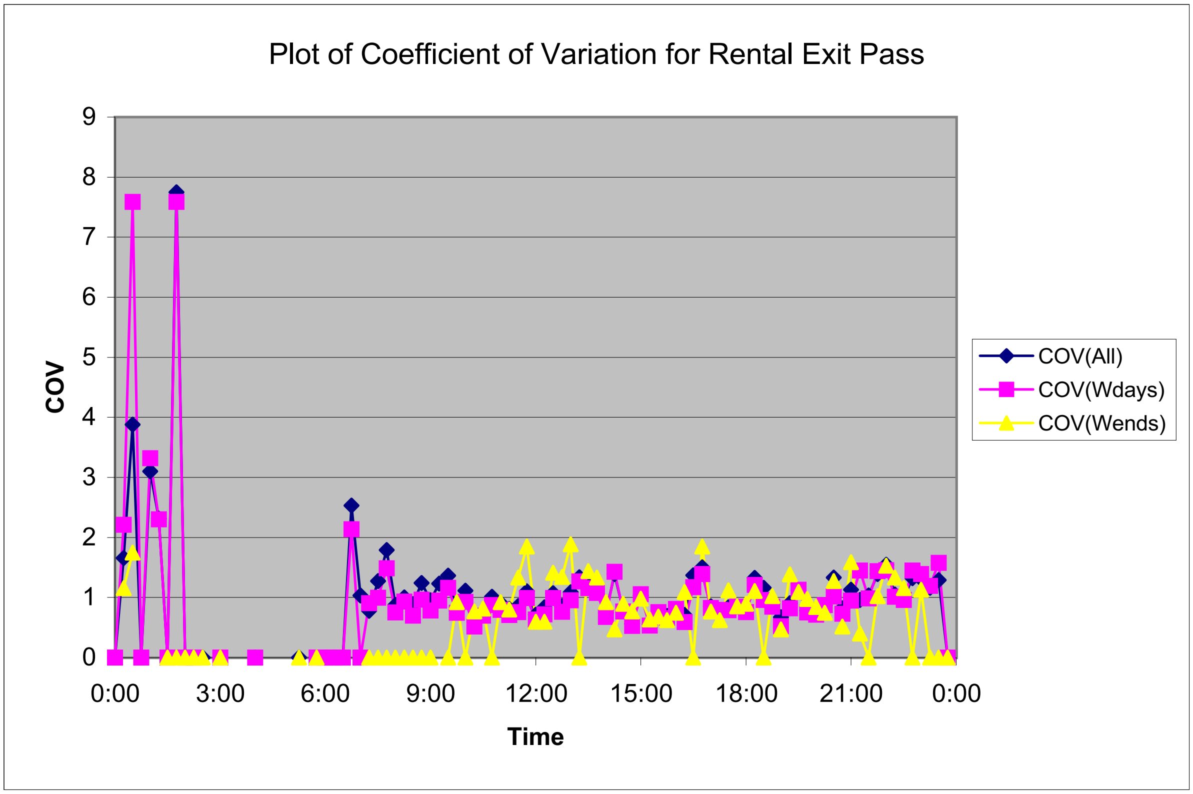

Figure 100: Plot of Coefficient of Variation for Rental Exit Pass

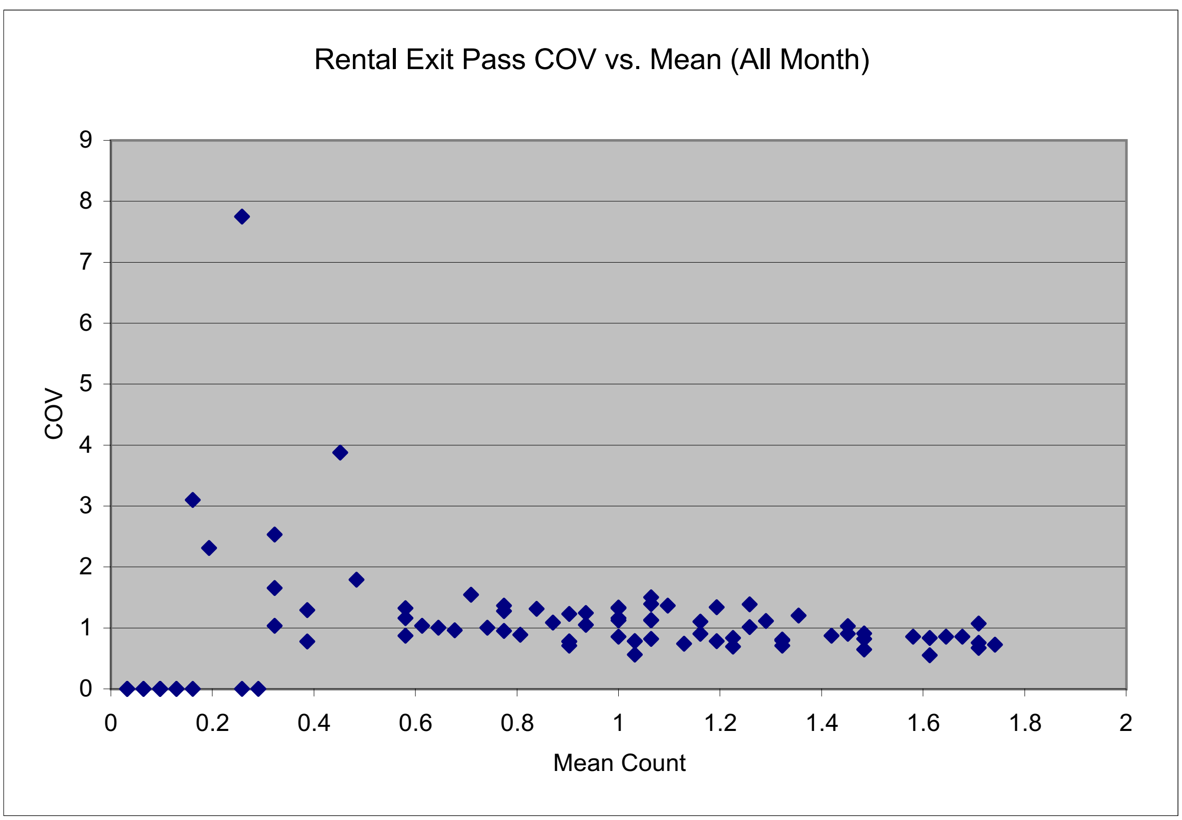

Figure 101: Rental Exit Pass COV vs. Mean (All Month)

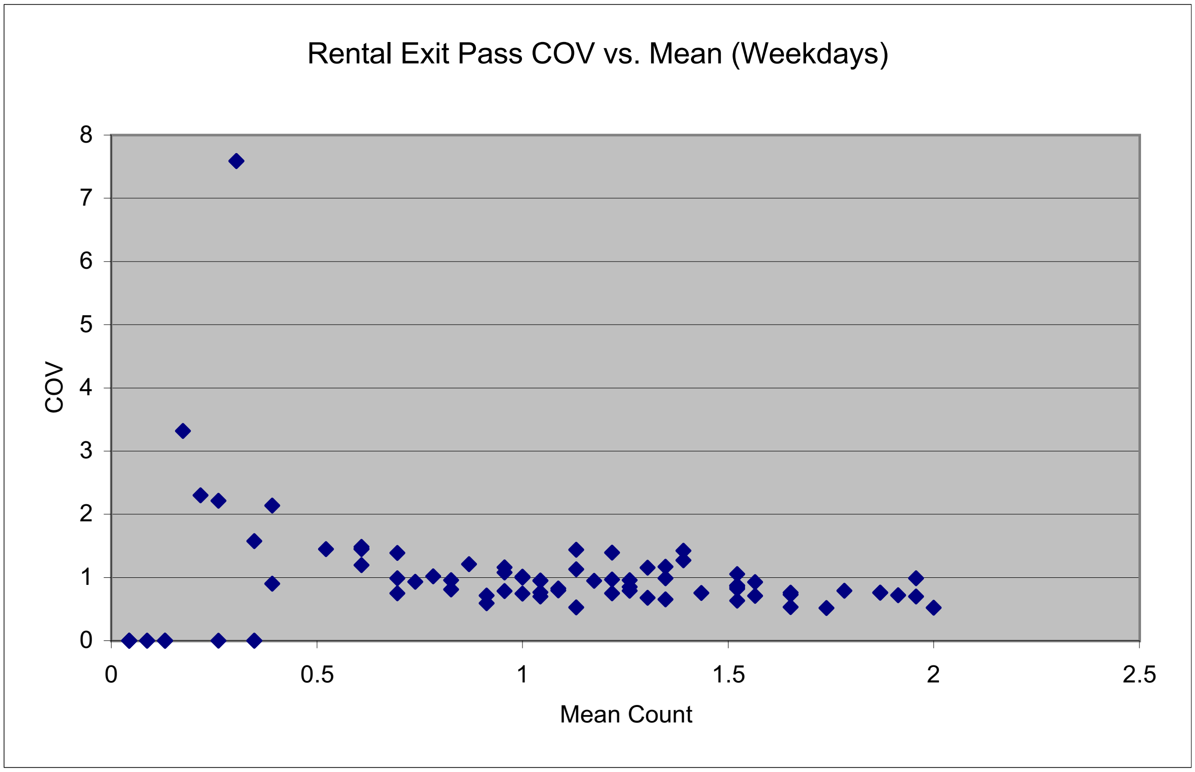

Figure 102: Rental Exit Pass COV vs. Mean (Weekdays)

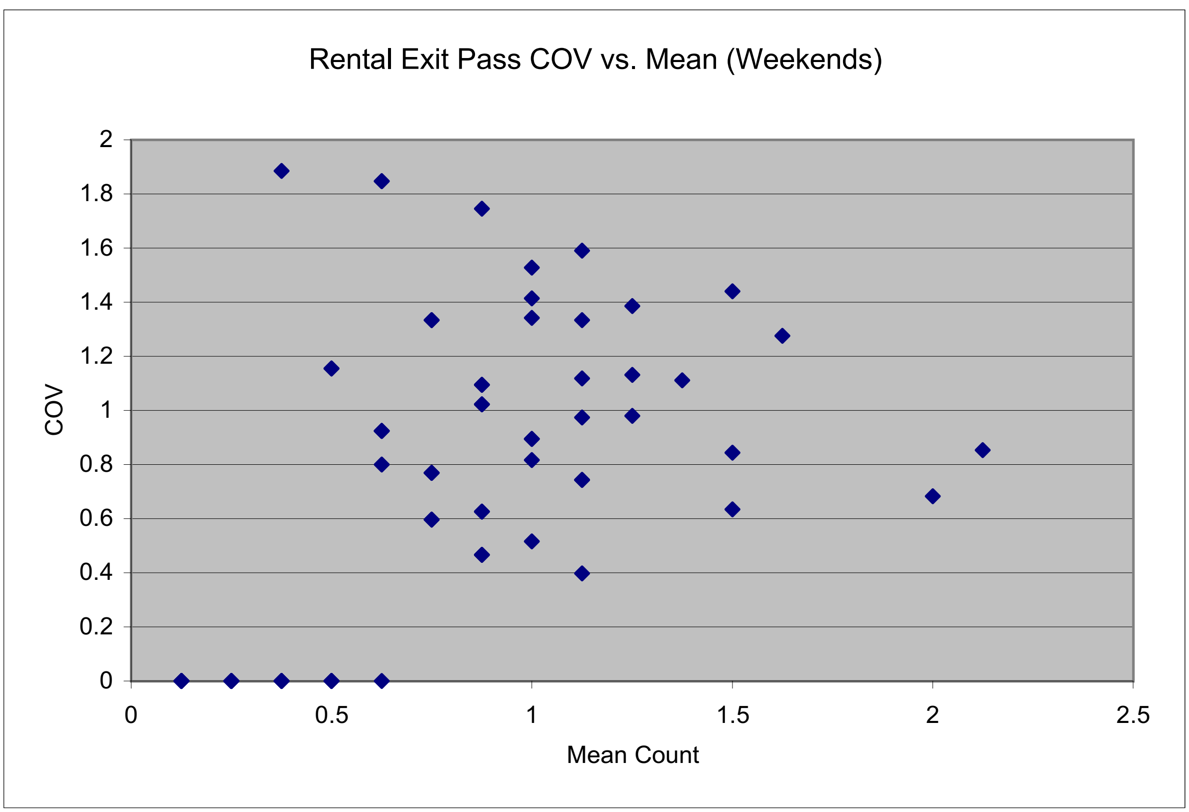

Figure 103: Rental Exit Pass COV vs. Mean (Weekends)

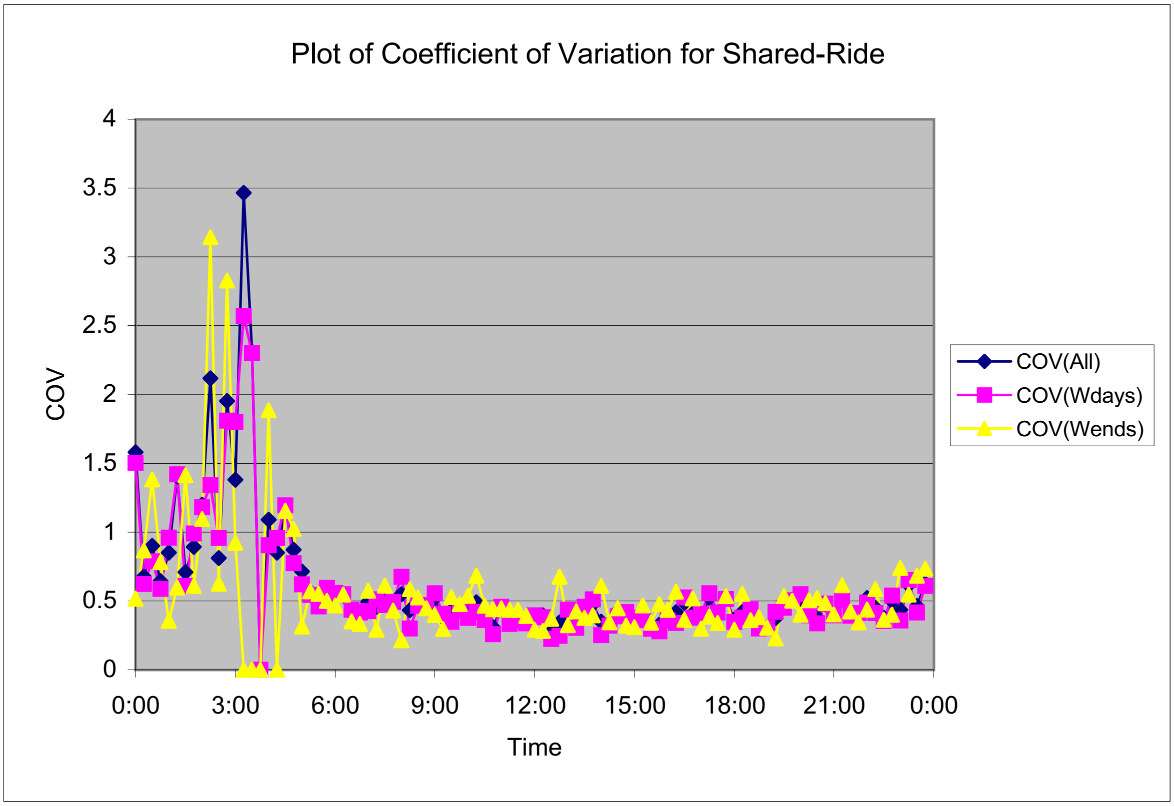

Figure 104: Plot of Coefficient of Variation for Shared-Ride

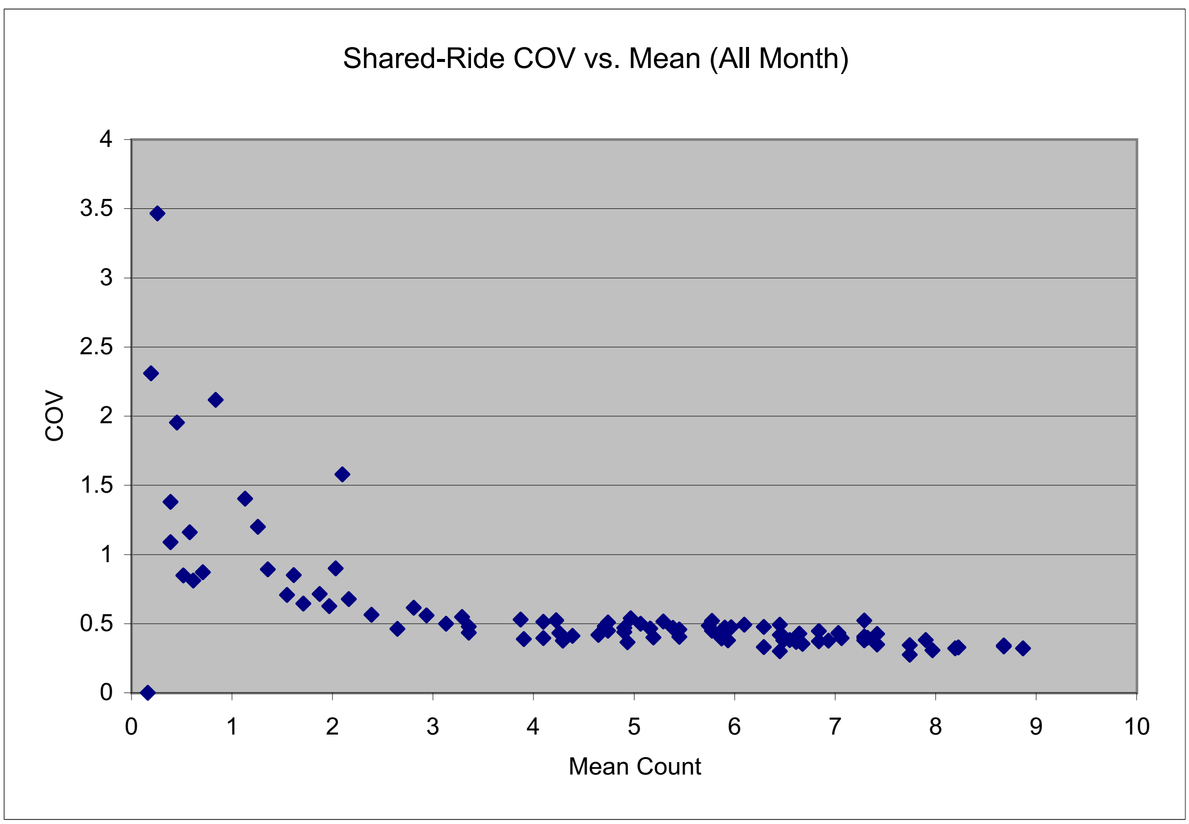

Figure 105: Shared-Ride COV vs. Mean (All Month)

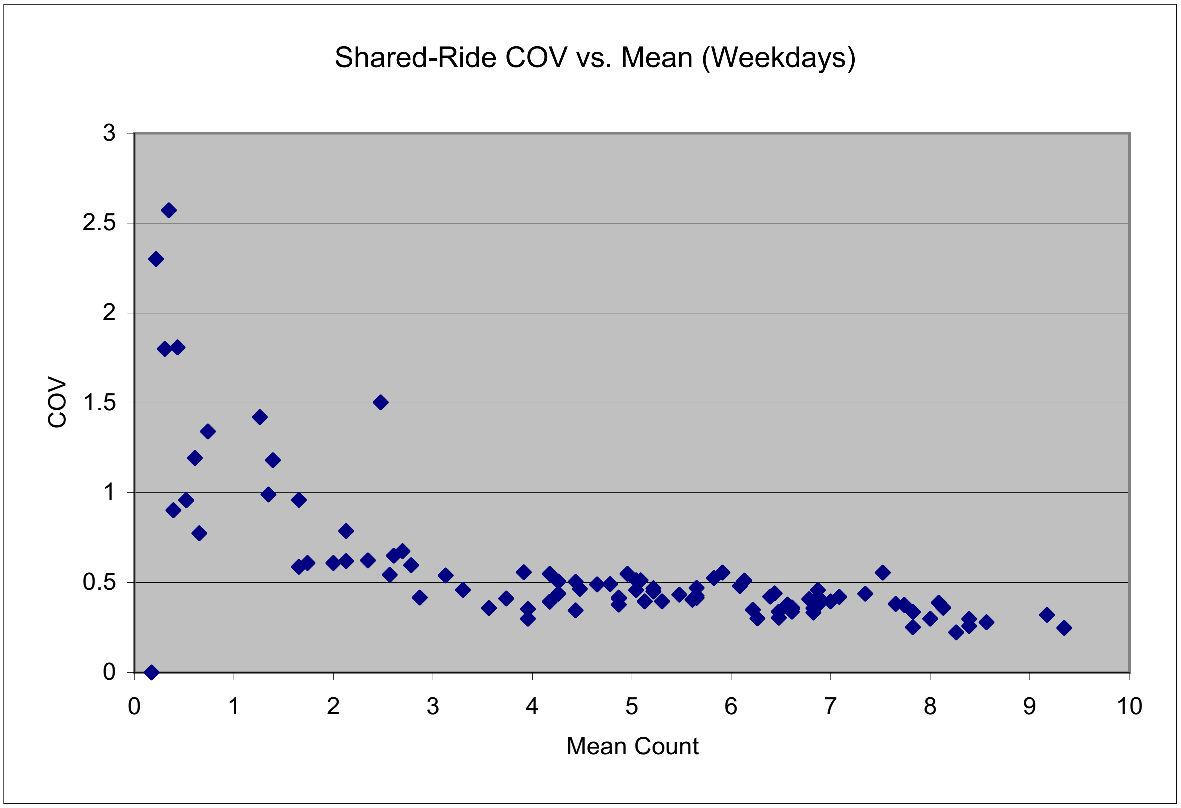

Figure 106: Shared-Ride COV vs. Mean (Weekdays)

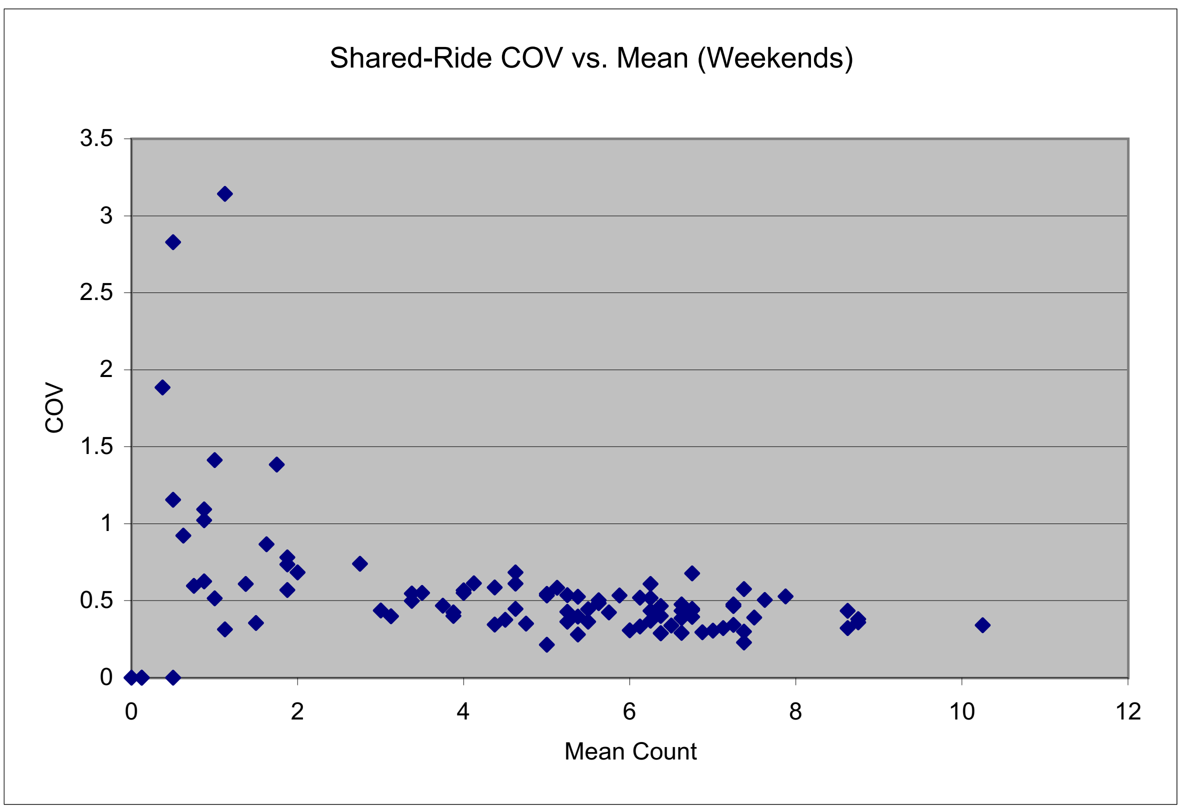

Figure 107: Shared-Ride COV vs. Mean (Weekends)

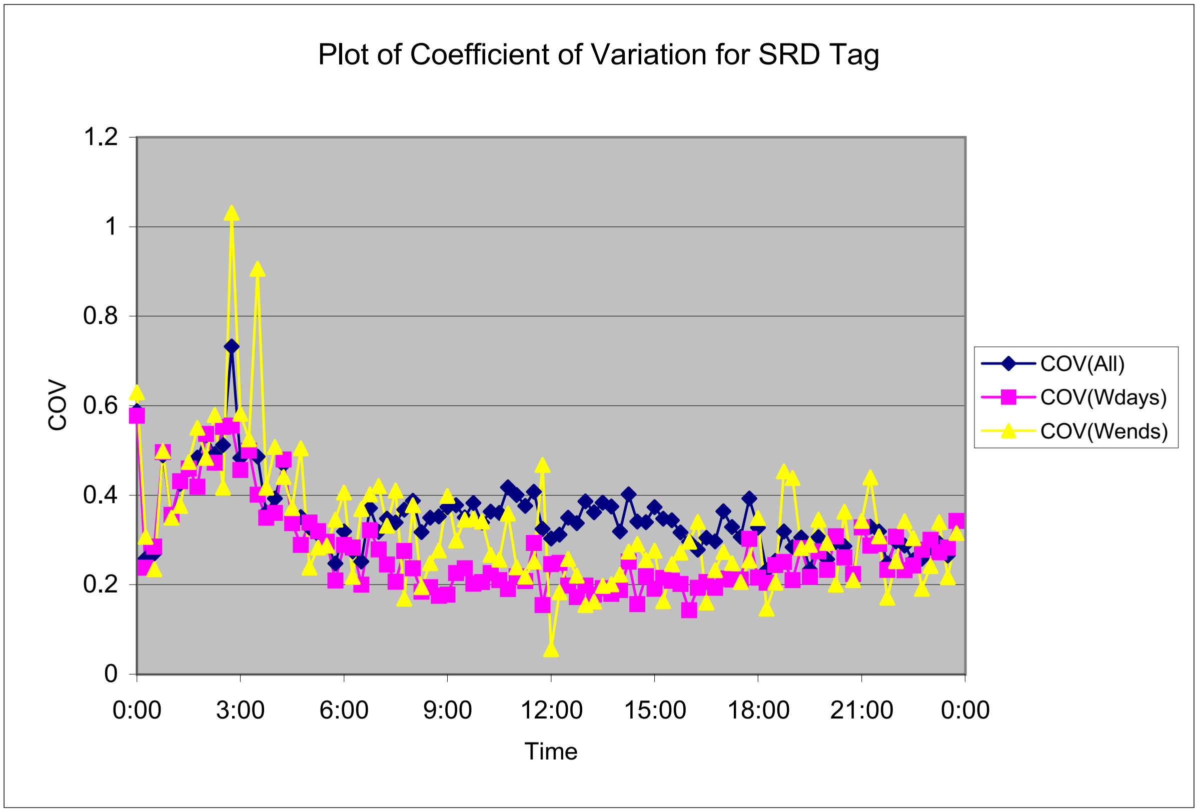

Figure 108: Plot of Coefficient of Variation for SRD Tag

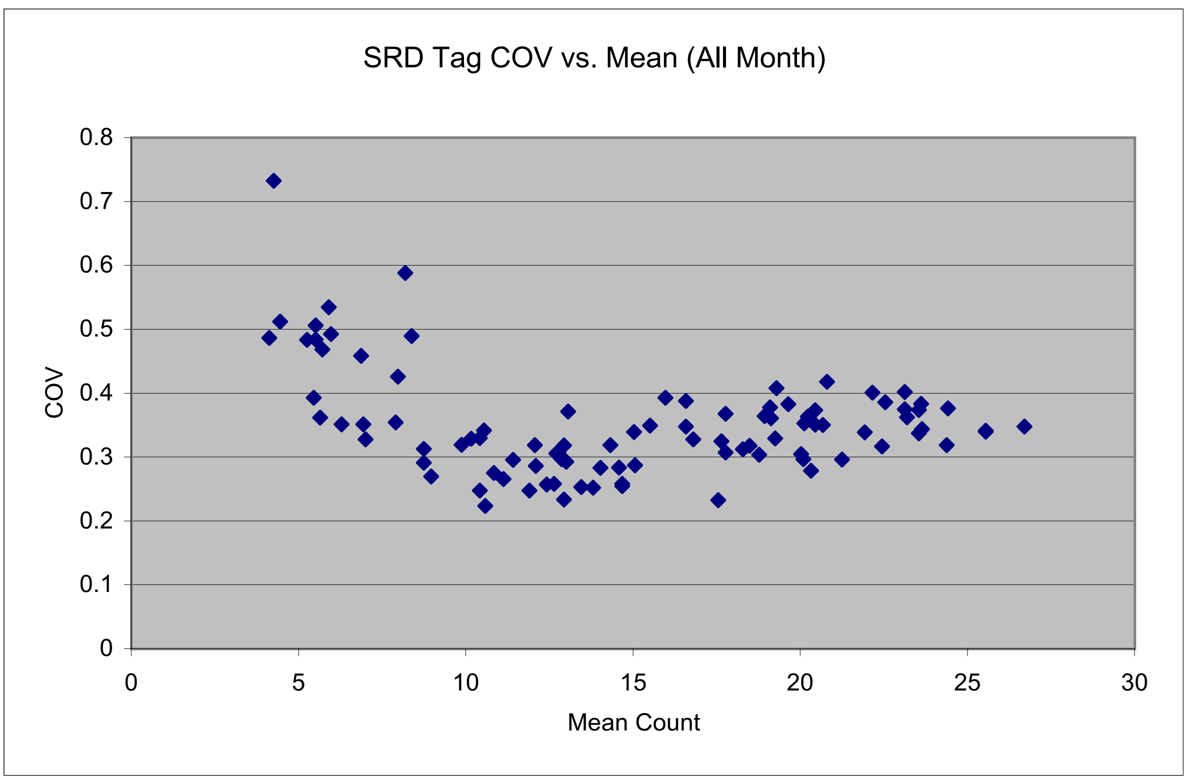

Figure 109: SRD Tag COV vs. Mean (All Month)

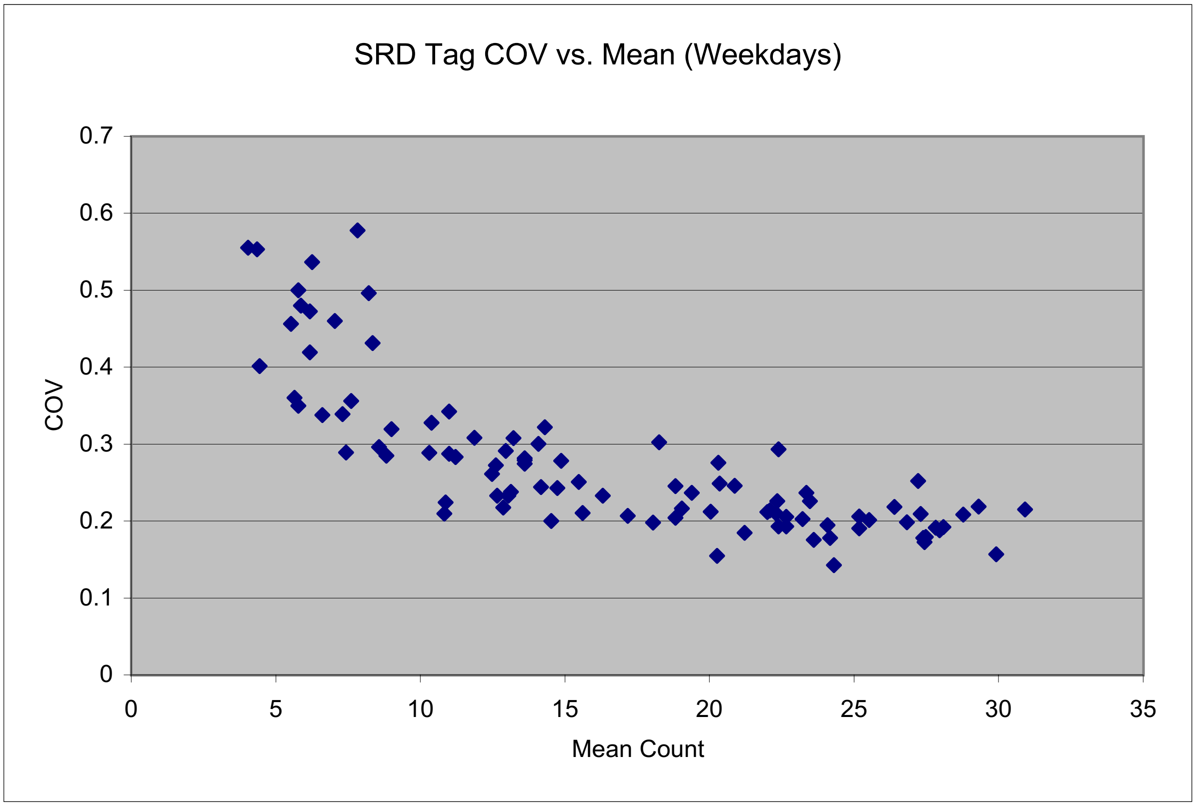

Figure 110: SRD Tag COV vs. Mean (Weekdays)

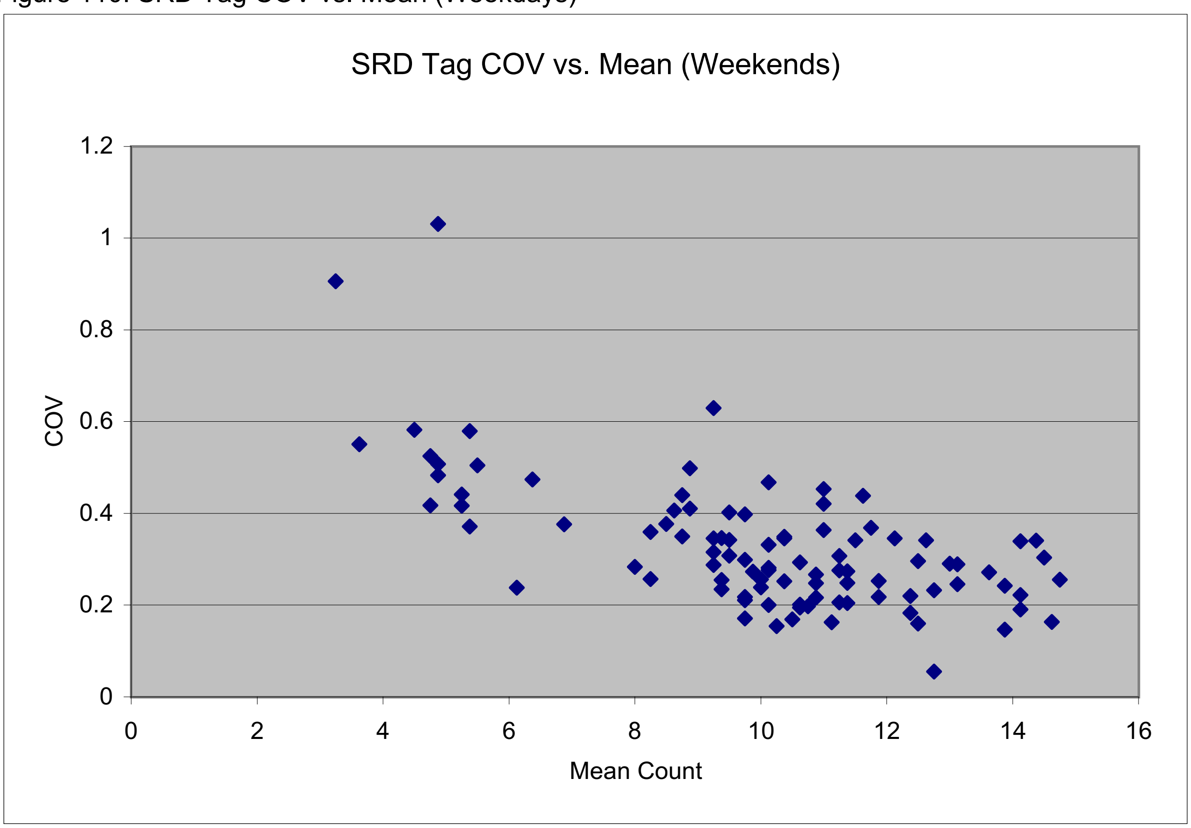

Figure 111: SRD Tag COV vs. Mean (Weekends)

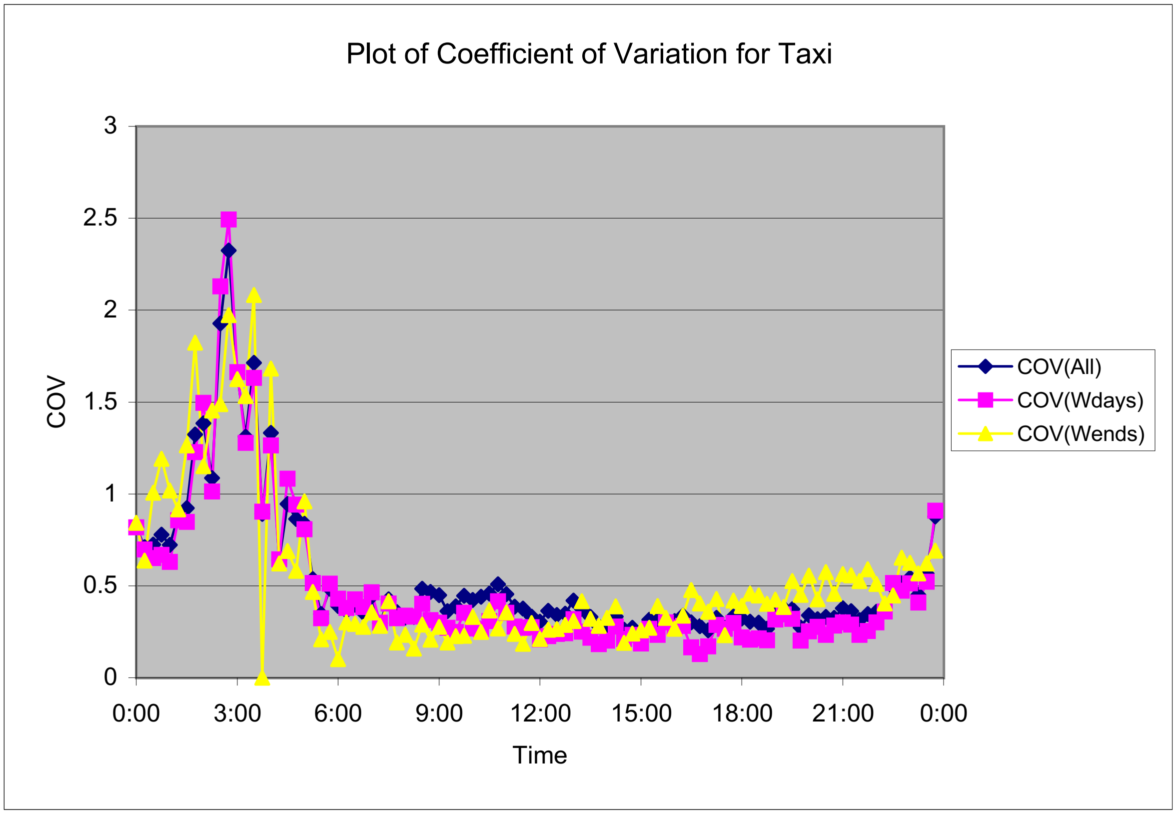

Figure 112: Plot of Coefficient of Variation for Taxi

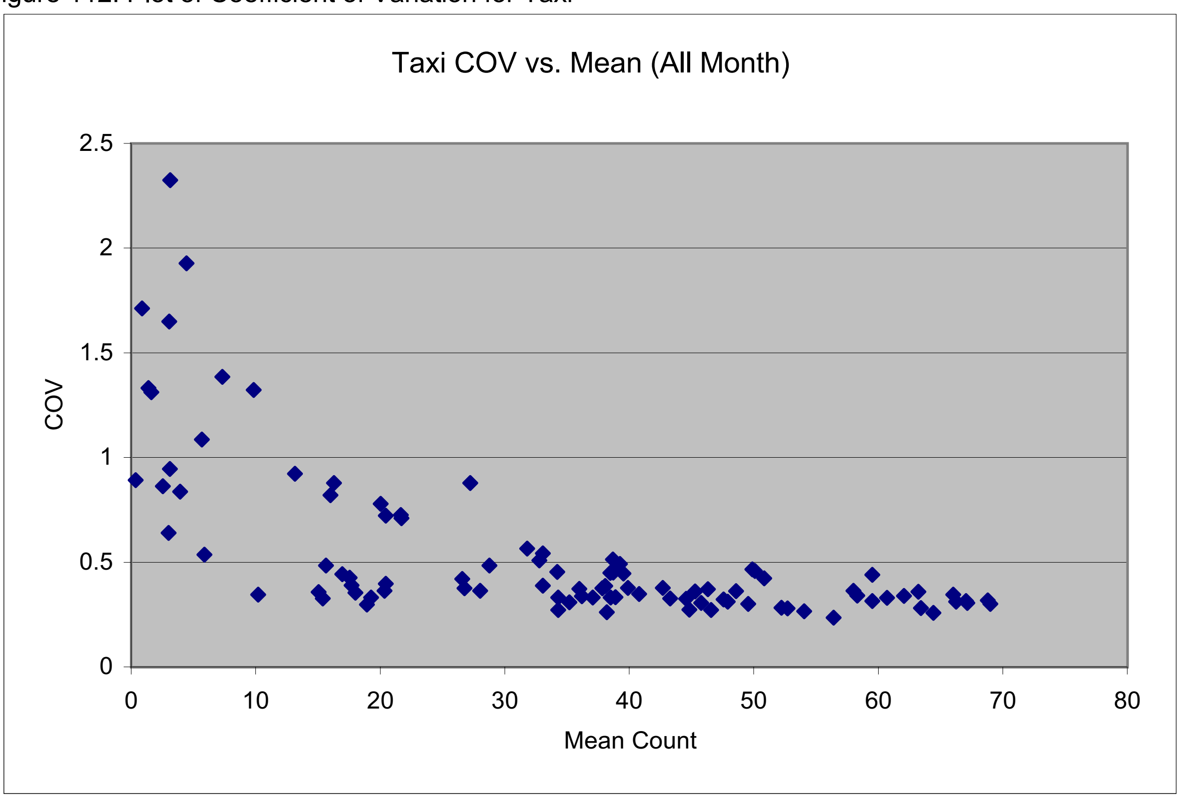

Figure 113: Taxi COV vs. Mean (All Month)

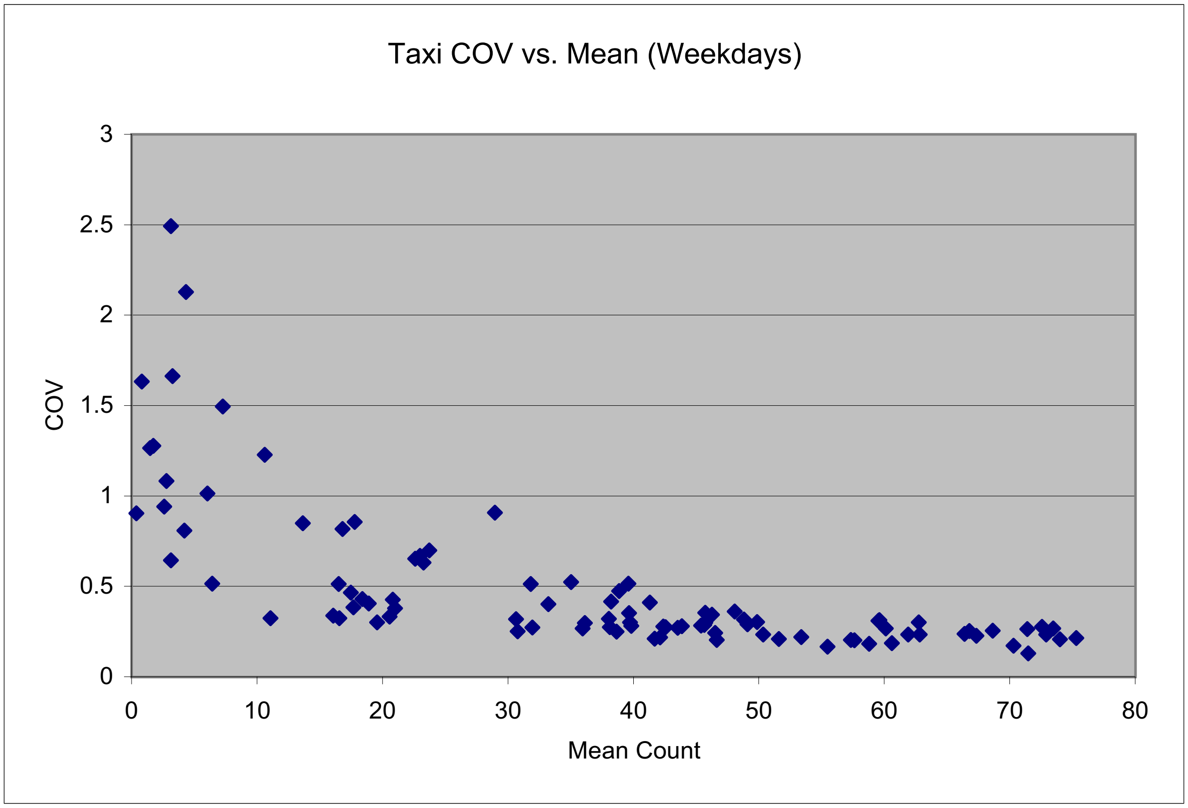

Figure 114: Taxi COV vs. Mean (Weekdays)

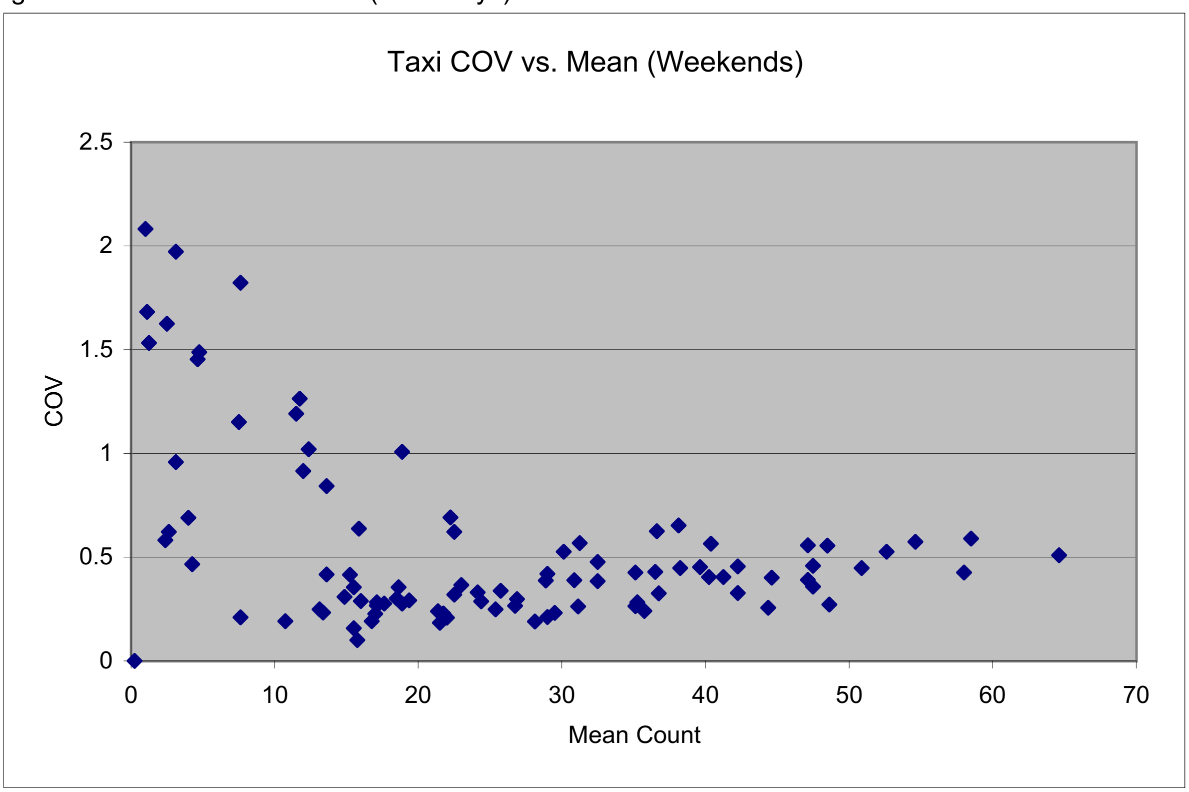

Figure 115: Taxi COV vs. Mean (Weekends)