Traffic Study

City of Diamondhead

Surface Street System Circulation

Diamondhead, MS

Prepared for:

City of Diamondhead

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Contents

I. Introduction

The purpose of this traffic study is to evaluate the circulation within the City of Diamondhead located along the Gulf Coast of Mississippi and Interstate 10 between Slidell, Louisiana and Gulfport, Mississippi. The study will evaluate the existing street system, which currently supports the City. Then it will estimate additional future traffic based on the current zoning assuming that in the future the City fully builds out its undeveloped areas. Using a trip generation of the proposed development, trips will be distributed on the existing and proposed street network. A capacity and level of service (LOS) analysis will be completed for each of the study intersections and roadway segments. Based on the analysis, the need from improvements will be assessed in order to accommodate the future development and promote growth within the City.

II. Study Area

A. Study Area Description

Incorporated in 2012, the City of Diamondhead boasts a current population of 8,425 within its 11.7 square-mile city limits, which is located in Hancock County. Figure 1 displays a location map. The City currently provides numerous residential developments, golf courses, a marina, a private airport, and small amount of commercial development. As the residential development sits as the City's backbone, the City desires to expand its commercial development as well as allow construction and reconstruction of a few residential areas.

Based on the current zoning for the City of Diamondhead several developments were assumed for the proposed development anticipated by the City. North of Interstate 10 and west of Gex Drive, it is planned to have a 300,000 square feet of gross leasable area commercial development. North of Interstation 10 and east of the existing commercial development along East Aloha Drive, another commercial development is anticipated, which could provide up to 90,000 square feet of gross leasable area. Additionally, a residential development is zoned along Noma Drive which could house up to 290 single-family units. A residential development in the southern part of the City along Airport Drive was developed at some point, but currently sits unoccupied. In the future, it is anticipated that this area will be revitalized to house approximately 365 single families. Recently, the City of Diamondhead has rezoned portions of the City south of Interstate 10 to resort/gaming commercial. From that point, the Gaming Commission has approved a future site for a full-service casino in the southeastern portion of

the City. The proposed Casino development will provide 70,000 square feet of gaming floor area. Figure 2 displays the locations of these proposed developments.

B. Existing Streets

Airport Drive/Diamondhead Drive South is an east-west roadway, which connects residential development and the private airport to Yacht Club Drive. From the airport on the west side to the vacant residential development on the east side, this roadway existing as a two-lane divided roadway with landscaped median and open shoulders.

Commercial Avenue (Future) is a proposed two-lane roadway that will extend north from East Aloha Drive east of the existing commercial development and terminate at Diamondhead Drive East running approximately parallel to Kalani Drive. This roadway will provide connectivity and facilitate the growth of commercial development in this area.

East Aloha Drive is an east-west two-lane roadway that provides access to a commercial shopping center, medical offices, and the public library. The roadway begins at Kalani Drive and extends east approximately 2,000 feet where it terminates at the public library.

Gex Drive/Yacht Club Drive is the main north-south roadway through the City Diamondhead and provides connection at Interstate 10 with an interchange. Immediately south of the interchange until West Aloha Drive, this roadway exists as a two-lane undivided roadway with open shoulders. A short portion from Airport Drive to the interchange and from West Aloha Drive to Noma Drive operates as a two-lane divided roadway with landscaped median and open shoulders. This roadway begins at the Yacht Club on the southern end of the City and terminates at the Diamondhead Circle near City Hall.

Live Oak Drive is an east-west two-lane open shoulders roadway with a concrete center median. This roadway currently extends west from Gex Drive and provides access to commercial development, which includes a hotel, restaurants, and a gas station.

Noma Drive is a two-lane roadway, which begins at the western end of the City at the current location of the wastewater treatment plant and winds through existing and proposed residential development until its easterly terminus at the Diamondhead Circle near City Hall. The roadway currently is constructed as a two-lane road and has the Right-of-Way to expend to a four-lane boulevard.

Park Ten Road is a narrow east-west two-lane roadway with unpaved shoulders. It provides access to industrial development extending west from Gex Road 1,200 feet. This study proposes to extend and

create a circulatory roadway, which will tie back into itself and would provide access to the potential commercial development.

West Aloha Drive/Kalani Drive is a three-lane roadway with curb and gutter and a center turn lane. It begins as West Aloha Drive at Gex Drive and extends east until East Aloha Drive where it curves to the north and becomes Kalani Drive, which terminates at Diamondhead Drive East. This roadway provides access to commercial development and a connection to many residential homes. In the future, this study proposes to extend West Aloha Drive, west of Gex Drive as a three-lane roadway continuing parallel to Interstate 10 and terminating at Noma Drive. This will provide increased circulation and open vacant lands to potential commercial development.

NOT TO SCALE

LOCATION MAP
FIGURE 1

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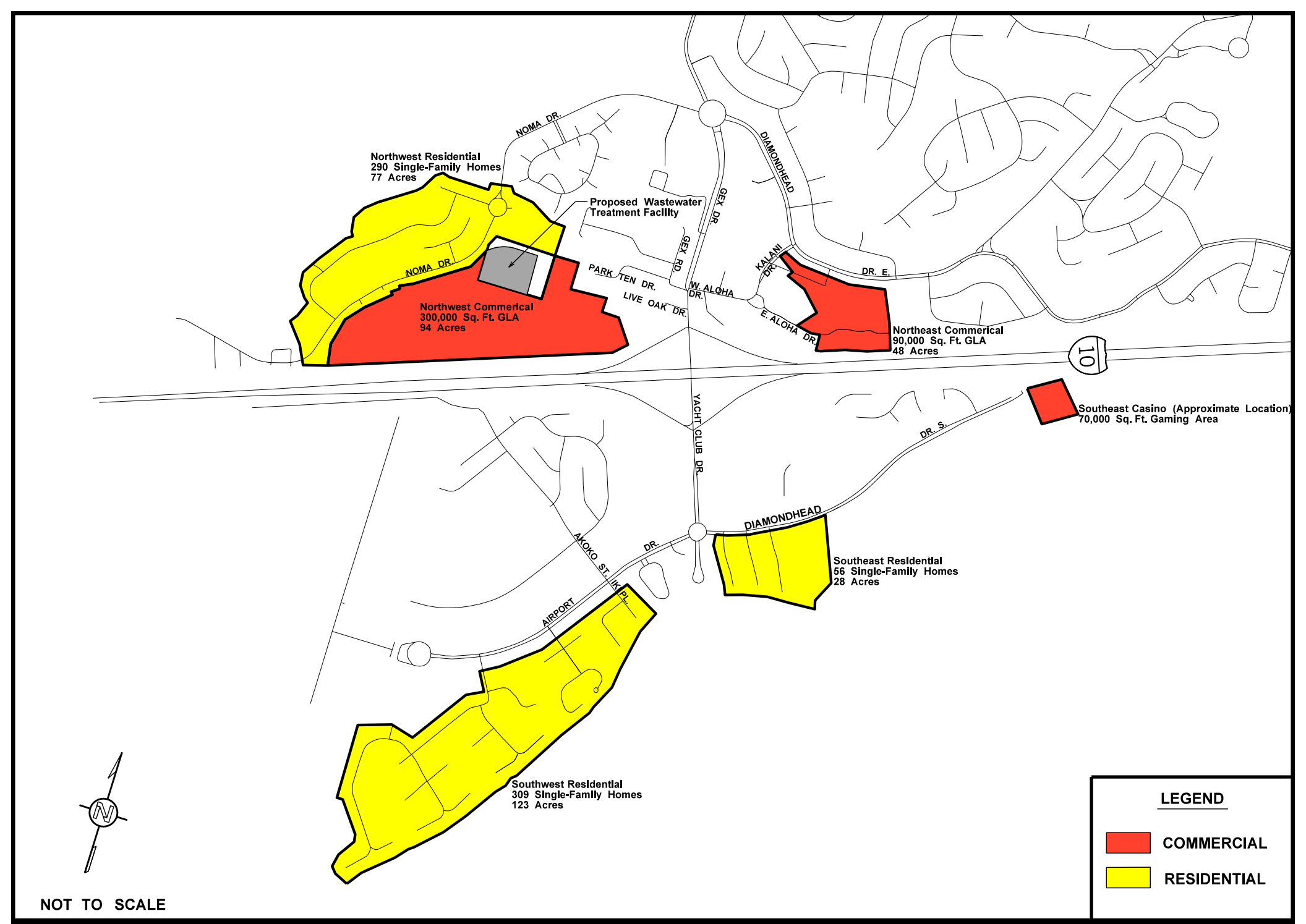

PROPOSED DEVELOPMENT MAP
FIGURE 2

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III. Existing Traffic

Existing turning movement volumes for the study intersections were field measured by Southern Traffic Services, Inc. in September 2015 for purposes of this study. Existing PM and AM peak hour volumes in addition to Daily volumes are displayed in Figure 3.

IV. Proposed Development Traffic

A. Trip Generation

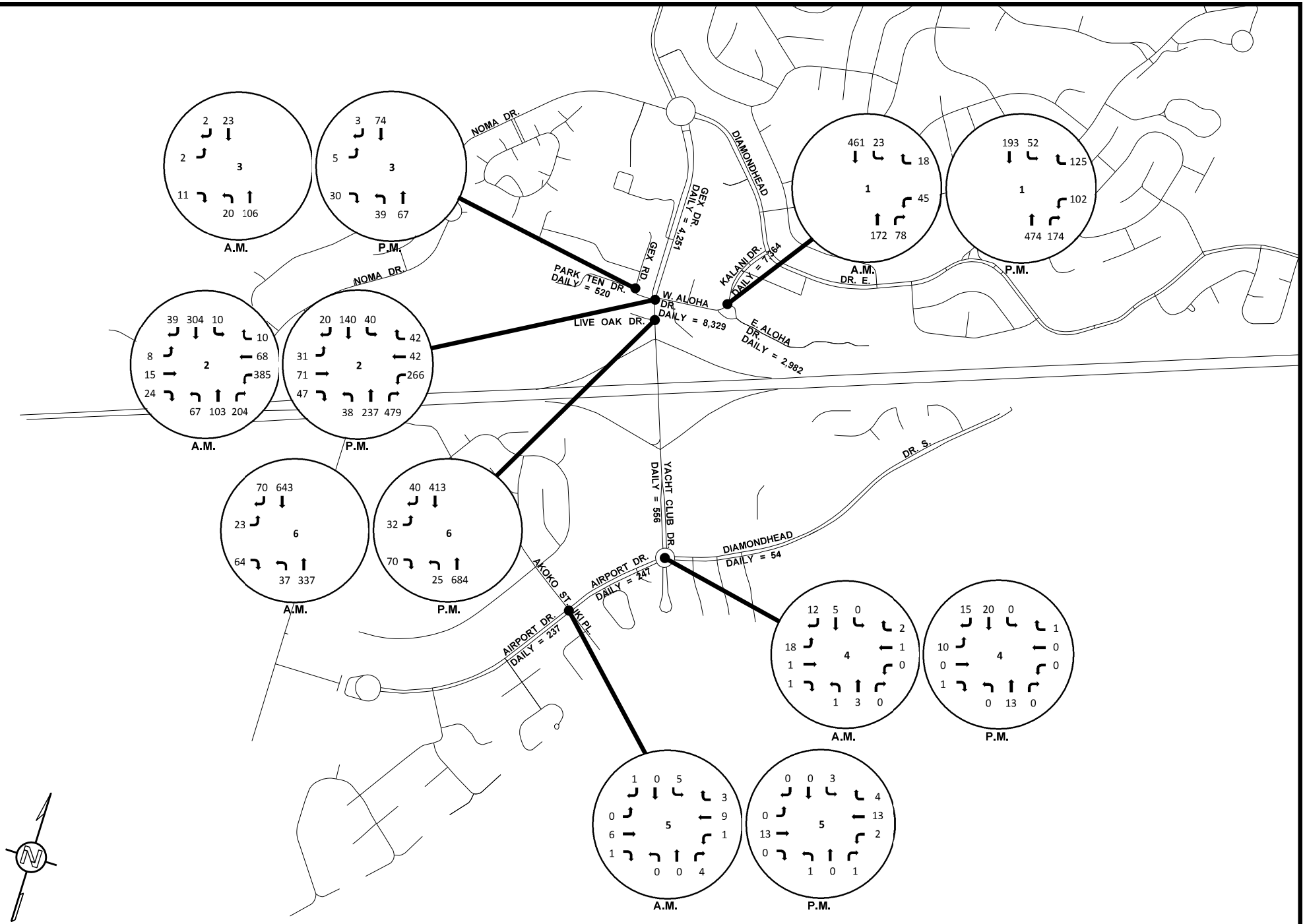
Based on the current zoning for the City of Diamondhead, a trip generation was calculated to account for the future development anticipated by the City. This Trip Generation calculation was prepared using Online Traffic Impact Study Software (OTISS), a software developed by Transoft Solutions that uses the information in Institute of Transportation Engineers (ITE) Trip Generation manual, 9th Edition. ITE code 820 "Shopping Center" with square feet of gross leasable area (GLA) was used as a conservative estimate of the potential traffic for each of the proposed commercial developments throughout the City. ITE code 210 "Single-Family Detached Housing" with dwelling units was used to calculate the potential traffic for each of the residential developments within the City. No ITE code is currently established for a Full-Service Casino development, therefore an estimation of trip generation was calculated using an ITE journal article entitled "Trip Generation Rates for Land Based Floating Casinos (Tunica, Mississippi)," which is attached in the Appendix of this report. Table 1 shows the trips generated based on the ITE Trip Generation.

Trip Generation
Table 1

Location	Land Use	Size	PM Peak Hour		AM Peak Hour		Daily	
			Entry	Exit	Entry	Exit	Entry	Exit
Northwest Commercial (Live Oak Dr)	820 - Shopping Center	300,000 Sq. Ft. Gross Leasable Area	600	651	189	116	6,935	6,935
Northeast Commercial (E. Aloha Dr)	820 - Shopping Center	90,000 Sq. Ft. Gross Leasable Area	268	290	91	55	3,171	3,171
Southwest Residential (Airport Dr)	210 - Single-Family Detached Housing	309 Dwelling Units	183	107	57	169	1,483	1,482
Southeast Residential (Diamondhead Dr South)	210 - Single-Family Detached Housing	56 Dwelling Units	39	23	12	37	308	308
Northwest Residential (Noma Dr)	210 - Single-Family Detached Housing	290 Dwelling Units	173	101	53	160	1,399	1,398
Southeast Casino (Diamondhead Dr South)	Casino (ITE Journal)	70,000 Sq. Ft. Gaming Area	296	296	150	50	4,896	4,896
	Total		**1,559**	**1,468**	**552**	**587**	**18,192**	**18,190**

V. Trip Distribution

Proposed development traffic was distributed from the each development based on existing development within the City, proposed City zoning areas, and the draw of Interstate 10 to the surrounding areas. Figure 4 displays the distribution at the study intersections and roadway segments. Figure 5 shows the proposed development traffic when added the existing traffic, which is referred to as Future Traffic, at each of the study intersections and roadway segments.



EXISTING PEAK HOUR AND DAILY TRAFFIC
FIGURE 3

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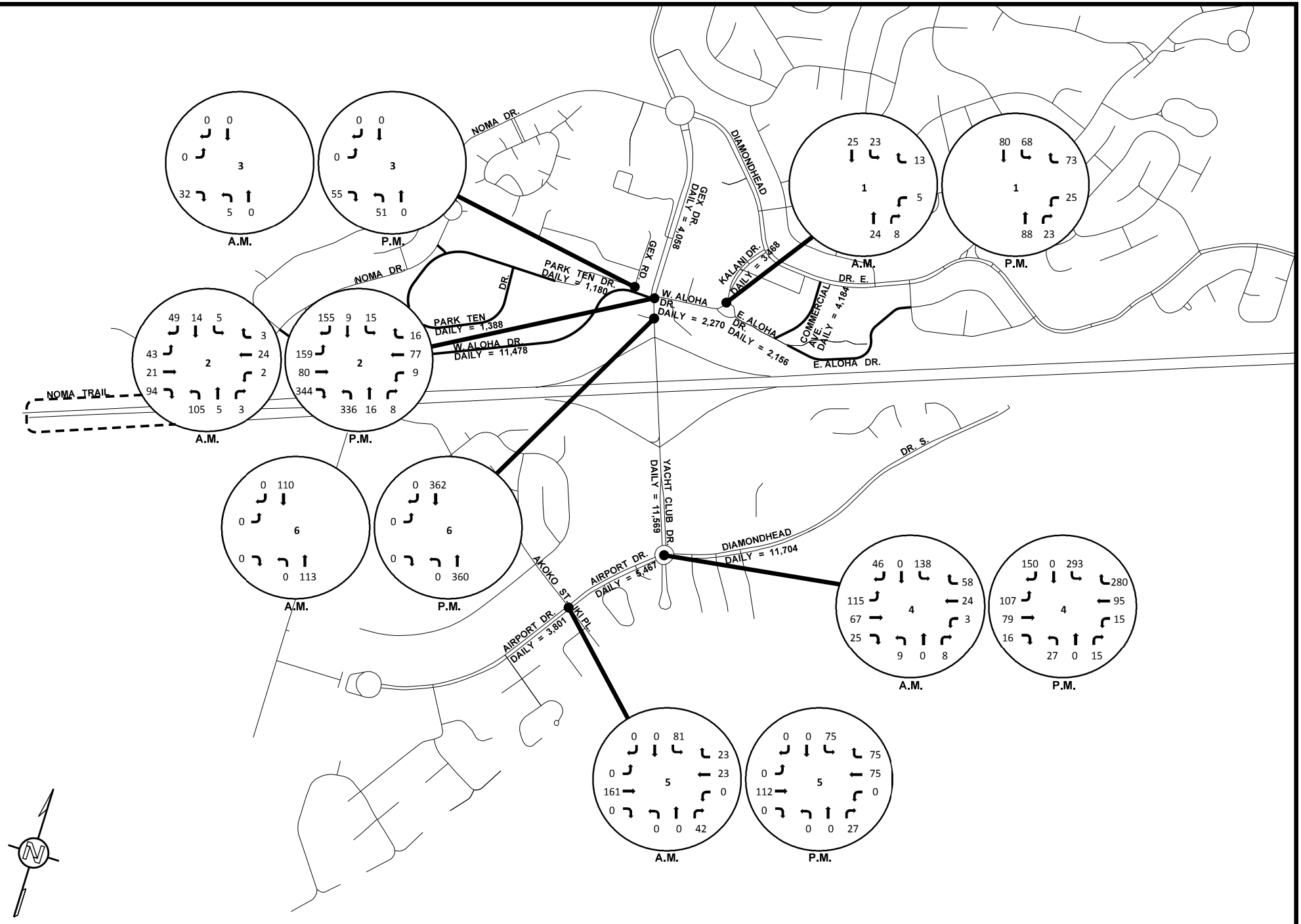

PROPOSED DEVELOPMENT PEAK HOUR AND DAILY TRAFFIC
FIGURE 4

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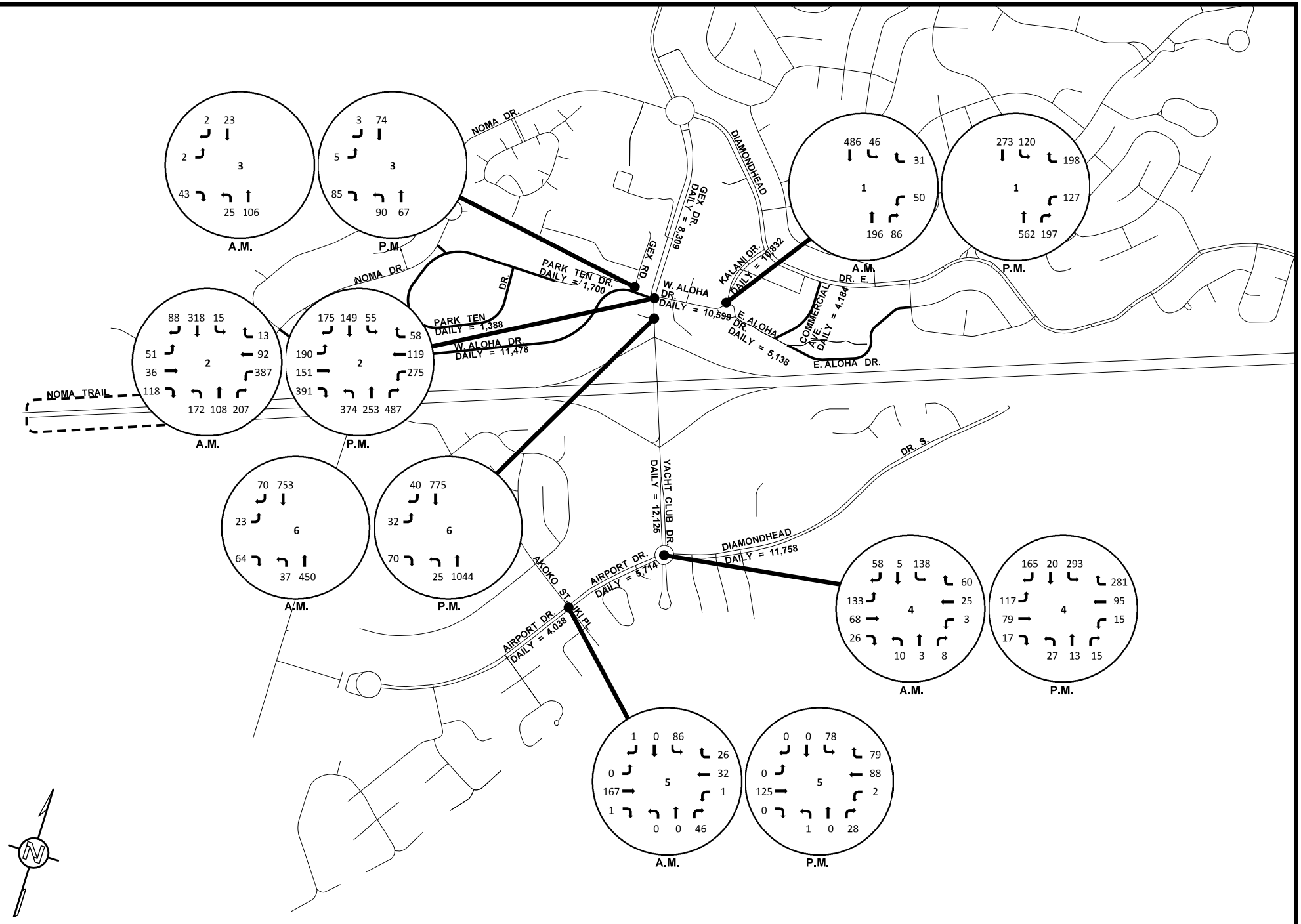

FUTURE PEAK HOUR AND DAILY TRAFFIC
FIGURE 5

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VI. Analyses

A. Intersection Analysis

An intersection level of service and delay analysis was conducted using Synchro 8 software from Trafficware for each study intersection. This software utilizes the capacity analysis methodology in the Transportation Research Board's Highway Capacity Manual 2010. The intersection analysis was performed for the following traffic scenarios: existing year, future year, and future year with mitigation. The future year is defined as the existing traffic in combination with the City's full development according to the current zoning plan. The "Mitigation" is defined as the necessary street network improvements in order to maintain acceptable level of service at each project intersection. See the Conclusion and Recommendation section of this report for more detail on the Mitigation. Weekday PM and AM peak hour levels of service and intersection delay times for the study intersection are presented in Tables 2 and 3, respectively.

PM Peak Hour Intersection Level of Service and Delay
Table 2

#	Name	Intersection Control		Existing	Future	Future w/Mitigiation
				PM Peak Hour		
1	Kalani Dr & E. Aloha Dr	WB Stop	LOS	C	F	C
			Delay (sec/veh)	20.8	61.2	19.4
2	Gex Dr & W. Aloha Dr	All-Stop	LOS	D	F	B
			Delay (sec/veh)	31.4	69.2	17.7
3	Gex Rd & Park Ten Dr	All-Stop	LOS	A	A	-
			Delay (sec/veh)	7.9	8.1	-
4	Yacht Club Dr & Airport Dr	Roundabout	LOS	A	A	-
			Delay (sec/veh)	3.4	9.1	-
5	Akoko St/Iki Pl & Airport Dr	All-Stop	LOS	A	A	-
			Delay (sec/veh)	7.3	9.1	-
6	Gex Dr & Live Oak Dr	EB Stop	LOS	C	D	C
			Delay (sec/veh)	16.0	43.5	16.9

AM Peak Hour Intersection Level of Service and Delay
Table 3

#	Name	Intersection Control		Existing	Future	Future w/Mitigiation
				AM Peak Hour		
1	Kalani Dr & E. Aloha Dr	WB Stop	LOS	B	B	B
			Delay (sec/veh)	13.1	14.1	13.1
2	Gex Dr & W. Aloha Dr	All-Stop	LOS	E	E	B
			Delay (sec/veh)	38.8	49.9	15.8
3	Gex Rd & Park Ten Dr	All-Stop	LOS	A	A	-
			Delay (sec/veh)	8.3	7.9	-
4	Yacht Club Dr & Airport Dr	Roundabout	LOS	A	A	-
			Delay (sec/veh)	3.3	5.3	-
5	Akoko St/Iki Pl & Airport Dr	All-Stop	LOS	A	A	-
			Delay (sec/veh)	7.1	9.1	-
6	Gex Dr & Live Oak Dr	EB Stop	LOS	C	C	C
			Delay (sec/veh)	18.5	23.6	18.8

B. Signal Warrant Analysis

Currently, all intersections in the City Diamondhead are unsignalized stop-controlled or roundabout intersections. To evaluate the condition of the unsignalized study intersections, a peak-hour signal warrant evaluation was conducted during the PM and AM peak hours for each of the following study scenarios: existing year and future year. The analysis was conducted using Warrants 8 from Trafficware. This software utilizes the methodology in the Manual on Uniform Traffic Control Devices (MUTCD), 2009 Edition. Weekday PM and AM peak hour signal warrants for the study intersections are presented in Table 4.

Peak Hour Signal Warrants
Table 4

		AM Peak Hour		PM Peak Hour	
#	Name	Existing	Future	Existing	Future
1	Kalani Dr & E. Aloha Dr	No	No	No	***Yes***
2	Gex Dr & W. Aloha Dr	No	***Yes***	No	***Yes***
3	Gex Rd & Park Ten Dr	No	No	No	No
5	Akoko St/Iki Pl & Airport Dr	No	No	No	No
6	Gex Dr & Live Oak Dr	No	No	No	No

C. Roadway Segment Analysis

A roadway capacity analysis was conducted using a volume to capacity ratio for each study roadway. A volume to capacity ratio of 0.80 or higher corresponds to a level of service less than LOS C as defined in the Transportation Research Board's Highway Capacity Manual 2010. Table 5 presents the roadway volumes, capacities, and analysis for the study roadway segments.

Roadway Segment Capacity Analysis
Table 5

Location	Existing Roadway Volume	Proposed Development Roadway Volume	Future Roadway Volume	Existing Capacity	Proposed Capacity	Existing Volume/ Capacity	Future Volume/ Capacity
Gex Dr: W. Aloha Dr to Noma Dr	4,251	4,058	8,309	20,000	-	0.213	0.415
Yacht Club Dr: I-10 to Airport Dr	556	11,569	12,125	20,000	-	0.028	0.606
Commerical Ave: E. Aloha Dr to Diamondhead Dr E	-	4,184	4,184	-	15,000	-	0.279
Park Ten Rd: Circle Roadway	-	1,388	1,388	-	15,000	-	0.093
Park Ten Rd: Park Ten Circle to Gex Rd	520	1,180	1,700	15,000	-	0.035	0.113
W. Aloha Dr: Noma Dr to Gex Rd	-	11,478	11,478	-	20,000	-	0.574
W. Aloha Dr: Gex Dr to Kalani Dr	8,329	2,270	10,599	20,000	-	0.416	0.53
Kalani Dr: W. Aloha Dr to Diamondhead Dr E	7,364	3,468	10,832	20,000	-	0.368	0.542
E. Aloha Dr: Kalani Dr to Commerical Ave	2,982	2,156	5,138	15,000	-	0.199	0.343
Airport Dr: Airport Cir to Akoko St	237	3,801	4,038	20,000	-	0.012	0.202
Airport Dr: Akoko St to Yacht Club Dr	247	5,467	5,714	20,000	-	0.012	0.286
Diamondhead Dr S: East of Yacht Club Dr	54	11,704	11,758	20,000	-	0.003	0.588

D. Proposed Circulation

The existing street system is inadequate to handle the additional traffic within the commercial zones of the City. Therefore, four additional roadway segments are recommended to be constructed to increase

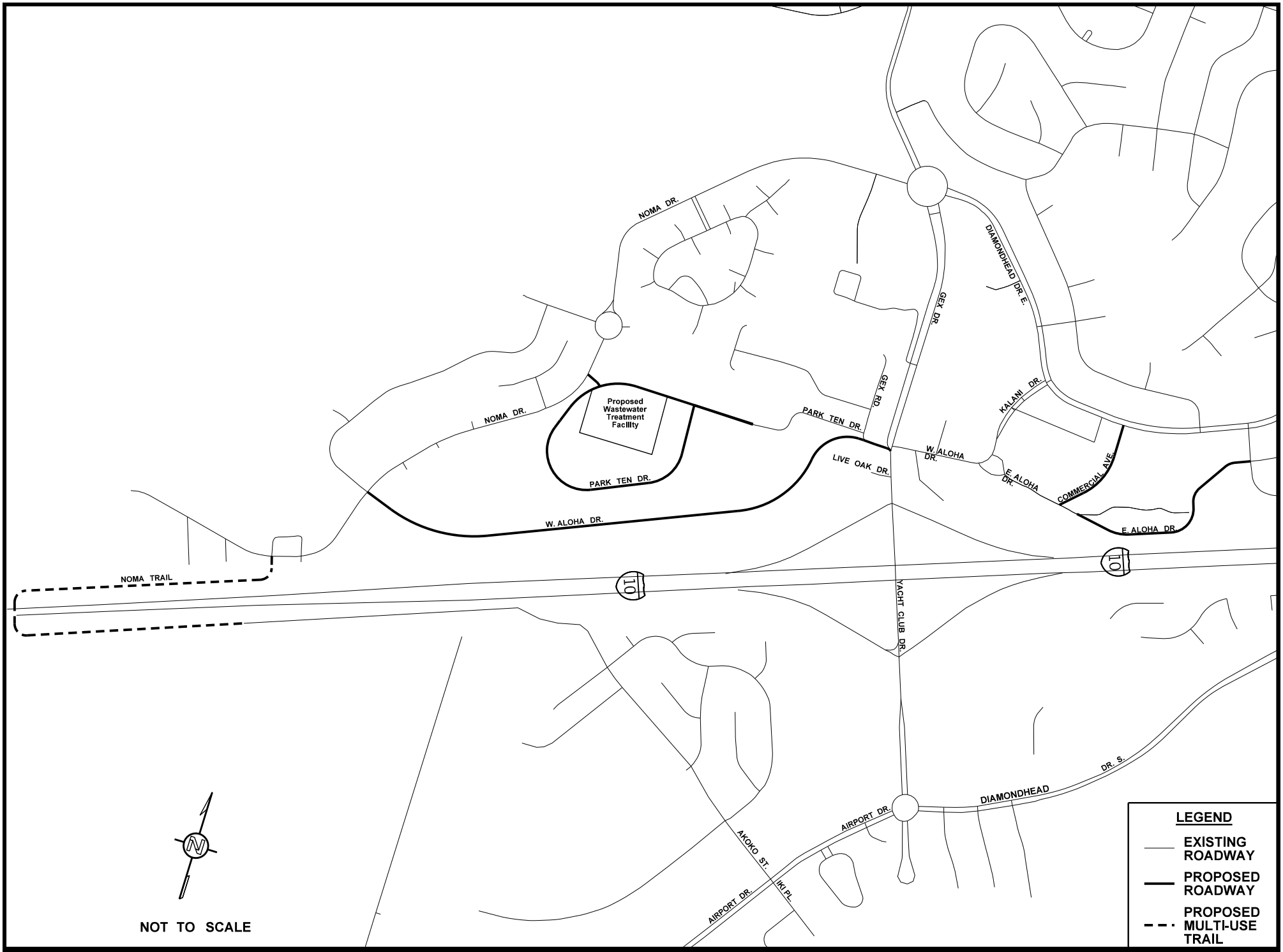
circulation within the city and promote growth of commercial developments. These roadways will allow the City to provide safe and appropriate circulation for its citizens, pass-by travelers, and commercial business operations. It is proposed to construct an extension of West Aloha Drive to serve as a three-lane roadway to provide access to customers using the zoned commercial areas in the northwest portion of the City. This roadway will extend from existing West Aloha Drive at Gex Drive and continue west to Noma Drive. The second proposed roadway would be a two-lane extension of existing Park Ten Drive and will provide access for service vehicles such as supply vehicles, garbage trucks, and mail carriers to the proposed commercial development in the northwest portion of the City. The third proposed roadway is a new alignment named Commercial Avenue, which would be a two-lane roadway that would serve as a connection between East Aloha Drive and Diamondhead Drive East in the middle of the zoned commercial area in the northeast portion of the City. Finally, the fourth proposed roadway would be an extension of East Aloha Drive as a two-lane roadway from the existing commercial area in the northeast portion of the City running parallel to Interstate 10, connecting to the existing roadway in front of the public library and extending east to Aila Street at its intersection with Ahoni Street. Figure 6 displays these proposed roadway segments.

In addition to the proposed roadway segments, one multi-use trail is proposed for the City of Diamondhead. Currently, the City promotes alternative transportation throughout the City for its pedestrians, bicyclists, and golf cart motorists. Although access is allowed for these alternative transportation methods across the Interstate 10 bridge along Gex Drive, the absent of a designated lane discourages these methods from traveling between the northern and southern portions of the City. Therefore, it is recommended that a 12-foot wide multi-use trail be constructed as Noma Trail extending west from Noma Drive near the current wastewater treatment plant and then running parallel to Interstate 10 until the Jourdan River Bridge. At the bridge, it would cross under and connect with existing Akoko Street near the airport. Figure 6 shows the proposed alignment of this trail.

VII. Proposed Zone Change

When the existing Zoning Plan is fully built out, all commercial development will be isolated to the area north of Interstate 10. This raises a traffic distribution issue, which will cause all residents in the southern region to cross the Gex Drive bridge over Interstate 10 in order to do any shopping or patronizing of any commercial development. Gex Drive currently experiences traffic congestion and will continue greater congestion once the future development is constructed. Therefore, it is proposed an area which is currently zoned High Density Signal Family Residential be rezoned to accommodate a commercial development which can service the commercial needs of the citizens in the southern

region. This vacant property could be developed as commercial and relieve a significate amount of traffic from the Interstate 10 interchange and the Gex Drive bridge.



PROPOSED CIRCULATION
FIGURE 6

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VIII. Conclusion and Recommendation

The City of Diamondhead desires to prepare for future growth based on its current zoning so that it is ready for future development that might take place within the City. This Traffic Study evaluated that existing street system of the City with these proposed developments. From this evaluation, several improvements are recommended to accommodate future growth and promote future development. Four proposed roadway segments are recommended as follows: West Aloha Drive from Gex Drive to Noma Drive, Park Ten Drive circulatory roadway, new Commercial Drive from East Aloha Drive to Diamondhead Drive East, and East Aloha Drive from proposed Commercial Drive to Aila Street. Reference the Proposed Circulation section of this report for more detail.

Along with these roadway improvements, three existing intersections will require mitigation in order to accommodate future development. The intersection of Kalani Drive and East Aloha Drive will need an additional westbound and northbound right-turn lane. The intersection of Gex Drive and West Aloha Drive meets both AM and PM peak-hour signal warrants and will require the installation of a traffic signal, along with the addition of eastbound left and right turn lanes. Alternatively, this intersection can be mitigated with a two-lane roundabout with two entry lanes from each direction and one exit lane in each direction. This would allow consistency within the City, including two other roundabouts along this corridor, allow lower future maintenance cost, and shorter queue lengths for the left-turning movements. Finally, the intersection of Gex Drive and Live Oak Drive will need to be limited to partial-access, specifically prohibiting eastbound and westbound left-turns, in order to accommodate the future traffic. When these roadway and intersection improvements are constructed, the City of Diamondhead will be able to accommodate all the additional traffic generated by the proposed development outlined in the current Zoning Plan.

Appendix

Trip Generation Rates for Land Based Floating Casinos (Tunica, Mississippi)

Glen R. Heath, Martin E. Lipinski, Jamie W. Hurley

INTRODUCTION

Over the past several years, the gaming industry has rapidly spread into many new markets throughout the United States. This unusual growth has occurred primarily because of two factors: (1) state legislation allowing gaming and (2) the growth in Native-American owned casinos. Until recently, the majority of legalized casino gaming took place in Las Vegas, Nevada and Atlantic City, New Jersey. In July of 1990, the Mississippi legislature legalized gaming for floating casinos on the Gulf of Mexico and the Mississippi River. In 1991, Tunica County, located 25 miles south of Memphis, Tennessee on the Mississippi River, legalized gaming.

Within the last ten years, many states have legalized gaming and experienced major increases in vehicular traffic on roadway networks in the vicinity of the casinos. In the Tunica County casino marketplace, the state and local municipalities were unprepared for the increase in traffic. Existing roadway systems experienced significant congestion and accident rates increased considerably. It was obvious that an analysis of the impacts of the increased traffic on the surrounding roadway network was not included in the casino development process.

Consideration of trip generation characteristics is a key factor in the analysis of the impacts of a major land use, such as a casino. Trip generation analysis predicts the number of trips made to and from land uses of identifiable size, type, and density of the development. These data are used to develop projections on the volume of traffic that will use the surrounding roadway network. The publication commonly used to determine trip generation is the Institute of Transportation Engineers *Trip Generation* manual.

The objective of this study was to determine trip generation characteristics of the Tunica County casinos. With the insight provided by studies such as this one, it is hoped that areas experiencing new or expanded casino growth will be capable of estimating the increased traffic generated by gaming operations. By using the results of this study, state and local public officials can review the characteristics of the new casino and apply the formulas developed here to reasonably predict the increase in vehicular traffic. Using this information, along with existing and projected non site-related traffic volume data, the agency can evaluate current roadway conditions and determine if the existing roadway network is adequate to handle the increased traffic. If the network is inadequate, the extent of the needed roadway improvements can be determined.

TUNICA COUNTY, MISSISSIPPI, CASINO DEVELOPMENT

The first casino in Tunica County was Splash Casino which opened in October of 1992. When Splash opened, gaming demand was high and waits to enter the casino were long, sometimes in excess of 4 hours. In addition, Splash Casino also had a $10 cover charge per person. Even with the long waits and cover charges, people were not deterred from making the trip to Tunica.

Approximately 1 year later, Lady Luck Casino opened for business; quickly followed by Bally's Casino without a cover charge, forcing Splash to drop their admission fee.

The next casino to open, Harrah's, chose a site approximately 20 minutes closer to Memphis than the first three. Soon several other casinos opened in this same area, dramatically impacting business at the original casino locations. Shortly thereafter, Bally's moved their operation to the new location closer to Memphis, while Lady Luck moved down river near Helena, Arkansas, abandoning the Memphis market. Eventually, even Splash could not survive in its original location and was forced to close.

Eleven other casinos have begun operation since the opening of Harrah's. Three of these casinos have closed, while Harrah's relocated to a larger building, once operated by one of the closed casinos. There are nine casinos currently operating in Tunica County within an area of 8 square miles. The remaining casinos currently offer much more than gambling. Many casinos have golf courses, fine dining, nightly entertainment, childcare, convention facilities, big name performers, and numerous special events.

Prior to the casino industry's arrival to Tunica County, Mississippi in 1992, US Highway 61 was a two-lane undivided highway. It served as a major roadway through the Mississippi Delta with an average daily traffic (ADT) volume of less than 4000 vehicles on the segment between the Desoto County line and Mississippi Route 304. This segment of US Highway 61 was not only used for through traffic, but it also functioned as a farm-to-market road. In 1998, after casino development, the ADT for this same segment of US Highway 61 was 27,000. Other roads leading to and from the casino area have also seen dramatic increases in ADT, some in excess of 13,000 vehicles per day.

The majority of casino visitors came from Memphis, Tennessee, the closest metropolitan area which was located 50 miles to the north of the original casinos. Access to the first casinos was very poor in the beginning; visitors had to travel through the old downtown Tunica area and the entire trip took in excess of one hour from downtown Memphis. The added casino traffic created congestion for several hours each day and the number of accidents increased.

Today's casinos are located closer to Memphis and have better access, thus, reducing the travel time to 30 minutes from Memphis. All of these casinos are located near the Mississippi River on roadways intersecting US Highway 61.

The casino boom resulted in dramatic changes to the roadway network. Congestion and safety concerns forced the Mississippi Highway Department to "fast track" the improvement of US Highway 61 to a 4-lane divided facility from the Tennessee border to Tunica. In addition, Tunica County constructed 4-lane facilities from US Highway 61 to the casinos. Individual casinos also constructed multi-lane access roadways. Direct access from I-55, 14 miles to the east, is being provided by the reconstruction of Mississippi Highway 304 to a 4-lane divided cross section along a new alignment.

The introduction of casinos and the roadway improvements in Tunica County during the past 6 years has accelerated the economic impact of casino operations. This growth is a result of the

rigorous competition among casinos for general business and the addition of hotels, golf courses, and other amenities. Plans are currently underway to build an airport with an 8000 foot runway to handle charter jet service and to construct an AmTrak rail line from Memphis to the casino area.

DATA COLLECTION

For this study, twenty four hour volume counts were performed for a minimum of four weeks and were compiled with two different types of automatic data collectors, the Streeter Richardson road tube counter and the Nu-metric 30. Of the eight casinos studied, two groups of three casinos each were combined to function as two individual generators. These grouped casinos share some parking space and many people park once and walk between these casinos.

In this study, data were obtained from eight of the nine casinos. The ninth casino was not studied because this casino did not grant permission to perform these counts. There are two major casino areas: Casino Strip and Casino Center. Each of these areas contains three casinos. Casino Strip includes Harrah's Casino & Hotel, Hollywood Casino & Hotel, and Sam's Town Hotel & Gambling Hall. Casino Center includes Sheraton Casino & Hotel, Horseshoe Casino, and Gold Strike Casino & Hotel. Two isolated locations, Bally's Saloon & Gambling Hall/Hotel and Fitzgerald's Casino & Hotel were included in the study, as well. Each Tunica casino was studied between the months of August and October in 1996 and/or 1997. ***Figure 1*** below represents all Thursday daily counts for Casino A. This graph is typical of all daily graphs for each day of the week for each casino.

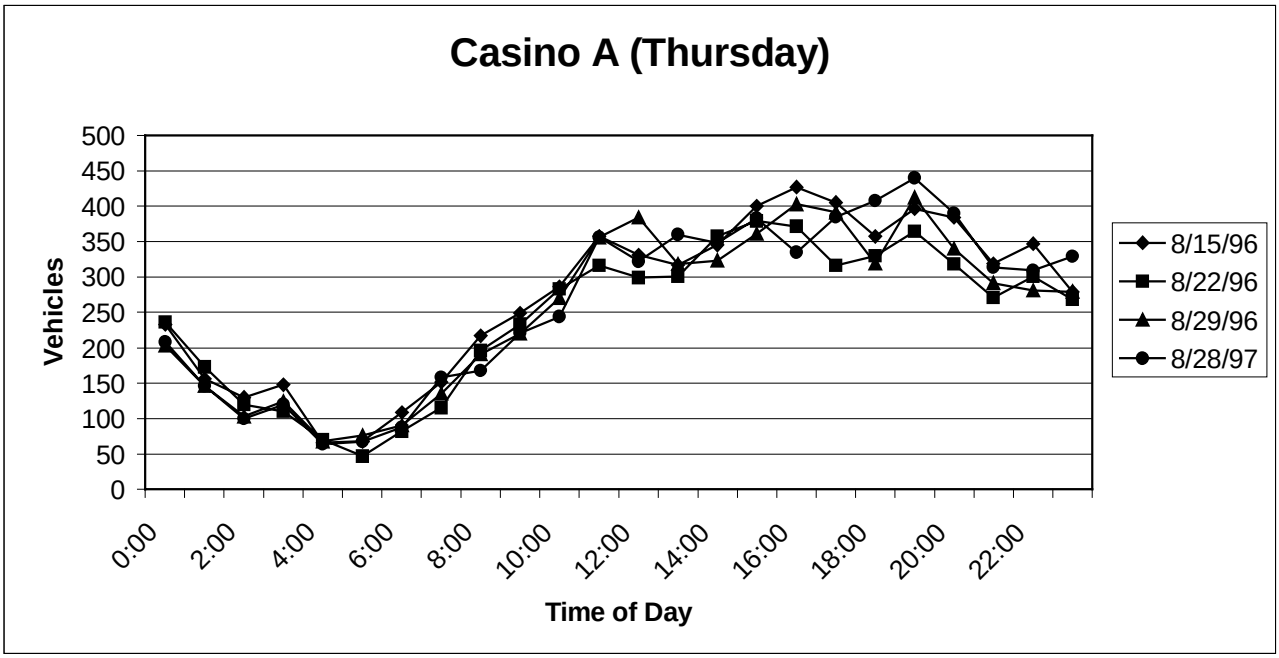

Figure 1.

ANALYSIS

The hourly counts collected in this study were used to develop prediction equations similar to those found in *Trip Generation*. Analysis of Variance was performed to determine if there was a significant difference between days of the week.

Analysis of Variance

The data were grouped into single casino's hourly totals and group casino's hourly totals. The hourly totals gathered from each casino or group were then grouped by each day of the week. When information was available for holidays, these data were used as a separate day. In order to determine which days of the week could be combined in the regression analysis, an analysis of variance (AOV) was conducted for A.M. and P.M. peak hours for the generator and adjacent street. Because primary access to the casino is via US Highway 61 and large numbers of visitors use this as primary access from the Memphis area, this highway was considered the adjacent street for all of the casinos. All of these proved to have a significant difference between the days of the week, except for A.M. Peak Hour of the generator. All AOV results are shown in ***Table 1***.

TABLE 1
AOV RESULTS

	F_{calc}	F_{table}
Single Casinos		
A.M. Peak Hour of the Generator	1.80	2.18
P.M. Peak Hour of the Generator	4.48	2.18
A.M. Peak Hour for the Adjacent Street	7.10	2.18
P.M. Peak Hour for the Adjacent Street	7.11	2.18
Group Casinos		
A.M. Peak Hour of the Generator	136.34	2.28
P.M. Peak Hour of the Generator	228.40	2.28
A.M. Peak Hour for the Adjacent Street	121.68	2.28
P.M. Peak Hour for the Adjacent Street	109.96	2.28

Least Significant Difference

Because a significant difference was determined by the AOV, Fisher's Least Significant Difference (LSD) Test was used to ascertain which days of the week could be grouped together to run a regression model to determine prediction equations. Most data in *Trip Generation* are reported as Monday through Friday and Saturday and Sunday.

In most cases, the LSD test results indicated a grouping of Monday through Friday and Saturday, Sunday and Holiday for the Tunica County casinos. When it did not, it was usually very close. To be consistent with *Trip Generation*, the data for all eight scenarios were broken down into the above mentioned groupings.

Regression Analysis

For the regression analysis, the independent variables: Gaming Area (Square Feet), Number of Employees, Number of Hotel Rooms, Number of Slot Machines, and Number of Table Games were used for each single or group of casinos. For the group casinos, the individual counts for each casino were added together to get a total to represent the group. A summary of the values for the independent variables and their corresponding casinos is shown in ***Table 2***.

Table 2
Independent Variables

Casino	Gaming Area (Square Feet)	Number of Employees	Number of Hotel Rooms	Number of Slot Machines	Number of Table Games
Casino A	44,383	868	234	1,273	57
Casino B	36,000	868	507	1,186	37
Casino C	112,000	4,057	200	3,552	144
Casino D	200,000	4,322	1,562	4,479	176

Regression analyses were performed for eight different models using different combinations of all five independent variables (X) with the actual hourly counts (Y), the dependent variable, used in the AOV.

Stepwise linear regression with backward elimination was used to determine which variables could be used in combination to produce valid prediction equations. The focus was placed on using Gaming Area (Square Feet) as one base X variable. The other two base X variables used were Number of Employees and Number of Hotel Rooms. All combinations of three or less X variables were placed with each of these main focus X variables. The objective of this regression analysis was to formulate accurate prediction equations.

In all regression analyses involving Hotel Rooms, this independent variable had a negative coefficient. A negative coefficient for Hotel Rooms is not unreasonable. For example, if someone was going to spend Friday afternoon through Sunday night at a casino without an overnight stay, six trips, three arriving and three departing the casino would be made. If the same casino has hotel rooms and a visitor stays three nights at the casino hotel, only two trips would be required: one arriving and one departing, eliminating four trips. Therefore, the more hotel rooms a casino has on-site, the greater number of people that can stay extended periods of time, reducing multiple trips. The equations developed by backward elimination can be seen in ***Table 3***.

Table 3 Equations and R Squared Values Determined By Backward Elimination Linear Regression	
Monday - Friday AM Peak Hour for Adjacent Street	
$R^2 = 0.716$	Trip Ends = 99+(0.0967*Employees)
$R^2 = 0.859$	Trip Ends = 77+(-0.222*Hotel Rooms)+(0.156*Slot Machines)
$R^2 = 0.859$	Trip Ends = 96+(-0.192*Hotel Rooms)+(3.623*Table Games)
$R^2 = 0.650$	Trip Ends = 79+(2.59*Table Games)

Table 3 Continued	
Monday - Friday PM Peak Hour for Adjacent Street	
$R^2 = 0.814$	Trip Ends = 187+(0.1816*Employees)
$R^2 = 0.925$	Trip Ends = 240+(0.2185*Employees)+(-0.2295*Hotel Rooms)
$R^2 = 0.914$	Trip Ends = 145+(-.368*Hotel Rooms)+(.2814*Slot Machines)
$R^2 = 0.884$	Trip Ends = 186+(-0.307*Hotel Rooms)+(6.42*Table Games)
$R^2 = 0.711$	Trip Ends = 159+(4.77*Table Games)
Monday - Friday AM Peak hour for the Generator	
$R^2 = 0.820$	Trip Ends = 194.0768+(0.1544*Employees)
$R^2 = 0.954$	Trip Ends = 244+(0.1888*Employees)+(-0.214*Hotel Rooms)
$R^2 = 0.953$	Trip Ends = 160+(-0.336*Hotel Rooms)+(0.2445*Slot Machines)
$R^2 = 0.936$	Trip Ends = 192+(-0.286*Hotel Rooms)+(5.63*Table Games)
$R^2 = 0.727$	Trip Ends = 167+(4.09*Table Games)
Monday-Friday PM Peak Hour of the Generator	
$R^2 = 0.871$	Trip Ends = 222+(0.215*Employees)
$R^2 = 0.930$	Trip Ends = 267+(0.246*Employees)+(-0.191*Hotel Rooms)
$R^2 = 0.923$	Trip Ends = 158+(-0.3476*Hotel Rooms)+(0.3173*Slot Machines)
$R^2 = 0.900$	Trip Ends = 203+(-0.281*Hotel Rooms)+(7.268*Table Games)
$R^2 = 0.790$	Trip Ends = 178+(5.757*Table Games)
Saturday, Sunday, & Holiday AM Peak Hour for Adjacent Street	
$R^2 = 0.952$	Trip Ends = 194+(9.89*1000 Square Feet Gaming Area) + (-.664*Hotel Rooms)
$R^2 = 0.920$	Trip Ends = 100+(0.2534*Employees)
$R^2 = 0.951$	Trip Ends = 2+(-0.3045*Hotel Rooms)+(0.3549*Slot Machines)
$R^2 = 0.960$	Trip Ends = 37+(-0.23*Hotel Rooms)+(8.26*Table Games)
$R^2 = 0.910$	Trip Ends = 6+(7.19*Table Games)
Saturday, Sunday, & Holiday PM Peak Hour for Adjacent Street	
$R^2 = 0.915$	Trip Ends = 245+(0.261*Employees)
$R^2 = 0.944$	Trip Ends = 290+(0.2834*Employees)(-0.173*Hotel Rooms)
$R^2 = 0.949$	Trip Ends = 153+(-0.346*Hotel Rooms)+(0.3694*Slot Machines)
$R^2 = 0.937$	Trip Ends = 193+(-0.264*Hotel Rooms)+(8.54*Table Games)
$R^2 = 0.876$	Trip Ends = 150+(7.47*Table Games)
Saturday, Sunday, & Holiday AM Peak Hour for the Generator	
$R^2 = 0.947$	Trip Ends = 235+(9.55*1000 Square Feet Gaming Area) + (-0.648*Hotel Rooms)
$R^2 = 0.905$	Trip Ends = 145+(0.243*Employees)
$R^2 = 0.941$	Trip Ends = 51+(-0.299*Hotel Rooms)+(0.3417*Slot Machines)
$R^2 = 0.949$	Trip Ends = 83+(-.0228*Hotel Rooms)+(7.97*Table Games)
$R^2 = 0.896$	Trip Ends = 52+(6.91*Table Games)

Table 3 Continued	
Saturday, Sunday, & Holiday PM Peak Hour for the Generator	
$R^2 = 0.898$	Equation = 284+(0.288*Employees)
$R^2 = 0.923$	Equation = 177+(-0.347*Hotel Rooms)+(0.4004*Slot Machines)
$R^2 = 0.921$	Equation = 217+(-0.261*Hotel Rooms)+(9.30*Table Games)

Additional Regression Analysis

The two most commonly used independent variables in *Trip Generation* are square footage and employees. In most cases, the stepwise regression (backward elimination) did not produce valid equations for square footage. These equations were not developed because the square footage variable was eliminated in the first step when it produced a negative coefficient. Because the independent variable, square footage is so commonly used in *Trip Generation*, additional regression analyses were run. These analyses were produced to develop equations based on square footage and employees and additional variables to determine if a multivariable equation would produce a better best-fit regression curve.

Trip generation rates were developed using the number of employees, the casino square footage, the number of hotel rooms, the number of slot machines, and the number of gaming tables as independent variables. Equations and charts were developed following the format used in the ITE *Trip Generation*. The equations produced by additional regression can be seen below in ***Table 4***.

Table 4 Additional Equations and R Squared Values	
Monday - Friday AM Peak Hour for Adjacent Street	
$R^2 = 0.395$	Trip Ends = 170+(1.8*1000 Square Feet Gaming Area)
$R^2 = 0.856$	Trip Ends = 166+(4.34*1000 Square Feet Gaming Area)+(-0.384*Hotel Rooms)
$R^2 = 0.849$	Trip Ends = 132+(0.1197*Employees)+(-0.143*Hotel Rooms)
Monday - Friday PM Peak Hour for Adjacent Street	
$R^2 = 0.454$	Trip Ends = 319+(3.39*1000 Square Feet Gaming Area)
$R^2 = 0.870$	Trip Ends = 312+(7.65*1000 Square Feet Gaming Area)+(-0.643*Hotel Rooms)
Monday - Friday AM Peak hour for the Generator	
$R^2 = 0.452$	Trip Ends = 308 + (2.866*1000 Square Feet Gaming Area)
$R^2 = 0.926$	Trip Ends = 302+(6.72*1000 Square Feet Gaming Area)+(-.582*Hotel Rooms)
Monday-Friday PM Peak Hour of the Generator	
$R^2 = 0.552$	Trip Ends = 352+(4.284*1000 Square Feet Gaming Area)
$R^2 = 0.888$	Trip Ends = 345+(8.67*1000 Square Feet Gaming Area)+(-0.6617*Hotel Rooms)
Saturday, Sunday, & Holiday AM Peak Hour for Adjacent Street	
$R^2 = 0.707$	Trip Ends = 169+(5.84*1000 Square Feet Gaming Area)
$R^2 = 0.937$	Trip Ends = 133+0.2713*Employees)+(-0.129*Hotel Rooms)

Table 4 Continued	
Saturday, Sunday, & Holiday PM Peak Hour for Adjacent Street	
$R^2 = 0.650$	Trip Ends = 337+(5.85*1000 Square Feet Gaming Area)
$R^2 = 0.928$	Trip Ends = 361+(10.18*1000 Square Feet Gaming Area)+(-0.719*Hotel Rooms)
Saturday, Sunday, & Holiday AM Peak Hour for the Generator	
$R^2 = 0.696$	Trip Ends = 210+(5.6*1000 Square Feet Gaming Area)
$R^2 = 0.923$	Trip Ends = 178+(0.261*Employees)+(-0.13*Hotel Rooms)
Saturday, Sunday, & Holiday PM Peak Hour for the Generator	
$R^2 = 0.674$	Trip Ends = 370+(6.64*1000 Square Feet Gaming Area)
$R^2 = 0.918$	Trip Ends = 395+(11.14*1000 Square Feet Gaming Area)+(-0.749*Hotel Rooms)
$R^2 = 0.915$	Trip Ends = 322+(0.307*Employees)+(-0.1465*Hotel Rooms)

The Sixth Edition of *Trip Generation* contains a collection of the regression curve, a regression equation, and a coefficient of determination (R^2) for each land use. Data plots are present for all land uses. The best fit regression curves, R^2 values, and equations are only shown when each of the following three conditions are met[(1)]:

1. the R^2 is greater than or equal to 0.50,
2. the sample size is greater than or equal to 4,
3. the number of trips increases as the size of the independent variable increases.

If *Trip Generation* were to expand the analysis and use regression with two variables, the R^2 value may be greater than 0.50 in some cases. Using this analysis, an equation could be formulated to project traffic volumes. For example, the equation based on Gaming Area (Square Feet) alone for the weekday a.m. peak hour for the generator had a R^2 value of 0.45. *Trip Generation* would not plot the fitted curve for this data. The equation for this linear regression analysis is:

Trip Ends = 308 + (2.866*1000 Sq. Feet Gaming Area) (1)

Figure 2 and ***Figure 3*** shows the graphs of the average weekday and weekend day for each casino along with the actual fitted curve equation. The actual data points represent the average for each casino.

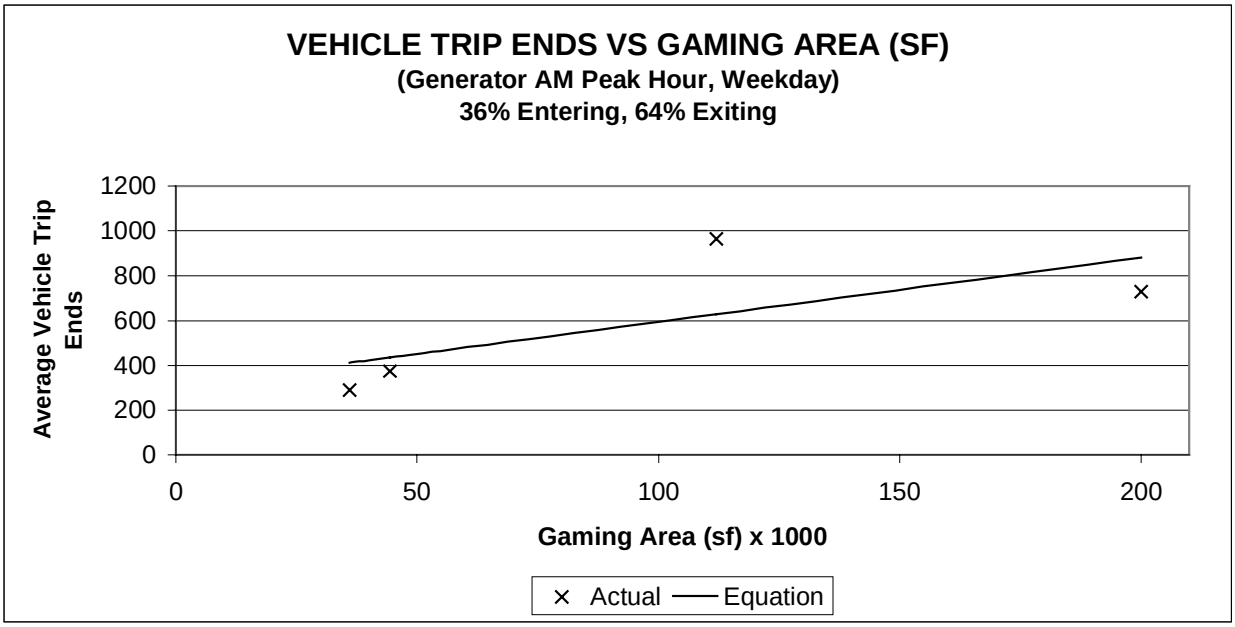

Figure 2

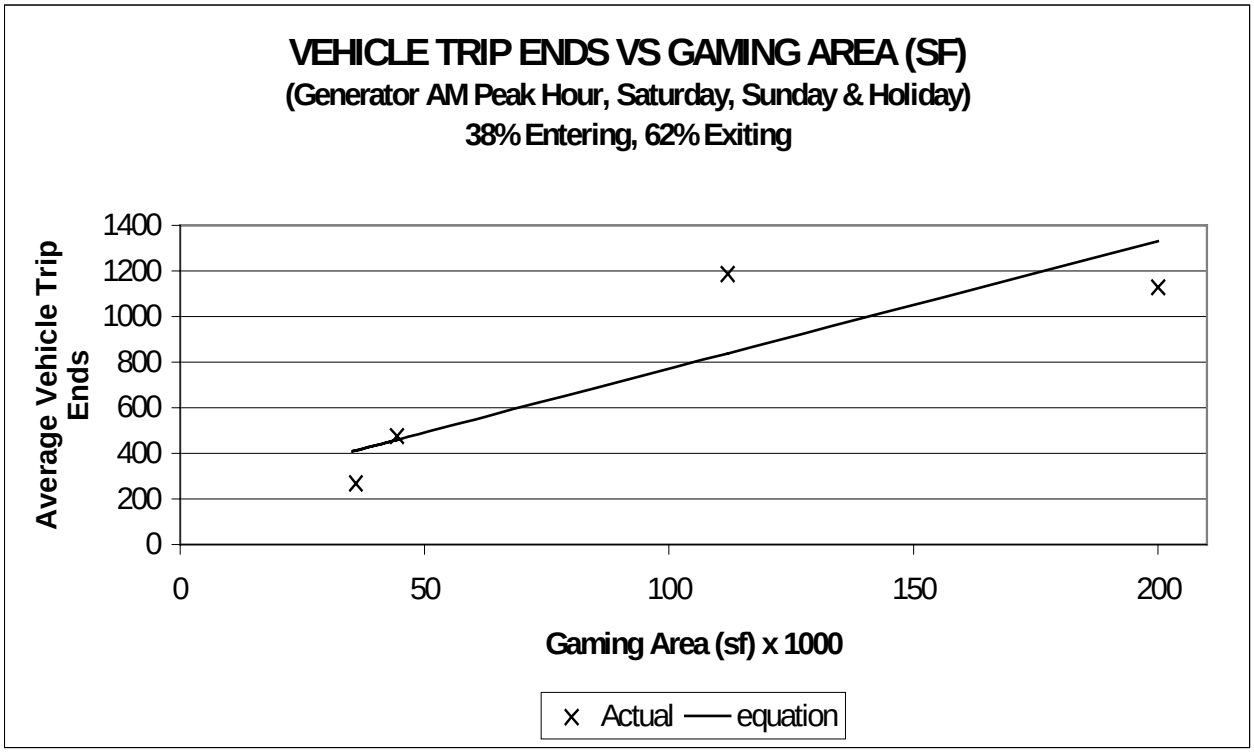

Figure 3

When the same data is analyzed for the same time period using the linear regression equation for two variables, Gaming Area (Square Feet) and Hotel Rooms, the R^2 value increases to 0.93. The equation for this linear regression analysis is:

Trip Ends = 302+(6.72*1000 Sq. Feet Gaming Area)+(-0.582*Hotel Rooms) (2)

Regression analyses were also performed on the daily total vehicle trip ends. The equations produced by this regression analysis can be seen in ***Table 5***, while two example graphs can be seen in ***Figure 4*** and ***Figure 5***.

Table 5 Daily Total Equations and R^2 Values	
Weekday Gaming	
$R^2 = 0.449$	Trip Ends = 5547 + (60.637*1000 Square Feet Gaming Area)
Weekend Gaming	
$R^2 = 0.656$	Trip Ends = 5114 + (103.90*1000 Square Feet Gaming Area)
Weekday Employees	
$R^2 = 0.824$	Trip Ends = 3084 + (3.268*Employees)
Weekend Employees	
$R^2 = 0.901$	Trip Ends = 3610 + (4.629*Employees)
Weekday Gaming & Hotels	
$R^2 = 0.908$	Trip Ends = 5369 + (0.140*1000 Square Feet Gaming Area) + (-11.956*Hotel Rooms)
Weekend Gaming & Hotels	
$R^2 = 0.949$	Trip Ends = 5624 + (0.185*1000 Square Feet Gaming Area) + (-13.387*Hotel Rooms)
Weekday Employees & Hotels	
$R^2 = 0.949$	Trip Ends = 4113 + (3.945*Employees) + (-4.336*Hotel Rooms)
Weekend Employees & Hotels	
$R^2 = 0.936$	Trip Ends = 4464 + (5.096*Employees) + (-3.371*Hotel Rooms)

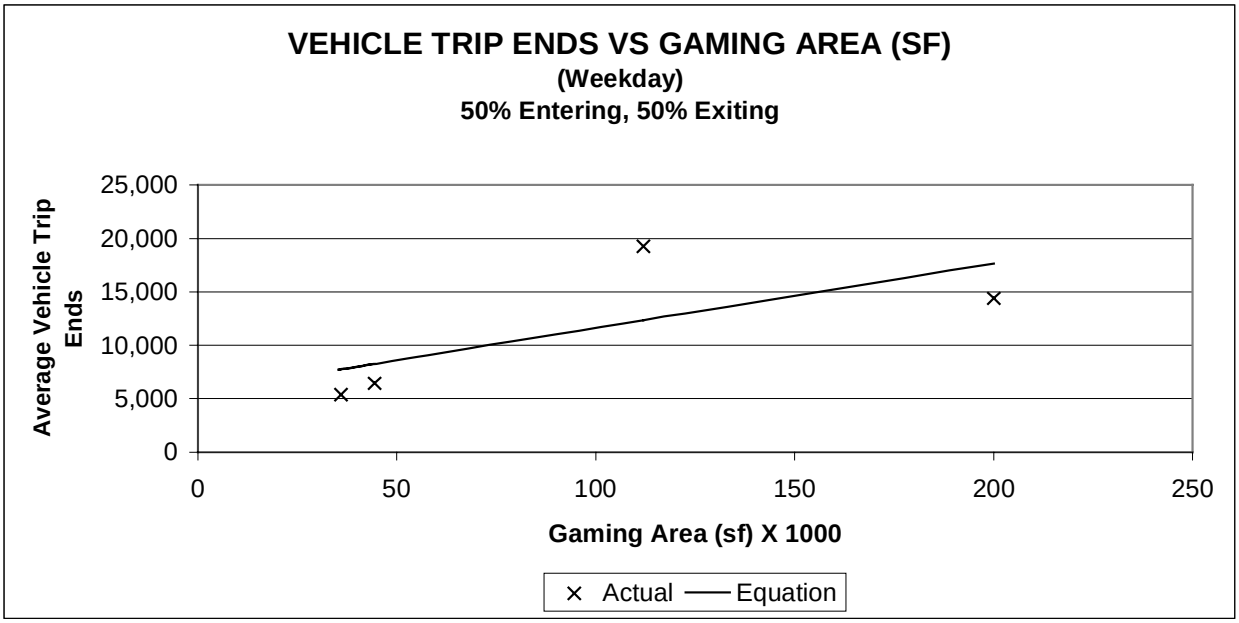

Figure 4

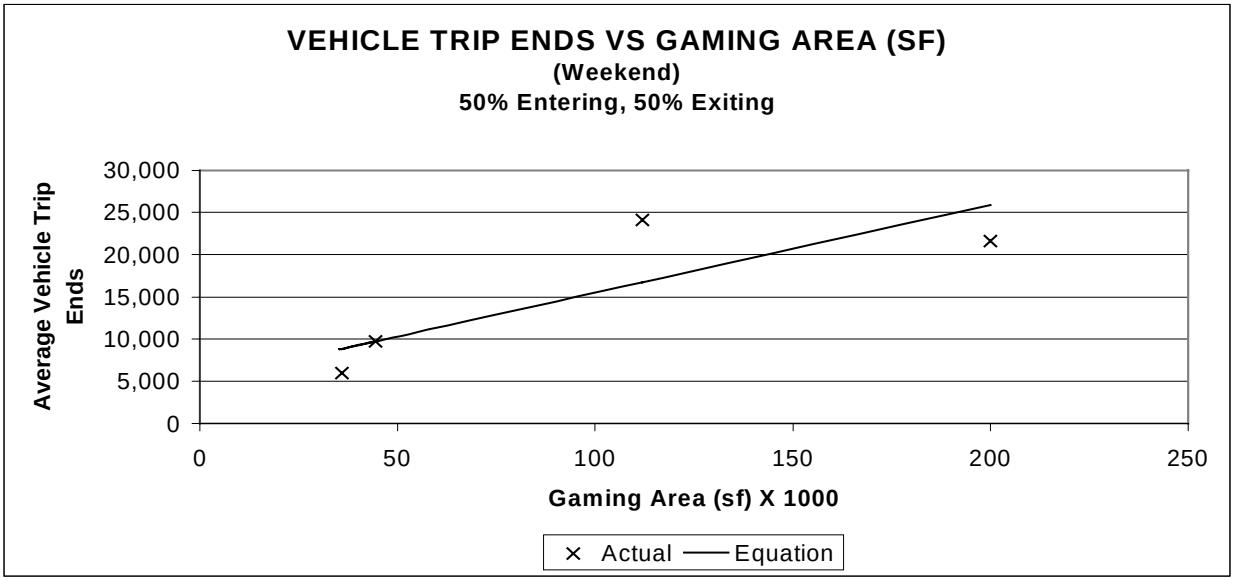

Figure 5

TRIP GENERATION PREDICTION EQUATIONS

In this study, thirty-two by stepwise regression (backward elimination) and twenty-six by additional regression were developed, producing a total of fifty-eight usable equations. Five equations were not used because R^2 values were less than 0.10. There were no equations

developed for Hotel Rooms alone with an R^2 value greater than 0.10. Graphs similar in format to those found in *Trip Generation* are included for Employees alone, Gaming area alone, Employees and Hotel Rooms, and Gaming Area and Hotel Room for A.M. and P.M peak hour of the generator and adjacent street for weekdays and weekends.

SUMMARY

This study was conducted in Tunica County, Mississippi with the objective of developing equations and graphs which could be useful in predicting the number of trips generated by casinos. The study yielded 50 equations and charts using the independent variables: Gaming Area (Square Feet), Employees, Hotel Rooms, Table Games, and Slot Machines. By applying these equations using known independent variables, these data can be used to evaluate current roadway systems operations to determine if they can adequately handle the increased traffic with the addition of the traffic generated by the new casino.

Prior to using the equations developed in this study, the limitations must be considered. These equations were developed by only using land-based casinos in Tunica County where in some cases multiple casinos were grouped together to function as a single generator. In addition, each casino offers its own amenities. If this same study was performed in another area of the country, the equations formulated may not be similar. Until studies like this one are conducted in other areas of the country and compared and added to the data set, the transferability to other locations is limited.

Several factors that were not considered in developing the equations were related to individual choice considerations why people chose to visit a particular casino. Each casino offers their own amenities that appeal to different people. Some of these amenities include: childcare facilities, youth entertainment, giveaways, special events, and food.

This list of positive amenities offered by casinos certainly affects the choice of one casino over another, but one negative factor, travel time, must be considered when evaluating the data. The failure of the original casinos (Splash, Lady Luck and the original Bally's) indicates that, as travel times increase between casinos, the less likely the visitor is to travel to the further casino. Tunica County casinos have constantly been moving closer to Shelby County, Tennessee. Memphis is the single largest generator of visitors to Tunica casinos. According to the Mississippi Gaming Commission survey data, 30% of the visitors to the northern region of Mississippi casinos come from Tennessee. The northern region includes casinos in Tunica and Helena. From actual license plate observations in Tunica casino parking lots, the percentage of vehicles from Shelby County seems to be even higher with some observations as high as 50%.

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ENDNOTES

1. Institute of Transportation Engineers, Trip Generation User's Guide. 6th Edition, Volume 3 of 3, Washington, D. C.: 1997.