Short Term Traffic Flow Prediction Of The Cross Bronx Expressway by Monte Carlo Method

Anushka Patel

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Abstract:

In major urban cities such as New York City traffic congestion is a major problem. Due to the restricted amount of roads due to lack of land and the rise of the human population especially in areas such as NYC where the situation is progressively getting worse. Traffic congestion remains a major problem. The Cross Bronx Expressway is ranked number 1 for the most congested U.S Roads in 2016. The congestion also has detrimental effects on the environment due to the vehicles emitting emissions that pollute the air. Additionally waiting in traffic also waste time,fuel, and money. In order to conclude suggestions to improve the traffic flow the predicted traffic flow count is a key parameter in handling traffic issues in relation to optimizing the flow. In order to predict traffic flow of the Cross Bronx Expressway the Monte Carlo method is used. It was found through this experiment conducted that the Monte carlo method provided an accurate model for predicted traffic volumes which could help traffic operations account for the inherent variability of daily demand volumes.

Introduction:

According to a study conducted by INRIX, a company that is dedicated to resolving transportation issues worldwide through the means of providing information on traffic and other analytics. New York, NY is ranked number one for the most congested U.S Roads for the year 2016. The I-95 Westbound from Exit 6A(I-278) to Exit 2 (Trans-Manhattan Expressway) has the worst peak period PM time with total hours of delay being eighty-six hours per year (Cookson,2017). Not only is time wasted as a result of traffic congestion, but traffic congestion is also known to cause detrimental effects to both the environment as well as our health (University, 2016). Since there are several vehicles that are emitting these harmful emissions it accumulates in the air causing multiple health problems for humans such as respiratory infections and can even place people at risk for cancer (Ghorani-Azam, 2016). In terms of the environment and the species living in our environment air pollution affects both animals and plants contributing to these species extinction (Lovett, 2009). Other major detrimental effects of air pollution on the environment from the emissions from these vehicles when they are in traffic including global warming, and acid rain (Schneider,1989). Waiting in traffic also wastes fuel, money, and prompts road rage which poses a direct threat to the driver itself as well as the people in his or her surroundings. In another study conducted by INRIX, they found that the yearly cost because of traffic for families in America is around 1,700 dollars and is expected to increase 33 percent to 2,300 in the year 2030 (Cookson, 2017). These statistics demonstrate that on top of traffic being a serious problem today the situation is only going to get much worse in the years to come with average driver spending increasingly more money each year. In New York City, the Cross Bronx Expressway built by Robert Moses is a significant freeway in the Bronx notorious for the mass amount traffic drivers face when they are on this roadway (Ploschnitzki, n.d). Starting at the Alexander Hamilton Bridge and ending at the Throgs Neck Expressway as depicted in figure 1 it functions at full capacity the whole day.

Figure 1. Image of the Cross Bronx Expressway starting at the Alexander Hamilton Bridge and ending at the Throgs Neck Expressway (Chinissai,2014).

Even at night when the traffic becomes lighter at 68 percent of its capacity, it functions at a level F in terms of the level of service (LOS). Level of service is a concept that measures the quality of traffic flow with rankings of A through F. A meaning free flow, E meaning very unstable flow, and F meaning failure of flow. Specifically pertaining to this case it means that the traffic flow is forced in which the magnitude of traffic approaching a given point surpasses the amount that is possible to function. It is marked by stop and go waves, dreadful travel times, poor comfort and convenience, and increases the likelihood of an accident occurring. The traffic a motorist experiences on this roadway is possibly due to the existing infrastructure. The tunnels are under a subway line and the motorway is full of narrow lanes with no shoulders which are the emergency stopping lanes located on the right side of the roads in the United States in order to provide safety to the driver in an event of an emergency as well as not disrupt the traffic flow of the

expressway (Alpert,2003). Many people depend on this roadway on a daily basis, however it makes the lives of individuals much more difficult. In urban cities such as New York City, traffic congestion is a major concern. Due to the rise in the population, an increasing number of vehicles with the combination of limited availability of land for roads, traffic management develops into an important concern. The proposed method for traffic engineers needed to combat this problem is to develop distinct new traffic management strategies. These methods that the traffic engineers use require a thorough study and analysis of traffic trends which are dependent on the different parameter for instance traffic volumes, travel speeds, and occupancies. In the report "On The Architecture of Intelligent Transportation Systems," the researchers established that the short term predictions of traffic flow count which is the process of directly estimating expected traffic conditions at a future time, taking into account continuous short-term feedback of traffic information using the Monte Carlo method can be applied to enhance the efficiency and the sustainability of the current road conditions (Du,2009). Although researchers have applied this technique in predicting the short term traffic flow for the different location it has not yet been applied to the Cross Bronx Expressway. Thus this is the gap my research is filling in the field of transportation engineering in relation to improving the flow of the Cross Bronx Expressway. Hence the main objective of my study is to resolve traffic-related problems dealing with analysis, design, planning, and management pertaining to the Cross Bronx Expressway by predicting the short term traffic flow. Since the predicted short term traffic flow is an extremely important parameter utilized by traffic engineers to prescribe methods to improve traffic flow (Mishra, 2015). The forecasted short-term traffic flow values are also vital to intelligent transportation systems (ITS) which are applications that better the effectiveness of surface transportation systems and resolve transportation issues by employing current information and communication technologies. Thus due to the increasing traffic demand it is necessary to implement intelligent transportation systems and employ traffic engineers which both require the short term forecasting data in order to improve the efficiency as well as the sustainability of the expressway. As a result, it makes the predicted short term traffic counts an extremely important in order to achieve the goal of reducing traffic congestion on this particular roadway.

Literature Review:

With an aim of understanding efficient strategies to improve the efficiency and sustainability of the Cross Bronx Expressway from Exit 6A(I-278) to Exit 2 (Trans-Manhattan Expressway), it is important to know the existing research about the topic of inquiry. Many different researchers in the field of traffic engineering have used the Monte Carlo Method which is a computerized statistical tool that is utilized when risk or uncertainty is involved, and this technique can also be used to forecast data by using historical data as utilized in my experiment. The Monte Carlo Simulation uses random numbers by simulating it in an effort to learn a system. Specifically pertaining to the field of traffic engineering it can be used to evaluate the performance of concrete pavement, analyzing vehicle collisions, and evaluate traffic assignment in intersections. Some of the researchers looked into applying this technique with the Accelerated Pavement Testing (APT) which is the controlled loading of the pavement to evaluate the structure and the performance of asphalt pavement (Li,2002). Other traffic engineers took the pavement testing step further and evaluated the performance of the pavement under different volumes of traffic in an effort to identify how the pavement reacts to different factors such as traffic volume on pavement reliability (Prozzi,2005). In terms of applying the Monte Carlo Simulation to testing pavement researchers have widely used this method to test their topics of inquiry an additional example being how the Monte Carlo Simulation was used by Lamptey et al. to conduct a life-cycle cost analysis of pavements taking into account the uncertainty of sustained funding for factors such as highway replacement, rehabilitation, and maintenance (Lamptey,2005). Another utilization was employing the Monte Carlo Simulation to look at collisions when the uncertainty for accidents is taken into account(Wach,2006). Furthermore, other research that was conducted specifically looked at intersections and created models using the Monte Carlo Method for traffic assignment using the turning probability since the professionals conducting the experiment were working with intersections(Du,2009). Moreover, John Taplin tested other simulation models to assign traffic to a network. His research demonstrated that an alternative approach to the standard method of traffic assignment which is to find a static equilibrium in which no motorist would have the ability to find a quicker route. Despite the fact that this standard technique allows for fairly good predictions the alternative approach using a stochastic user equilibrium accounts

for much more variability. Thus he concluded that microsimulations such as the Monte Carlo simulation provide excellent models for Traffic Flow (Taplin,1999). The Monte Carlo Method has not exclusively been applied to solving traffic congestion for highways, and intersections, but it can also be applied to resolving other additional types of congestion such as optimizing the air traffic flow to improve the safety of flights. This method proved to be successful in improving the safety of many individuals by upgrading the minimum safe separation of aircraft which depends heavily on the density of air traffic and the region. (Visintini, 2006). In regards to the objective of this study, although there has been various studies involving the prediction and analysis of traffic flow, there is still yet to apply the Monte Carlo simulation to predict the short traffic flow where the Cross Bronx Expressway is concerned. Currently, there has been no additional word to what actions are being taken to reduce traffic congestion on the Cross Bronx Expressway. Last any proposals about reducing congestion on the Cross Bronx Expressway was from Mayor De Blasio in October of 2017 where he revealed a five-point plan aimed at reducing traffic congestion. Specifically for the Cross Bronx Expressway, they were testing measures like placing traffic lights at exits and emergency vehicles along the route to quickly handle accidents. (Mayor,2017) These proposals have yet to be enforced thus indicating the significance of forecasting the short term traffic flow of this segment (Vlahogianni,2014). Although predicting the short term traffic flow volume of the Cross Bronx Expressway utilizing the Monte Carlo Method has yet to be done. Other researchers have successfully applied this technique to different motorways throughout the world. One study selected the Delhi-Gurgaon Expressway in India the traffic engineers took past traffic flow data for a twenty-four hour time period and used the Monte Carlo Simulation to obtain short term predictions. The researchers found that short term traffic prediction is a major step in traffic management strategies as well as Intelligent transportation systems it provided accurate results that could be easily utilized. Similarly, another team of researchers applied the Monte Carlo Method to junction-1 and junction 2 of the Dublin Airport route in Ireland. They collected traffic flow data every ten-minute interval for a twenty-four hour day. The researchers found that the simulated results can be used to improve traffic management by using these predictions and distribution properties as a way for traffic management and operations to change according to the demand traffic flow in order to achieve

better traffic management. As a result, short term predicted traffic flow is significant in improving the current highway condition, therefore, it can be applied to a highly congested highway such as the Cross Bronx Expressway in an effort to reduce the severe amount of traffic congestion.

Methods:

In order to predict the traffic flow of the Cross Bronx Expressway the Monte Carlo method was used. The Cross Bronx Expressway was selected because the I-95 westbound from Exit 6A (I-278) to Exit 2 (Trans-Manhattan Expressway) is rated the most congested roadway in the United States. Thus this particular segment of this roadway was chosen due to the mass amount of congestion motorist experience on just this segment alone. Once the area of study was determined, the traffic hourly volumes were received for the segment that was studied. In order to obtain the data, the New York State Department of Transportation was contacted and asked that they provided the most recent data from the I-95 westbound from Exit 6A (I-278) to Exit 2 (Trans-Manhattan Expressway). The data eventually received from the New York State Department of Transportation was a Traffic Count Hourly Report from Macombs Rd over to the end of I-95/ US 1 Olap Webster Ave for the month of December during the year 2017. This segment of the Cross Bronx Expressway is depicted in figure 2.

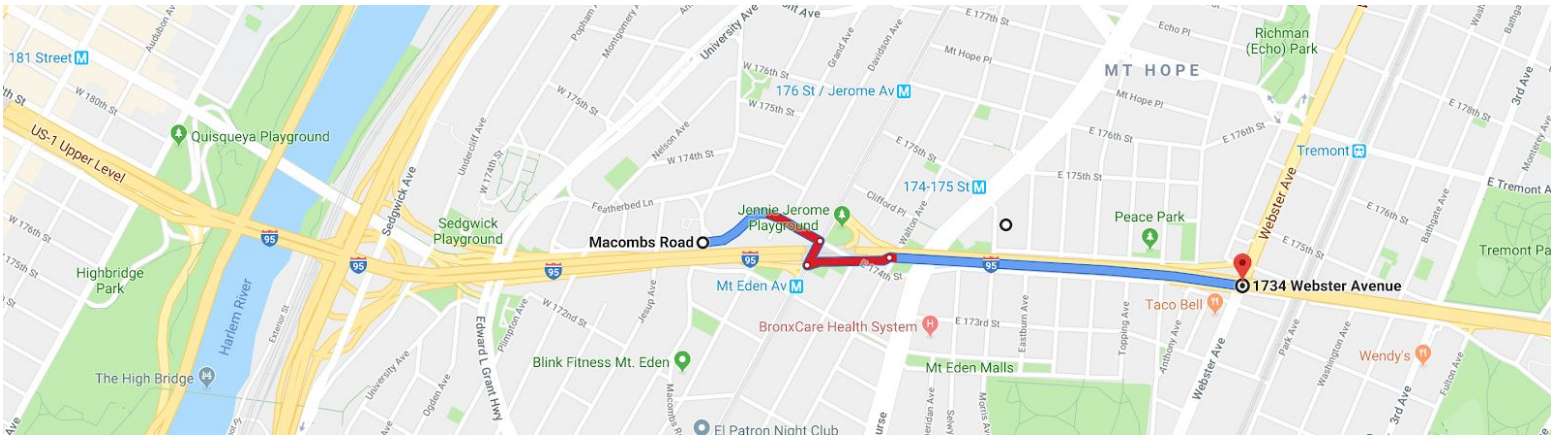


Figure.2. A screenshot of a segment on the Cross Bronx Expressway from Macombs Rd over to the end of I-95/ US 1 Olap Webster Ave from google maps.

STATION: **010003**

New York State Department of Transportation

Traffic Count Hourly Report

ROUTE #: I 95 ROAD NAME: **Cross Bronx Exp** FROM: **MACOMBS RD OVER** TO: **END I95/US1 OLAP WEBSTER AVE** COUNTY: **Bronx**
DIRECTION: Northbound FACTOR GROUP: 30 REC. SERIAL #: 0000 FUNC. CLASS: 11 CITY:
STATE DIR CODE: 1 WK OF YR: 48 PLACEMENT: NHS: no LION#:
DATE OF COUNT: 12/01/2017 @ REF MARKER: JURIS: City BIN:
NOTES LANE 1: Right lane ADDL DATA: Speed CC Stn: 0199 RR CROSSING:
NOTES LANE 2: Middle lane COUNT TYPE: VEHICLES BATCH ID: DOT-12-December HPMS SAMPLE:
COUNT TAKEN BY: ORG CODE: DOT INITIALS: DGV PROCESSED BY: ORG CODE: DOT INITIALS: TEW

		AM												PM													
DATE	DAY	12 TO 1	1 TO 2	2 TO 3	3 TO 4	4 TO 5	5 TO 6	6 TO 7	7 TO 8	8 TO 9	9 TO 10	10 TO 11	11 TO 12	12 TO 1	1 TO 2	2 TO 3	3 TO 4	4 TO 5	5 TO 6	6 TO 7	7 TO 8	8 TO 9	9 TO 10	10 TO 11	11 TO 12	DAILY TOTAL	DAILY HIGH COUNT	DAILY HIGH HOUR
1	F	1484	1234	1071	1233	1802	3175	4097	3777	4070	3880	2785	2807	2842	2915	3766	3680	3648	3003	3714	3798	4424	4425	3037	1910	72577	4425	21
2	S	1815	1557	1524	1508	1683	1567	1816	2870	3992	4212	3223	3178	3214	3844	4575	4430	4394	4210	4310	4635	4566	4454	4803	4431	80811	4803	22
3	S	3954	2855	2097	1899	1840	1495	1693	2380	2987	3585	4449	4878	4749	4469	4011	4110	4456	4396	4579	4701	4514	4023	3571	2976	84667	4878	11
4	M	2179	1391	1217	1318	1938	3409	4265	4428	4213	3943	4273	3429	4319	4300	4558	3988	3859	4003	3881	4246	3962	3606	2906	1700	81331	4558	14
5	T	1345	985	920	1058	1773	3224	4494	4861	4221	3910	3971	3941	3779	4103	4034	3595	3748	3872	3873	3883	3047	3455	2976	1814	76882	4861	7
6	W	1326	1031	1134	1008	1541	2579	3730	4528	4331	4287	2923	2790	2737	3254	4180	3786	3786	3857	4061	4575	4277	3912	3230	2483	75346	4575	19
7	T	1490	1306	1202	1232	1799	3334	4047	4118	3917	4326	4042	4111	3830	4084	4194	3830	3768	3697	4138	4438	4373	4233	3710	2844	82063	4438	19
8	F	1568	1325	1259	1220	1887	3292	4531	4404	4321	4263	4180	4165	3199	3786	4173	3762	3718	3342	3998	3338	3138	3597	3892	2276	78634	4531	6
9	S	1693	1623	1502	1668	1757	1736	2179	2807	3634	3733	3829	3953	3858	3778	4134	3865	4105	4094	3954	3639	3612	3593	3471	3416	75633	4134	14
10	S	2832	2060	1641	1431	1436	1224	1470	2066	2578	3187	4062	4610	4736	4578	4664	4379	4753	4245	4327	4646	4370	4092	3740	2867	79994	4753	16
11	M	2013	1462	1161	1234	2013	3387	4527	4579	3871	3903	3915	3801	3776	3862	4000	3723	3378	3807	3901	4027	3988	3528	3065	2296	79217	4579	7
12	T	1842	1348	1141	1133	1773	3289	2783	2676	3969	4155	4261	3791	4106	3957	3925	3883	3677	3199	2913	3563	3675	4020	3378	2240	74697	4261	10
13	W	1639	1344	1165	1131	1737	3185	4428	4351	4338	4401	4110	3811	4217	4147	3726	2564	3659	3224	3757	4251	4278	3940	3068	2300	78771	4428	6
14	T	1490	1227	1080	1294	1782	2940	3952	3962	3909	4172	3956	4016	3984	4060	3912	3729	3693	3122	3606	3927	4005	4209	3484	2656	78167	4209	21
15	F	2541	1869	1488	1405	2108	3203	4526	4434	3884	4039	3880	3149	3812	4062	3403	3132	2670	2668	2787	3437	3991	3963	3713	3284	77448	4526	6
16	S	2705	2104	1692	1563	1643	1776	2312	2985	3983	4323	4468	4397	4232	4468	4186	4155	3594	4141	4297	4317	4131	3571	4439	4398	83880	4468	10
17	S	4290	3076	2470	1622	1958	1582	1696	2137	2602	3620	4419	4676	4906	4463	4339	4148	4270	4292	3842	2892	4455	4264	4133	3231	83383	4906	12
18	M	2272	1494	1275	1290	988	854	2830	3768	4151	4153	4108	3946	4194	3818	4024	3760	3710	3268	3800	3899	3551	3761	3368	1880	74162	4194	12
19	T	1426	1231	1123	1143	1795	3233	4438	4614	3974	4030	3931	3938	4049	3968	4051	3806	3816	3513	3582	4249	4405	4077	3519	1977	79888	4614	7
20	W	1496	1313	1178	1174	1800	3307	4358	4246	3870	4131	4026	3987	3693	4052	3723	3616	3604	3740	3812	3421	4097	4185	3496	3018	79343	4358	6
21	T	2296	1729	1364	1356	1761	3376	4520	4305	3873	3595	3618	4113	3833	3945	3798	3691	3682	3661	3922	4116	4363	4402	2043	1759	79121	4520	6
22	F	1627	1402	1410	1432	1729	3306	4344	4473	4277	4314	4052	4053	3759	3078	3744	3666	3313	3994	2935	3241	3958	4603	4305	3843	80858	4603	21
23	S	3044	2395	2089	1781	1881	1783	2251	2969	3654	4000	4402	4276	4190	4077	4091	4144	4103	4156	4449	4521	4519	4122	4400	4273	85570	4521	19
24	S	3304	2393	1969	1639	1684	1440	1599	2264	2837	3617	4445	4937	4926	4566	4352	4167	4412	4423	4106	4275	4623	4218	4323	4318	84837	4937	11
25	M	3527	3314	2290	1671	1308	1048	1254	1610	1860	2374	3305	4512	4263	3979	4563	4351	4059	2506	4026	4824	4758	4695	4474	3446	78017	4824	19
26	T	2226	1414	1111	995	1350	2379	3640	3504	3915	4130	4356	4567	4253	4210	4089	3844	3834	3843	4165	3996	4436	4235	3547	2867	80906	4567	11
27	W	2021	1393	1250	1230	1716	2825	4027	3921	4069	4206	4141	3481	4167	4029	3918	3888	3378	2194	2415	3990	4479	4208	3590	2585	77121	4479	20
28	T	1989	1541	1382	1247	1728	2727	3187	2953	3987	4058	3117	3091	3640	3976	4142	3809	2860	3896	4319	4231	4384	4185	3992	2865	77306	4384	20
29	F	2404	1697	1374	1334	1810	2341	3749	3741	4018	4214	4441	4480	3738	4319	3905	3899	3906	4078	4301	4422	4595	4630	4371	3730	85497	4630	21
30	S	2945	2281	1968	1637	1872	1714	2005	2483	3121	3476	3923	4036	4109	4296	4373	4202	4400	4400	4480	4538	4351	4231	4054	3560	82455	4538	19
31	S	2745	2185	1659	1563	1575	1253	1446	1827	2270	2899	3667	4104	4431	4790	4999	4687	4948	4594	4715	4638	3494	3463	3755	2679	78386	4999	14
		AVERAGE WEEKDAY HOURS (Axle Factored, Mon 6AM to Fri Noon)																								**ADT**		
		1777	1376	1215	1213	1758	3042	3892	3964	3954	4023	3876	3809	3928	3984	4052	3741	3657	3463	3761	4102	4130	4041	3365	2421	78544		

DAYS Counted	HOURS Counted	WEEKDAYS Counted	WEEKDAY Hours	AVERAGE WEEKDAY High Hour	AVERAGE WEEKDAY % of day	Axle Adj. Factor	Seasonal/Weekday Adjustment Factor	ESTIMATED
31	744	17	420	4130	5%	1.000	1.019	**AADT 77079**

ROUTE #: I 95 ROAD NAME: **Cross Bronx Exp** FROM: **MACOMBS RD OVER** TO: **END I95/US1 OLAP WEBSTER AVE** COUNTY: **Bronx**
STATION: **010003** STATE DIR CODE: **1** PLACEMENT: **DATE OF COUNT: 12/01/2017**

Figure.3. An image of the Traffic Count Hourly Report from December 2017 for the Macombs Rd over to the end of I-95/ US 1 Olap Webster Ave.

The Traffic Count Hourly Report received from the New York State Department of Transportation is shown in figure 3. The Traffic Count Hourly report contains numerous different kinds of information such as the hourly traffic counts, daily total, daily high count, daily high hour, and information about the segment itself. The hourly traffic counts itself included all types of vehicles that came upon this roadway during this given time period. Even though the report contained multiple pieces of information the only piece of information that was required in

order to run the Monte Carlo Simulation was the traffic hourly volumes. The traffic count data that the New York State Department of Transportation had in their possession was collected from a continuous count station these locations run 24 hours 365 days a year. The continuous count stations are permanent sites that are used to monitor overall traffic trends they collect a variety of different kinds of data such as speed, vehicle classification, and volume. These sites use many different sensors and arrays to gather this type of data. The traffic count stations are located where there are short segments of the route in which traffic volumes are approximately equal. The sections start and finish at points where there is a significant change in traffic volume, for instance, major intersections with another highway or at places of important traffic-generating features. Using the data received from the New York State Department of Transportation each hour of the data was fitted to a normal distribution. Given that Excel was not capable of fitting data to a normal distribution, XLSTAT a statistical software used to analyze data was necessary to implement in this experiment. To identify if a normal distribution would fit the data a Kolmogorov- Smirnov Goodness of Fit Test (K-S test) was conducted to test the goodness of fit of the distribution. The Kolmogorov- Smirnov Goodness of Fit Test compares your data with a known distribution. For this experiment, it was comparing the hourly original traffic volumes to a normal distribution and then the results of that test lets you know whether or not your data fits the known distribution. A normal distribution is a function that portrays the distribution of random variables as a symmetrical bell-shaped. In this case, the Kolmogorov-Smirnov Goodness of Fit Test tested the goodness of fit for each hourly data to a normal distribution at a significance level of alpha=.05 since that was the significance level that was used in the peer review article "Short Term Traffic Prediction Using Monte Carlo Simulation"(Mishra, 2015)The reason why a normal distribution was fitted to each hour was in order to avoid an unlikely comparison between the original data and forecasted data. For instance, if you were predicting the traffic volume for the Cross Bronx Expressway at 2 AM. The original hourly traffic volume for 2 AM is typically around 1215 and when the Monte Carlo Simulation ran the forecasted value calculated came out to be 4023 a value that is common during the time period of 9 PM and not common during the time period of 2 AM. In order to avoid these comparisons since the average count does vary widely by time of day in most places

due to a normal active hour and commuting patterns, it was necessary to create hourly fitted distributions. If the p-value calculated for each hour was greater than the significance level alpha=.05, one can accept the null hypothesis, and reject the alternative hypothesis that the sample does not follow a normal distribution. The null hypothesis pertaining to this experiment was the sample follows a normal distribution, and the alternative hypothesis was the sample does not follow a normal distribution. Thus if the calculated p-value for each hour is greater than the significance level alpha=.05 a normal distribution does provide a good fit and the parameters can be used. Based off of the normal distribution the parameters from each hour were obtain**ed** and the Monte Carlo Simulation was conducted using the mean and the standard deviation of the fitted normal distribution. The Monte Carlo Simulation itself was conducted in Excel. Excel was chosen to conduct the Monte Carlo Simulation over other spreadsheet programs such as Numbers due to the fact that Excel is a powerful tool commonly used to conduct this type of simulation in a variety of different fields whereas other spreadsheet programs such as Numbers are not as commonly used to conduct this type of traffic simulation. The Monte Carlo Simulation was chosen as a method to use in order to predict the short term traffic flow of the Cross Bronx Expressway. This technique was utilized instead of additional methods such as Artificial Neural Networks (ANN), and Fuzzy logic which are other methods to predict the traffic flow. Because although both of these methods are used by several researchers to predict the short term traffic flow. The Monte Carlo Simulation was selected due to how the technique itself was more commonly utilized in the field to predict the short term traffic flow than Artificial Neural Networks (ANN), and Fuzzy logic. Additional this technique is simple yet extremely powerful and proves on multiple occasions just how efficient and robust the simulation is when applied to predict the short term traffic flow. For instance in both the papers "The Short Term Traffic Flow Prediction By Monte Carlo Simulation" and "The Short Term Traffic Prediction Using Monte Carlo Method." The Monte Carlo Method was successfully used to predict the short term traffic flow resulting in low mean absolute percent errors demonstrating how the quality of the predicted traffic flow counts are very good. After the Monte Carlo Simulation was conducted with 6000 iterations in Excel for each hour the iterations were averaged and the average of the original data was compared to the average of the forecasted data on an hour by hour basis using

the Mean absolute percent error test (MAPE) to measures the quality of the predicted counts. The formula is shown below in figure 4.

$$MAPE = \frac{\sum \frac{|A-F|}{A} \times 100}{N}$$

Figure. 4. A photo of the Mean Absolute Percent Error Formula from The Institute of Business Forecasting and Planning.

Results:

All the calculated p-values for each hourly distribution were greater than a significance level of alpha=.05. Thus one can not reject the null hypothesis that the sample follows a normal distribution and reject the alternative hypothesis that the sample does not follow a normal distribution. In figure 5 it depicts the normally fitted distribution for each hour during the time period 12 AM to 12 PM all the AM values, and in figure 6 it shows the normally fitted distribution for each hour during the time period of 12 PM to 12 AM all the PM values. The results of the Monte Carlo Simulation for the short term prediction using the 24 hour time interval for the whole month of December in the year 2017 found that the mean absolute percentage error is .19 percent which is depicted in figure 7.

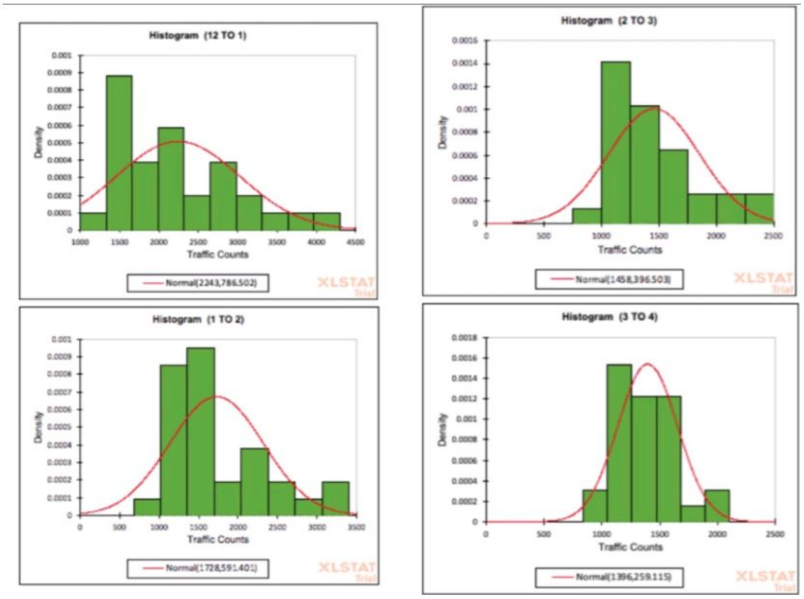
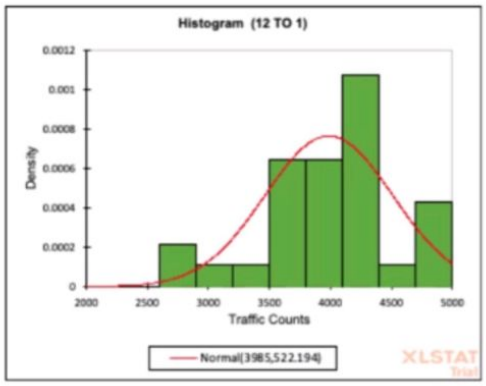
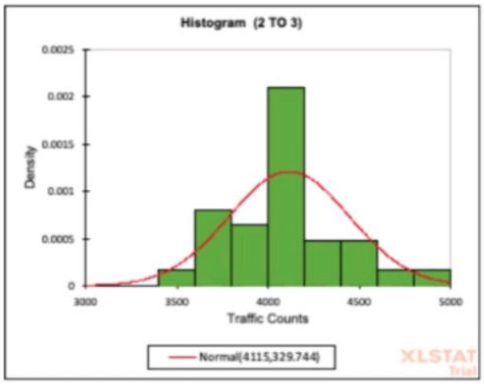
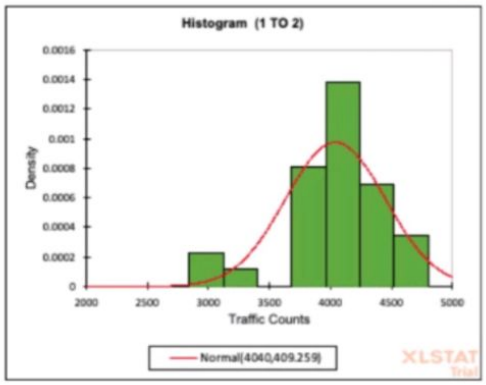
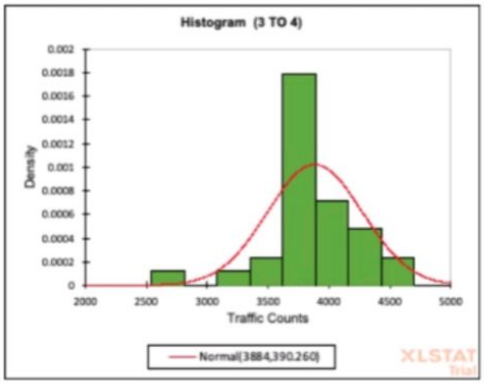


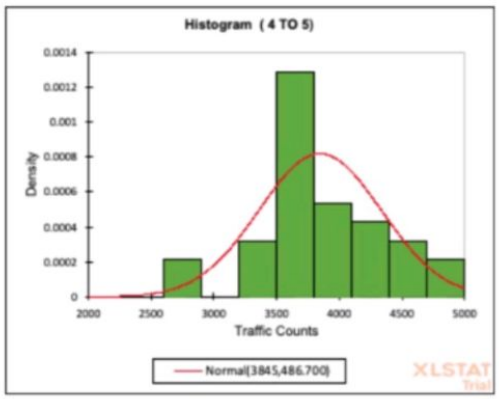
Figure 5. 12 AM to 12 PM hourly normally fitted distributions.

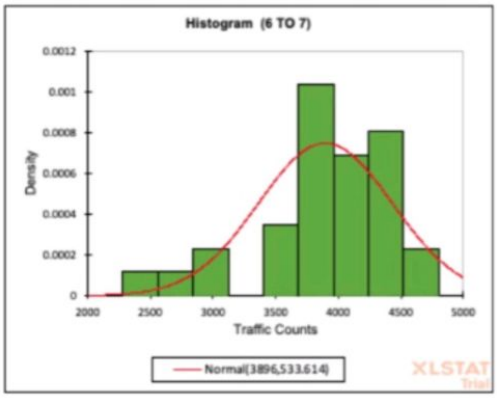

Histogram (12 TO 1)
Density
Traffic Counts
Normal(3985,522.194)
XLSTAT
Trial

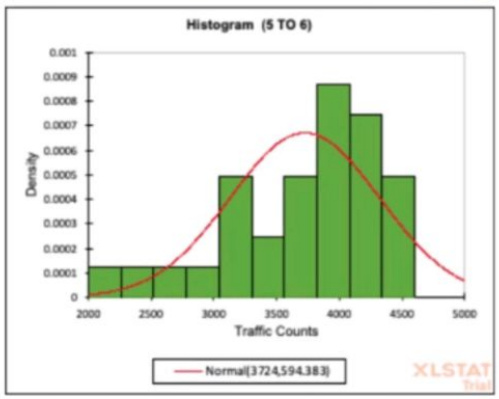

Histogram (2 TO 3)
Density
Traffic Counts
Normal(4115,329.744)
XLSTAT
Trial

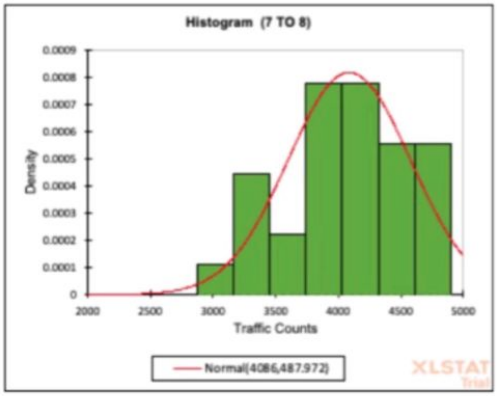

Histogram (1 TO 2)
Density
Traffic Counts
Normal(4040,409.259)
XLSTAT
Trial


Histogram (3 TO 4)
Density
Traffic Counts
Normal(3884,390.260)
XLSTAT
Trial


Histogram (4 TO 5)
Density
Traffic Counts
Normal(3845,486.700)
XLSTAT
Trial


Histogram (6 TO 7)
Density
Traffic Counts
Normal(3896,533.614)
XLSTAT
Trial


Histogram (5 TO 6)
Density
Traffic Counts
Normal(3724,594.383)
XLSTAT
Trial


Histogram (7 TO 8)
Density
Traffic Counts
Normal(4086,487.972)
XLSTAT
Trial

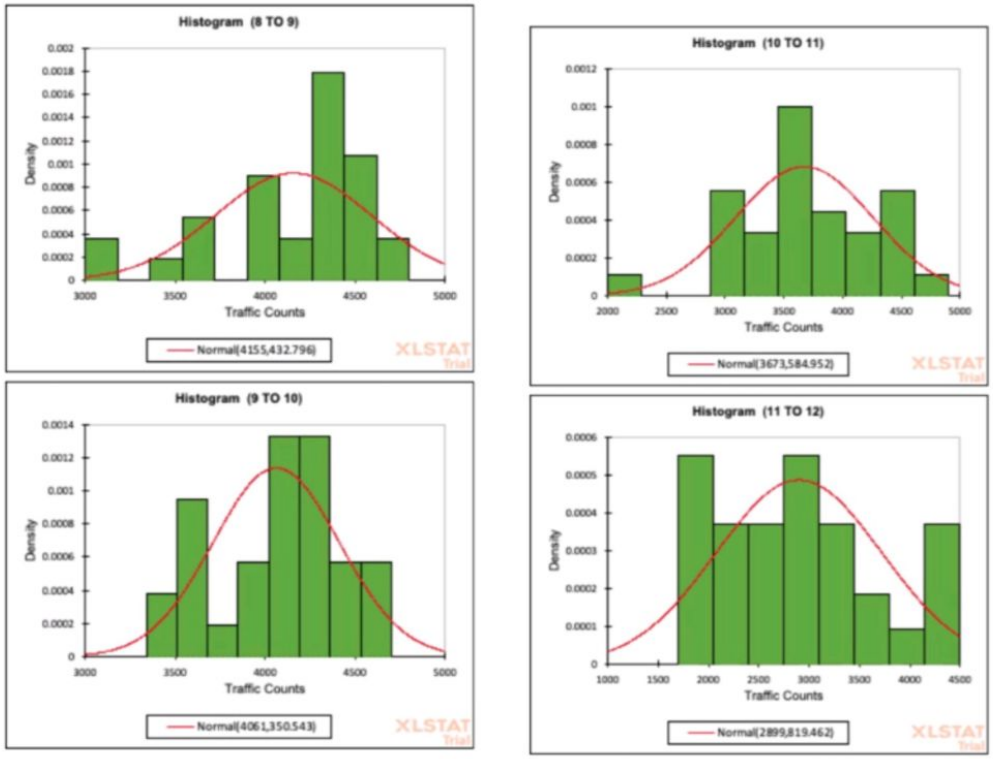


Figure 6. 12 PM to 12 AM hourly fitted normal distributions

Discussion and Implication:

The Monte Carlo simulation resulted in a mean absolute percent error of .19 percent. This indicates that the approach is taken matches historic data very well thus the Monte Carlo Simulation provides an accurate model for predicting traffic volumes. Moreover, since the approach matches existing data very well the variability within the Monte Carlo Simulation can be a way of considering sensitivity to the overall system.

Period	Actual	Forecast	Error	Absolute Value of Error	Square of Error	Absolute Values of Errors Divided by Actual Values.
t	At	Ft	At -Ft	| At -Ft|	(At -Ft)^2	| (At -Ft)/At|
1	2242.83871	2239.690177	3.149	3.149	9.91326005	0.0014
2	1728.354839	1733.976768	-5.622	5.622	31.60608568	0.0033
3	1458.258065	1457.625847	0.632	0.632	0.39969960	0.0004
4	1395.516129	1391.603307	3.913	3.913	15.31017600	0.0028
5	1724.741935	1726.680988	-1.939	1.939	3.75992654	0.0011
6	2415.580645	2408.439773	7.141	7.141	50.99205292	0.0030
7	3232.064516	3210.830273	21.234	21.234	450.89307578	0.0066
8	3483.741935	3479.024019	4.718	4.718	22.25873138	0.0014
9	3520.387097	3536.729424	-16.342	16.342	267.07165177	0.0046
10	3907.612903	3894.240556	13.372	13.372	178.81966429	0.0034
11	3948	3947.15378	0.846	0.846	0.71608829	0.0002
12	3968.516124	3975.335418	-6.819	6.819	46.50277066	0.0017
13	3985.193548	3987.821771	-2.628	2.628	6.90755614	0.0007
14	4039.774194	4043.111687	-3.337	3.337	11.13885953	0.0008
15	4114.903226	4114.941733	-0.039	0.039	0.00148279	0.0000
16	3883.516129	3880.91005	2.606	2.606	6.79164775	0.0007
17	3845.193548	3855.59478	-10.401	10.401	108.18562712	0.0027
18	3730.825234	3730.825234	0.000	0.000	0.00000000	0.0000
19	3895.645161	3895.631591	0.014	0.014	0.00018414	0.0000
20	4086.258065	4082.408664	3.849	3.849	14.81788806	0.0009
21	4155.451613	4157.01226	-1.561	1.561	2.43561906	0.0004
22	4061.290323	4058.665888	2.624	2.624	6.88765907	0.0006
23	3673.258065	3661.542098	11.716	11.716	137.26388275	0.0032
24	2899.419355	2917.195441	-17.776	17.776	315.98923348	0.0061
	Totals		9.350	142.279	1688.663	0.046
	n	24				
	MAD					
	MSE					
	RMSE					
	MAPE	0.19				

Figure.7. Mean Absolute Percentage Error Formula from average predicted counts and average original counts on an hour by hour basis.

One possible example could be using various percentiles of the calculated predicted values to help traffic operations account for the inherent variability of daily demand volumes. One example being focusing on conditions that are closer to outliers than they are to the average conditions. This approach while not a direct comparison in terms of commuting to and from work, ~~it~~ is an important thing to consider that the average travel time really only represents what happened just half of the time. Thus this method could be used in scenarios such as if someone were to plan on being on time with a work commute 80-90% of the time, it becomes more useful to consider a high percentile distribution beyond the mean to make sure it falls within the acceptable band, and looking at the variability within my simulation could help transportation analysts plan for these types of conditions on this segment of the Cross Bronx Expressway from the Macombs Rd over to the end of I-95/ US 1 Olap Webster Ave.

Limitations:

Some limitations of this study include that the most recent data received from the New York State Department of Transportation was from the year 2017 for this reason the short term forecasted data is not as current as initially desired which if the data was more recent it can possibly make the implications of this project more accurate. Another limitation was that the data obtained from the New York state Department of Transportation were missing some values hence the reason why the study conducted was limited in selection of what could be chosen to predict the hourly traffic count values. Additionally, one more limitation I faced in conducting my project is how the data obtained was only hourly traffic volume thus there was a limitation in the type of analysis that could be conducted than if I had received a shorter segment of time such as every 10 minutes a much more thorough analysis could have been conducted.

Future Research:

Suggestions for future research include predicting the short term traffic flow using another method. For instance, in the future, I could test other additional methods such as the Artificial Neural Networks (ANN) or Fuzzy Logic instead of using the Monte Carlo Method for each hour. Another method one person could use is a daily volume profile. A daily volume profile would

show how the counts vary by hour of the day in order to do this the first step is to come up with an adjustment factor by averaging the counts and the resulting percentages could be used to scale down the predicted volumes based on the time of day they were assigned. In the future, one could look at these different methods and identify which method determines the best-predicted counts. Another suggestion for future research is testing which platform runs the best Monte Carlo Simulation to predict the short term traffic counts thus this would include trying more platforms other than Excel such as R to come to a conclusion on which method is truly the best. Additionally, another possible topic of inquiry for the future could be using the Monte Carlo Method on other roadways or dates to see how this method can be used to help traffic congestion worldwide.

Conclusion:

Traffic congestion drastically affects the lives of many motorists each year. From time, fuel, and road rage. Traffic manages to cause detrimental effects on every aspect of our lives. Thus in order to improve the lifestyles of many drivers who utilized the Cross Bronx Expressway the project aimed at predicting the short term traffic flow of a segment of the Cross Bronx Expressway which was the I-95 westbound from Exit 6A (I-278) to Exit 2 (Trans-Manhattan Expressway). This study concluded that since this method provided an accurate model for the existing data the predicted counts calculated in this experiment can be utilized in order to prescribe suggestion to improve the traffic flow of this roadway thus taking a step forward in reducing the congestion of the Cross Bronx Expressway from Exit 6A (I-278) to Exit 2 (Trans-Manhattan Expressway) bettering the lives of thousands of motorist each year.

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