T.C.
SAKARYA UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

TRAVEL TIME RELIABILITY ANALYSIS OF URBAN TRANSPORTATION NETWORK IN CITY OF BAGHDAD USING PROBE VEHICLE

MSc THESIS

Mustafa Mimoon Habeeb AL-FATYAN

Department of Civil Engineering

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Thesis Advisor: Assist.Prof.Dr. Hakan ASLAN

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The thesis work titled “Travel Time Reliability Analysis of Urban Transportation Network in City of Baghdad Using Probe Vehicle” prepared by Mustafa Mimoon Habeeb AL-FATYAN was accepted by the following jury on …./…. /……. by unanimously/majority of votes as a MSc THESIS in Sakarya University Graduate School of Natural and Applied Sciences, Civil Engineering department, Transportation program.

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To my family and to the victims of Turkey's devastating earthquake.

ACKNOWLEDGMENTS

I would like to thank to my supervisor, Assist. Prof. Dr.HAKAN ASLAN, for his patience, motivation, and immense support. His guidance helped me throughout my research and writing of this thesis. I would also like to thank to my family for continuously supporting me from the first moment till the final stage. It gives me a great pleasure to thank to Assist. Prof. Dr. KAWKAB AL FATYAN. for his insightful comments and encouragement.

I'd really like to thank PTV Group for providing me with the license and their quick response.

Mustafa Mimoon Habeeb Al-Fatyan

TABLE OF CONTENTS

Sayfa

LIST OF TABLES

Page

LIST OF FIGURES

Page

TRAVEL TIME RELIABILITY ANALYSIS OF URBAN TRANSPORTATION NETWORK IN CITY OF BAGHDAD USING PROBE VEHICLE

ÖZET

Modern çağda, ulaşım güvenilirliği genellikle üzerinde önemle durulan bir kavramdır. Ulaşım sektöründeki son gelişmeler, hareketlilik taleplerinin karşılanmasını her zamankinden daha kolay ve hızlı hale getirmiştir. Dijital teknolojinin yükselişiyle birlikte; hızlı trenler, güncel kent içi modern raylı sistemler, araç paylaşım sistemleri ve otonom araç kullanımı gibi yeni hizmetler kullanılabilir hale gelmiştir. Teknolojideki gelişmeler, toplu ve özel taşımacılığın artan verimliliği, hem uzun mesafelerin hem de kısa yolculukların güvenilir bir hız ve güvenlik derecesi ile etkin bir şekilde yapılabilmesini sağlamaktadır.

Bununla beraber, sektördeki kazanımların ve yeniliklerin sunduğu ulaşım güvenilirliğinin sürekliliğinin sağlanması ve iyileştirilmesi, ulaşım mühendislerinin ve planlayıcılarının önünde duran önemli görevlerden biridir. Bunun sağlanabilmesi adına operatörler ve mühendisler, yolcuların güvenli, güvenilir, konforlu ve uygun maliyetli bir yolculuk yapmasını sağlamak için yeni teknolojilere ve daha iyi altyapılara yatırım yapmalıdır. Bahsi geçen bu sürekliliğin temini için bu ihtiyaçlardan bir veya daha fazlasının gerçekleştirilmesine engel teşkil edecek en önemli unsur olan trafik sıkışıklığına sebep olan faktörlerin belirlemesi gerekmektedir. Trafik sıkışıklığı, yolun bir bölümündeki reel trafik hacminin o bölüm için planlanan mühendislik kapasitesini aştığı durumlarda ortaya çıkmaktadır. Trafik sıkışıklığı, özellikle büyüyen şehirlerde insan sayısındaki ve araç sahiplik oranlarındaki hızlı artış ile arazi kullanım alanlarının doğru planlanamaması sonucu çok daha ciddi boyutlara ulaşmaktadır. Altı farklı hizmet seviyesi kriteri tıkanıklık derecesini değerlendirmek için kullanılmaktadır. Bunların en yaygın olanları Highway Capacity Manual de belirtilen ve ABD Karayolu Kapasite Endeksi olarak bilinen A, B, C, D E, F hizmet düzeyleridir.

Bağdatda bulunan ve gündelik hareketlilik taleplerinin karşılanmasında önemli rol oynayan üç adet ana güzergah üzerindeki reel trafik hacimleri bu anlamda seyahat süresi güvenilirliği içeriğinde analiz edilip değerlendirelerek mevcut hizmet seviyelerinin belirlenmesi, farklı hacim artışı senaryolarına göre performansların iyileştirilmesi için önerilerin yapılabilmesi bu çalışmanın temel konusunu ifade etmektedir. Böylece doğru planlama ve yönetim stratejilerinin belirlenmesi ile hizmet düzeylerinin arzu edilen standartlarda sağlanması ve trafik sıkışıklığının önüne geçilebilmesi amaçlanmıştır.

Sistem mühendisliğinde güvenilirlik, bir sistemin normalde sunduğu hizmet kalitesinin istikrar derecesi olarak tanımlanabilir. Yüksek düzeyde hizmet için artan kullanıcı talepleri karşısında, ulaşım ağlarının planlanması, inşası ve işletilmesinde sistem güvenilirliği giderek daha önemli hale gelmektedir. Güvenilir bir ulaşım sistemi, yalnızca doğal afetleri değil, trafik yapısındaki gündelik dalgalanmaları da

dikkate almalıdır. Şebekedeki linklerin kabul edilebilir bir hizmet seviyesinde servis sunmaları bu anlamda sağlanmalıdır. Ulaşım sisteminin istikrarı, normalde sağlayacağı hizmetin kalitesini yansıtır. Güvenilir bir ulaşım sistemi, ekonomide rekabet avantajı sağlayacaktır. Bu nedenle, güvenilir ve istikrarlı bir ulaşım sisteminin önemi yadsınamaz bir gerçektir. Daha iyi ve daha güvenilir hizmetlere yönelik artan taleple birlikte, birçok sistem (örneğin, elektrik güç sistemleri, su dağıtım sistemleri, iletişim ağları, vb.) planlama, tasarım ve operasyonlarının ayrılmaz bir parçası olarak güvenilirlik analizini bünyesine katmıştır. Her şeyin verimli ve güvenilir olmasının beklendiği günümüzün hızlı dünyasında, ulaşım şebekelerine olan güvenilirlik giderek daha önemli hale gelmiştir. Kullanıcı memnuniyeti için tutarlı bir şekilde güvenilir hizmetler verebilen sistemlerin başarılı olma olasılığı daha yüksektir. Güvenilirliği ölçmek için istatistiksel modeller ve müşteri anketleri dahil olmak üzere çeşitli ölçütler ve yöntemler kullanılmaktadır. Güvenilirlik ölçümüne proaktif bir yaklaşımın olduğu sistemlerde, sorunlar büyük sorunlar haline gelmeden önce ele alınabilmekte ve nihayetinde sistem kullanıcıları için daha iyi ürün ve hizmetler geliştirilebilmektedir. Bu anlamda ele alındığında herhangi bir çalışmada veya sistemde kaliteli sonuçlar elde etmek için, toplanan verilerin güvenilirliği dikkate alınmalıdır. Güvenilirliğin ölçülmesi, sonuçların tutarlılığının ve istikrarının ölçülmesini içerir. Araştırmacılar tutarlılık düzeyini anlayarak, toplanan verilerden güvenli sonuçlar çıkarabilirler. Güvenilirliği ölçmeye yönelik bazı yaygın yöntemler arasında test güvenilirliği ve iç tutarlılık güvenilirliği yer alır. GPS teknolojisi, son birkaç on yılda birçok alanda devrim yaratmıştır. Bunlardan biri, GPS kullanımının ekoloji, jeoloji ve meteoroloji gibi alanlarda daha iyi veri toplanmasına ve analizine izin verdiği bilimsel alandır. Araştırmacılar, kesin coğrafi konumları saptayarak ortamdaki değişiklikleri daha doğru bir şekilde ölçebilmekte ve izleyebilmektedir. GPS, hayvan popülasyonlarını ve göç modellerini izlemek için de kullanılmış ve bilim insanlarının bu canlıların ekosistemleriyle nasıl etkileşime girdiğini daha iyi anlamalarını sağlamıştır.

Güvenilirlik, herhangi bir sistem veya süreçte kritik bir faktördür. Potansiyel sorunları belirlemeye ve performansı optimize etmeye yardımcı olduğu için güvenilirliği ölçmek önemlidir. İster imalatta, ister yazılım geliştirmede veya başka herhangi bir sektörde olsun, güvenilirliği ölçmek sürekli iyileştirmeye olanak tanır ve sonuç olarak daha yüksek kaliteli ürün ve hizmetlerin sunulmasına olanak sağlar. Güvenilirliği sağlamak için, etkin test ve yönetim prosedürlerini uygulamak ve verileri sürekli olarak izlemek ve analiz etmek gerekir.

Bu tezin amacı, esasen Bağdat'ın Rusafa tarafında bulunan üç önemli güzergahın seyahat süresi güvenilirlik analizi ile ilgilidir. Bu anlamda ilgili üç güzergah için seyahat süresi ve toplam gecikme değerleri (yavaşlama gecikmesi, durma gecikmesi ve hızlanma gecikmesi vb.), üç periyot (sabah, öğle ve gece) döneminde her rota için 34 tur boyunca GPS cihazı bulunan araç kullanılarak gerçek zamanlı olarak elde edilmiştir. Çalışma da incelenen güzergahlar, Bağdatın ulaşım şebekesinde önemli fonksiyonlara sahip olan Mohammed AlQasim, Ordu Kanalı otoyolu, Filistin caddesi, Al-rubiae caddesi gibi caddeleri ve yolları içermektedir. Mart 2022'den Mayıs 2022'ye kadar hafta içi günlerde kuzey ve güney yönlerinde toplam 34 test sürüşü gerçekleştirilerek, ilgili güzergahlarda toplam seyahat süresinin ve gecikmelerin değişimlerini incelemek amacıyla veriler GPS cihazlı araç üzerinden elde edilmiştir. Elde edilen sonuçlar, araçlar için durma süresinin, tüm güzergahlar için her iki yön için toplam kontrol gecikmesinin büyük bir bölümünü oluşturduğunu göstermiştir. Bu süreler kuzey ve güney yönleri için sırasıyla % 74,69 ve % 63,46'dır. İkinci güzergahın kuzey ve güney yönleri için oranlar ise sırasıyla %71,19 ve %34,83'tür. Üçüncü güzergah için ise kuzey ve güney yönleri sırasıyla %60,76 ve %74,74 oranlarına sahiptir.Yavaşlama ve hızlanma oranları birbirine yakın değerlerde elde edilmiştir. İncelenen güzergahlardaki gecikmelerin ve hızın yavaşlamasının birincil nedeni kavşaklarla ilgili olmakla beraber, yolun kendisiyle ilgili faktörler de vardır. Her iki yönde (sabah ve akşam saatlerinde) tüm güzergahlar için ulaşımın güvenilirliği karşılaştırıldığında, sabah periyodunun gece periyoduna kıyasla düzensiz olduğu belirlenmiştir.

Genel olarak, bu tutarsızlıklar, seyahat süresi söz konusu olduğunda dikkatli bir planlamaya ihtiyaç olduğunu göstermektedir. SPSS ve PTV Vissim programları sonuçları temsil etme biçimleri açısından bu amaçla kullanılmıştır.Kontrol gecikmesi ve açıklayıcı bağımlı değişkenler için bir ilişki bulmaya yönelik istatistiksel modeli elde etmek bu anlamda önem arz etmektedir.

Hız analizlerinde, kavşakların hızın ara sıra serbest akış hızından sıfıra yakın bir değere (durma) düşmesine neden olduğu gerçeği önemini korumakla beraber, kavşaklar yavaşlamanın tek nedeni olarak kabul edilemez. Güzergah üzerinde, yolların geometrik yapısı veya güzergah 1'de gösterilen tüneller gibi etkin olan başka unsurlar da vardır. Gecikme konusunda ise üç güzergah arasında uyumsuzluk tespit edilmiştir. Birinci ve ikinci güzergahlarda sabah gecikme değerleri düşükken, üçüncü güzergahda farklı bir yapı belirlenmiştir.

Bu çalışmada kullanılan VISSIM yazılımı, mikroskobik, zaman adımlı ve davranış tabanlı trafik simülasyon modelidir. Program, trafik analizlerini; trafik kompozisyonu, hız limitleri, trafik sinyalleri ve günün saati gibi kısıtlamalar altında analiz edebilmekte, böylece çeşitli alternatiflerin karşılaştırılarak değerlendirilmesi için yararlı bir araç olma imkanı sunabilmektedir. Muhtemel gecikmeleri ortadan kaldırmak için kabul edilebilir bir buffer indeksi belirlemek amacıyla, çeşitli senaryolar için simülasyonlar çalıştırmak üzere VISSIM yazılımı kullanılmıştır. Kuzey ve güney yönleri için birinci güzergah için elde edilen buffer indeksi değerleri sırasıyla %10,24 ve %21,03 olarak belirlenmiştir. İkinci güzergahın kuzey ve güney yönleri için karşılık gelen değerler sırasıyla %20,21 ve %19,87'dir. Üçüncü güzergah için ise kuzey ve güney yönleri sırasıyla %27,06 ve %26,15 değerlerine sahiptir. Tıkanıklık sorununa klasik anlamda

Önerilen çözümler, kapasiteyi artırmak için yeni yollar inşa etmek veya bunları genişletmekti. Uygulanan bu çözümler yalnızca kısa vadede istenen sonuçları verebilir. Uzun vadede kalıcı sonuçlar üretmek, trafik sorunun ana parametrelerinin belirlenmesi ile mümkün olabilmektedir. Bu araştırmanın sonuçları, trafik akışları, kapasite ve gecikmeler açısından hizmet düzeyini iyileştirmek için incelenen ulaşım şebekesi be güzergahları için önemli ve değerli bilgileri sağlamaktadır. merminin sabah ve gece saatleri için regresyon modelinde hızlanma, durma ve

İncelenen güzergahlarda bulunan trafik sıkışıklığı ile başa çıkmak ve seyahat süresi güvenilirliğini artırmak için geliştirilebilecek stratejiler söz konusudur. Filistin Caddesi ve Al-Rubaie Caddesi gibi ana ve ticari caddelerde rastgele durmanın önlenmesi amacı ile işaretli ve düzenlenmiş park alanlarının eklenmesi, tıkanıklığı büyük ölçüde azaltacak ve akışın çok daha düzgün olmasına yardımcı olacaktır. Bu araştırmanın ana bulgularından bir diğeri, yerel makamlara kesintisiz trafik akışının sağlanabilmesi adına gereksiz kontrol noktalarını kaldırmalarını tavsiye etmektir. Teze içeriğinde de gösterildiği gibi bu noktaların, güzergâh kapasitelerini azaltıp seyahat sürelerini önemli ölçüde artırarak derinlikli olumsuz bir etkisi vardır. Dolayısı ile bu noktaların kaldırılması, mevcudiyetlerine kıyasla trafik gecikmelerinde önemli pozitif katkılar sağlayarak, şebekenin seyahat süresi güvenilirlik değerlerini artıracaktır. Ana yollara bağlanan tali yolların açılması, bu yollara farklı erişim noktaları sağlayarak ana yolların yoğunluğunu ortadan kaldıracaktır. Her ne kadar bahsi geçen bu tali yollar başlangıç ve varış noktaları arasında ana yollara etkili bir alternatif olmayacaklar ise de trafiği dağıtıp yollardaki yoğunluğu azaltıcı etki oluşturacaktır.

TRAVEL TIME RELIABILITY ANALYSIS OF URBAN TRANSPORTATION NETWORK IN CITY OF BAGHDAD USING PROBE VEHICLE

SUMMARY

In the modern age, transportation reliability is something often taken for granted. With the rise of digital technology, a host of new options have become available, from traditional trains to new services. The increased efficiency of public and private transportation has enabled us to traverse both great distances and short jaunts with a reliable degree of speed and safety. However, the current state of transportation reliability can be taken for granted too easily, as it is only the end result of decades of hard work and innovation within the industry. Hence, the biggest challenge that remains is ensuring that these services are resiliently reliable and efficient. To do this, operators and managers must invest in new technologies and better infrastructure to ensure that passengers get a continuously safe, comfortable, and cost-effective journey. The factors, with that regard, contributing to the achievement of one or more of these needs must be identified.The level of traffic congestion is one of the main indicators of the performance of transportation networks. The congestion simply implies that the actual traffic flow on a segment of a roadway exceeds the related available capacity. Traffic congestion is well-known phenomena that has evolved in both developed and growing cities due to the rapid increase in the population and automobiles. There are described six levels of service designated by A,B,C,D,E,F by HCM. In this study the paths available in Baghdad transportation network were investigatigated in terms of the level of service they provide to evaluate their effect on travel time reliability. Reliability in systems engineering can be defined as the degree of stability of the service that a system normally offers. In the face of increasing user demands for high levels of service, reliability concept is becoming increasingly more important in the planning, construction, and operation of transportation networks. Control delay at inntersection is considered one of the most important measures of effectiveness for signalized intersections as these are used to determine the level of service (LOS). The purpose of this thesis is essentially related to the travel time reliability analysis of the three important streets available at the Rusafa side of Baghdad. A GPS device equipped car was driven in actual traffic to collect data from the links along these three routes for three time periods of the day (morning, noon, and night) during 34 rounds for each route to assess the travel time and total delay (deceleration delay, stopped delay, and acceleration delay etc.) experienced. The study in this sense included paths consisting of several streets. Mohammed AlQasim, Army Canal motorway, Palestine street, Al-rubiae street are the selected ones. to study the variations of total travel time and delays through the data collected from March 2022 to May 2022 during the weekdays except for the off days. A total of 34 test runs were carried out in the north and south directions for each case. The obtained results

indicated that the stopping times for vehicles represents the major part of the total control delay for both direction through all routes. The related control delay ratios for the first route of the north and south directions represent 74.69% and 63.46% respectivel., The ratios for the north and south directions of the second route were 71.19% and 34.83%,. As for the third route, the north and south directions had the ratios of 60.76% and 74.74%, respectively.The ratios regarding deceleration and acceleration were obtained as close figures. The intersections present on these routes are the primary cause of delays and speed deceleration. However, it should be stated that there are also other factors related to the road itself. The reliability analysis of transportation networks for all routes in both direction (morning and evening periods) indicates that the reliability structure of morning period of the three routes is uneven as compared to the night period. Overall, these discrepancies show that there is a need for careful planning when it comes to travel time concerns. VISSIM software was employed to run simulations for various scenarios in order to identify an acceptable buffer index to eliminate any potential delays. The values obtained as for the first route for the north and south directions are respectively given as 10.24% and 21.03%. The corresponding values for the north and south directions of the second route were 20.21% and 19.87%, respectively. And for the third route, the north and south directions had the values of 27.06% and 26.15%, respectively. There are possible proposals and recommendations to alleviate congestion at intersections and on the road itself.These strategies are less costly and provided both immediate and long-term efficiency.

1. INTRODUCTION

A transport network, or transportation network, is a network or graph in geographic space, describing an infrastructure permitting and constraining movement or flow. Road networks, railways, air routes, pipelines, aqueducts, and power lines can be given as examples of the various types of networks. The digital representation of these networks and their methods are a core part of spatial analysis, geographic information systems, public utilities, and transportation engineering. Network analysis is an application of the theories and algorithms of graph theory and is a form of proximity analysis. When moving from one place to another, there are determinants that govern this transition, some of which, the distance, the permitted speed and the number of intersections etc, are known and expected (a non-fixed value). The travel time, which depends on the speed at which the vehicle will move remains generally an unstable variable from day to day and from hour to hour (peak period value is higher than the normal period). But by virtue of previous studies, it is possible to imagine an approximate value, and since it is a non-fixed value, we add an additional time value that depends on previous studies, which is known as Buffer Index (BI), which will be explained in detail at the following sections of this study. This value may it possible to get rid of some unexpected delays for whatever reason, which in turn will cause an increase in travel time. But what matters to the drivers is to reach the destination as quickly as possible, with less delay time and with sure peace. Those interested in road and traffic studies aim to discover the causes of delay and reduce them as much as possible. As solutions may differ in terms of type, cost, and effectiveness, this study review some of the direct and indirect causes of delays in the network. In this sense, the causes affecting the travel time in one way or another were also reviewed.

1.1. Purpose of Thesis

The aim of this study is to determine the effects of the engineering characteristics of some of the streets and network elements present in city of Baghdad transportation network on the network reliability. Another point to mention is to determine the causes of congestion and traffic obstacles so that the level of service may be compared through the field measurement results obtained between morning and night time period. Proposals that contribute to improve the level of service of the streets, providing smooth movement were also suggested

1.2. The Importance of the Study

The importance of this study lies in an accurate evaluation and realistic assessment of some of the major streets in the city of Baghdad, Iraq, in terms of the impact of the congestion on the level of service resulted in. Congestion has been a prime problem for the urban transportation networks for a long time increasing the commuting travel times and delays between origin and destination points. Fuel consumption and increased pollution are other important issues. to be considered as negative effect of the congestion. Reducing congestion will alleviate all these undesired consequences and contribute the economy along with better urban life conditions.

1.3. Research Challenges

The research problem listed in several point:

• Organization and management: the means of traffic control and traffic signals and their follow-up

• Infrastructure: narrow streets in light of the increase in the number of vehicles and the illegal parking of the vehicles

• Improper stops: some public or private transport unskilled drivers may stop in places not designated for them.

The paths investigated within the aspect of this research have some paricular points lead drivers to drive at low speeds and sometimes stop for varying periods. The presence of some security control points reduces the number of the lanes from 4 lanes to one lane only, which results in significant traffic delays causing repeated acceleration and deceleration processes especially in peak times.

The analysis carried out within this research under the present conditions with different scenarios revealed the possible strategic advices to improve the performance of the investigated network especially in terms of better travel times in favour of system users.

1.4. Area of Study

The research examined some streets/paths linking commercial centers with residential neighborhoods in the city of Baghdad. All of them are distinguished major streets surrounding the city center by gathering central governmental departments and universities having various scientific, commercial and religious events.

As Baghdad connects the Northern provinces with the Southern provinces there is significant increase in the number of cars coming to the city center. Accordingly, it has been noticed that significant increase in constantly repeated traffic congestion in the city center at peak hours causes many negative effects and mess.

The study investigates three separate routes starting from Al Adhamya to Zayona in both ways vice versa, The geometric and structural characteristics of these routes vary greatly among themselves, even within the same street, in terms of length, number of lanes and their widths, parking places, number of intersections and distances between each intersection. Because of their importance in mobility, in addition to the above reasons, these routes were chosen to study in the reliability analysis.

1.5. Data and Application

The required data were collected through probe vehicle method. The Speed View GPS mobile application was employed during the field study of each route for data collection. Maximum and minimum speed, average speed, total distance travelled, total trip time, and stopping time for each trip were either recorded or calculated.Once there were speed changes during the trip for any reason, the application recorded the Latitude and Longitude values of the point along with all the above data stated. The

The required data were collected through probe vehicle method. The Speed View GPS mobile application was employed during the field study of each route for data collection. Maximum and minimum speed, average speed, total distance travelled, total trip time, and stopping time for each trip were either recorded or calculated.Once there were speed changes during the trip for any reason, the application recorded the Latitude and Longitude values of the point along with all the above data stated. The locations were measured according to WGS 1984 datum as can be seen in Figure 1.1.

Point	Time	Date	Duration	Speed(km/h)	Distance(km)	Latitude(WGS84)	Longitude(WGS84)
55	4/25/2022	8:19:41	00:01:58	24.803999	0.7438779	33.37209155	44.38439753
56	4/25/2022	8:19:44	00:02:01	28.547998	0.76655793	33.37192898	44.38454533
57	4/25/2022	8:19:46	00:02:03	30.636	0.78343904	33.37181083	44.38465959
58	4/25/2022	8:19:48	00:02:05	33.552	0.8021208	33.37167425	44.38477679
59	4/25/2022	8:19:50	00:02:07	35.604	0.8215288	33.37153208	44.38489837
60	4/25/2022	8:19:52	00:02:09	38.592	0.8417649	33.37138453	44.38502627
61	4/25/2022	8:19:53	00:02:10	40.32	0.8525137	33.37130079	44.38508441
62	4/25/2022	8:19:54	00:02:11	42.12	0.8644857	33.37121137	44.38515647
63	4/25/2022	8:19:55	00:02:12	43.56	0.8764223	33.37112331	44.38523021
64	4/25/2022	8:19:56	00:02:13	44.604	0.889149	33.37102446	44.38529966
65	4/25/2022	8:19:58	00:02:15	44.351997	0.9134508	33.37083324	44.38542713
66	4/25/2022	8:20:00	00:02:17	42.516	0.9380278	33.37063939	44.38555489
67	4/25/2022	8:20:02	00:02:19	35.244	0.9582592	33.37048382	44.3856684
68	4/25/2022	8:20:04	00:02:21	28.404	0.9743487	33.37036391	44.38576565
69	4/25/2022	8:20:07	00:02:24	25.344	0.99561405	33.37020006	44.3858843
70	4/25/2022	8:20:09	00:02:26	32.688	1.01324	33.37006363	44.38598143
71	4/25/2022	8:20:11	00:02:28	39.312	1.034812	33.3699005	44.38610736
72	4/25/2022	8:20:13	00:02:30	43.056	1.0578448	33.36972533	44.38624026
73	4/25/2022	8:20:14	00:02:31	44.639996	1.0705526	33.36962718	44.38631071
74	4/25/2022	8:20:15	00:02:32	45.972	1.0835769	33.36952873	44.386387
75	4/25/2022	8:20:16	00:02:33	47.772	1.096718	33.36942944	44.38646405
76	4/25/2022	8:20:17	00:02:34	49.536	1.1107675	33.36932742	44.38655354
77	4/25/2022	8:20:18	00:02:35	51.156	1.1248693	33.369221	44.38663646
78	4/25/2022	8:20:19	00:02:36	52.704	1.1395366	33.36911031	44.3867227
79	4/25/2022	8:20:20	00:02:37	53.748	1.1542956	33.36899899	44.38680959
80	4/25/2022	8:20:21	00:02:38	54.648	1.169277	33.36888345	44.38689298

Figure 1.1. Sample for the data.

1.6. Thesis Organization

This thesis is organized as follows: The next chapter discusses related literature regarding reliability in general and travel time reliability with the elements that affect them such as delays and physical or geometric conditions of the road elements. Chapter 3 introduces the routes studied and the dataset. Chapter 4 discusses the direct time measuring method, the elements that influenced travel time, and the reasons of delay in each route. In addition, the analysis through SPSS software was stated at this chapter along with the findings of road modeling through the VISSIM program.Chapter 5 discusses the results obtained in in the previous chapter. Chapter 6 includes advice and strategies for reducing traffic congestion and improving travel time reliability.

2. LITERATURE REVIEW

Road network reliability is an estimate index, which determines the size of the road network prospect in the daily and unexpected or unplanned cases, and is described by the access probability from the origin to the destination through one or more links inside the whole network. However, it has only been two decades, after Kobe earthquake in 1995, since the concept of the reliability started to be implemented into transportation networks and traffic systems. Its research content is continuously ameliorating along with the changes of traffic technology and methods. One of these methods called the complex network method, developed in recent years, has provided a new outcome for the researches. Two articles of the complex network, published in “Nature and Science” in 1998 and 1999, respectively, indicates to the connectivity distribution for many complex networks in real-world possesses exponential forms, and indicative to a such networks with that property as scale-free networks. (D. J. Watts and S. H. Strogatz, 1998, A. Barabási, 1999). This research aims to evaluate the travel time reliability, probability that a trip can reach its destination within a given period of time at a given time of the day.There are different methods that can be applied to the assessment of the problem. The principle can be divided into three primary elements: scope, output, and method (Vlahogianni et al., 2004). There are two primary ways with different results in the estimation of travel times using probe data regarding imaginary output. First method is providing expected travel time. Most large-scale navigation systems, such as Google Maps have this result which can be applied to any large-traffic network. The other method involves providing probability classification of travel times and inferring their parameters using different mathematical intensive statistical methods that can be used for small-to-medium-sized networks (Hunter, 2013). Since the time dimension is one of the most important factors describing the characteristics of traffic flow, there are abundance of study for the research object of travel time taking into consideration various traffic factors. Among them, researchers carried out many researches in terms of modelling methods, data collection application, and special vehicles’ travel time focused on the estimation method travel time. For example Ma et al. 2017 used the Markov process to estimate the probability classification of travel time based on the interconnection between time and space.(Yang et al, 2018) proposed Gaussian mixture model to be convenient for urban road travel time distribution characteristics, and analysed the real-time collected data. (Jenelius and Koutsopoulos, 2018) used a multivariate potential statistical principal component analysis model to guess the travel time of urban roads based on floating car data.(Fu et al,2019) used the license plate recognition data technique to estimate the travel time of urban roads along with Hopkins statistics method to describe the clustering trend when ruling the relevance of the travel time of adjacent road sections. (Chen et al, 2019).proposed a method considering spatial correlation to study the road estimation method of urban road signal intersections by employing the Gaussian copula model to describe the road association degree. Delay caused by the factors of some expected or unexpected characterictics of traffic flow is the prime factor affecting the travel time. There are several types of delay, but in this study we will focus on the control delay. Control delay at a signalized intersection is defined as the delay due to the operation of traffic signals at signalized intersections. It is just a part of the total delay, which includes the control delay (acceleration, stopping, and deceleration), geometric delay, volume delay, and incident delay (Powell, J.L. 1998). Ko, Hunter, and Gentler presented a methodology to estimate the control delay using GPS data by defining the control points for acceleration and deceleration profiles based on speed differences in test vehicles (J. Ko, M. Hunter, R. Gentler 2007), (Ko, J., Hunter, M., and Guenslier, R., 2008). Due to the comprehensive development of urban cities like Baghdad, the tendency for private car usage mode caused an increase in traffic as a result of diversity of land uses (Noor, M. A., Namir, G. A., 2019). Z A Alkaissi and R Y Hussain carried out analysis and modelling of signalised intersections using Global Positioning System (GPS) (Z A Alkaissi and R Y Hussain, 2020). Sumayah T. Ayob, Zainab A. Alkaissi also performed assessment of travel speed for urban streets using Global Positioning System (Sumayah T. Ayob, Zainab A. Alkaissi, 2021). This study focuses on those methods that use probe data. in general for arterial travel time estimation/prediction.

2.1. Transportatıon Network Terminology

A transportation network may formally be represented as a set of links and nodes. A link connects two nodes and a node connects two or more links. Links may be directed. In that case the direction of movement is specified. Two links are said to be parallel if they connect the same pair of nodes in the same direction.

A loop is a combination of links with the same node at either end. Some of the algorithms described later require the exclusion of parallel links and loops. It shoul be stated that all links referred to in later chapters are directed. Links may have various characteristics. In the context of transportation network analysis, the followings are some of the characteristics of interest:

• Link length (in meters or kilometres)

• Link cost (sometimes travel time but more generally a linear combination of time and distance).

• Link capacity (maximum flow).

A link may be regarded as a conduit for flow whose units of measurement will depend on the application (for example, vehicles per hour or passengers per hour).

As far as transportation networks are concerned, the flow generally refers to the number of vehicles in terms of car equivalency. On the other hand, the flow may also be considered as the type of one or more commodities which may be referred to different kinds of goods and services. Each trip has a beginning and end points known as origin and destination of the trips (sometimes referred to as the source and sink respectively). If there is only one origin and one destination, and no other relevant classification, flow is said to be a single commodity. In addition to commodities, user classes are sometimes identified to distinguish between units of flow with different forms of travel behaviour. A movement in a transportation network corresponds to a flow with a distinct origin and destination. Origins and destinations may correspond to specific buildings, like a house, an office, or zones, depending on the level of aggregation. From the perspective of a transportation network, an origin or destination is represented by a kind of node, referred to as a centroid. Each centroid is connected to one or more internal nodes by a kind of link referred to as a centroid connector (or just a connector). While links tend to correspond to identifiable pieces of transport infrastructure (like a section of road or railway), centroid connectors are artifacts.

Figure 2.1 depicts a transportation system network featuring a single origin centroid, 2 destination centroids,5 links, four nodes within it, 3 connectors, and five pathways. Take note of the conventions for representing centroids, connectors, internal nodes, and linkages.

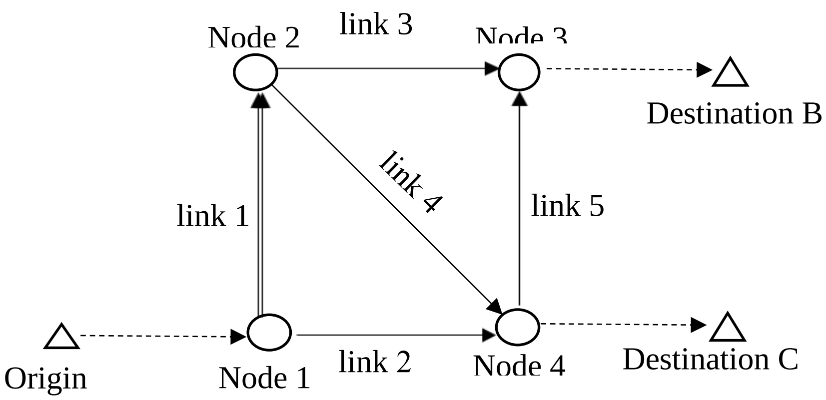


Figure 2.1. An example of transportation network.

A related discipline of mathematics known as graph theory employs nomenclature that varies from that employed by planners for transportation or even traffic engineers. The transport network is also known as a valued graph, a net, or a network. A directed link is called an arc, while unconstrained links are called edges. A great deal of the transportation network literature produced by operations researchers and mathematicians employs graph theory nomenclature. Transportation planners, transportation engineers, and traffic engineers use the terminology employed in this thesis.

Another useful terms with mostly intuitive interpretations (see Fig. 2.2) are A path is a sequence of distinct nodes connected in one direction by links; a cycle is the path linking itself at its ends; a tree is a network where each node is visited one time and only once; and a cut set is an optimum set of links whose elimination from the network would divide the network into two parts without links between each of the resulting subnetworks (see Fig. 2.2). Table 2.1 summarises network principles in light of these explanations subnetworks.In the light of these eplanations network concepts are summarized in Table 2.1

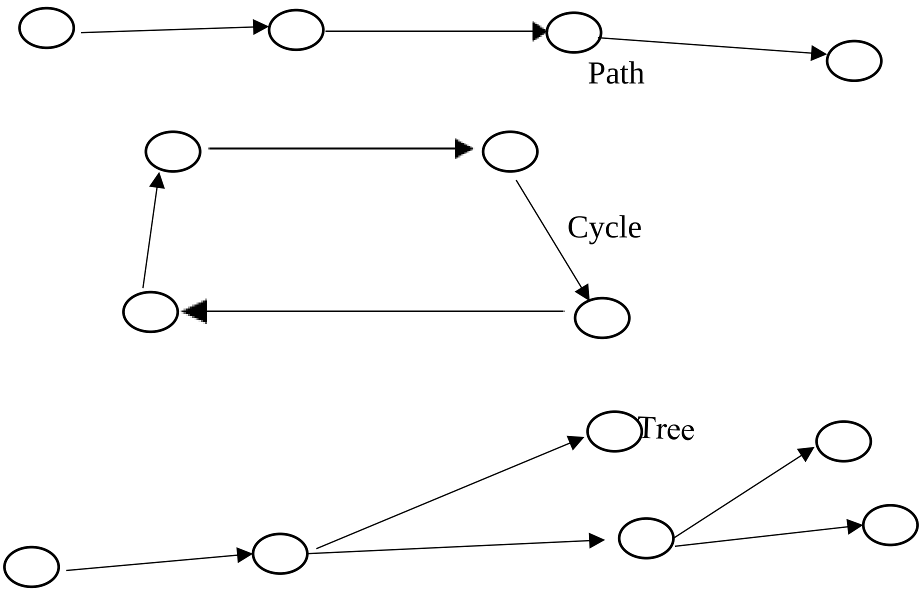


Figure 2.2. Example of a path, cycle and tree.

Table 2.1. Network concepts and their definitions

Concept	Definition
Node	The junction of at least two connections It is neither an internal node (neither origin nor sink) nor just a centroid (one of both).
Link	Flow conduit between two different nodes.
Connector	A connection between an internal and a centroid node.
Movement	Flow with a known point of departure and arrival.
Path	A series of nodes interconnected by links in a single direction, allowing movement from the beginning to the latest node in the series. The first and last nodes in the series are frequently centroids.
Cycle	Is the path linking itself at its ends.
Tree	Is a network where each node is visited once and only once.
Cutset	Is an optimum set of links whose elimination from the network would divide the network into two parts without links between each of the resulting.
Commodity	a flow distinguished by its origin, destination, or another component.
User class	a type of flow differentiated by its behaviour, such as its cost sensitivity.

2.2. Transportation Network Types

Some network topologies are generally faced with in transportation systems. One like in the linear network, examples of which may be an expressway, an arterial road, or a railway line. There perhaps are a lot of origins and destinations but there is no specific path. On the other hand, the grid network which describes an urban area consisting of blocks as common in many countries. There may be many origins and destinations as well as many alternative routes.

Junctions may be represented in many ways, depending on the situation. For example the junction depicted in Fig. 2.3 illustrates only the approaching traffic flows. Where details are required, a junction may be represented as shown in Fig. 2.4(a) by a single node and each approach by two links (one in and one out). However, in this case, vehicles approaching from west and making a right turn constitute a separate stream and may well in practice be signalized differently.

When queuing has a very important effect, as is the case in traffic signal control, it will be necessary to represent the flow by separate links, as shown in Fig. 2.4(b). Since parallel links can cause problems for some shortest-path algorithms specifically, it may be important to introduce an additional node.

At some junctions specific turning movements may be excluded. In this cases each turning movement and flow can be represented explicitly by introducing extra nodes, as shown in Fig. 2.4(c).

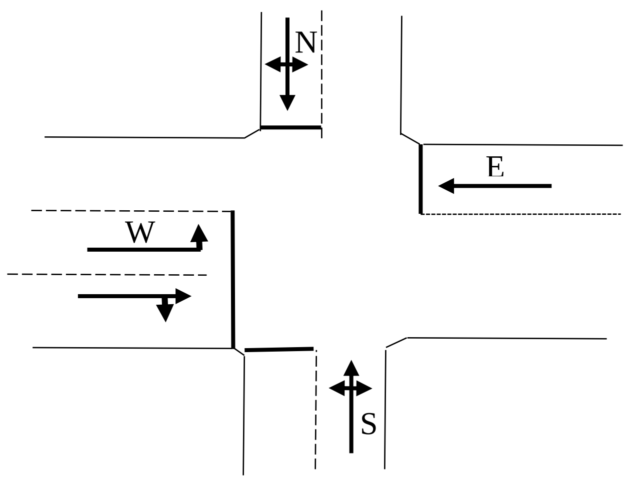


Figure 2.3. General junction representation

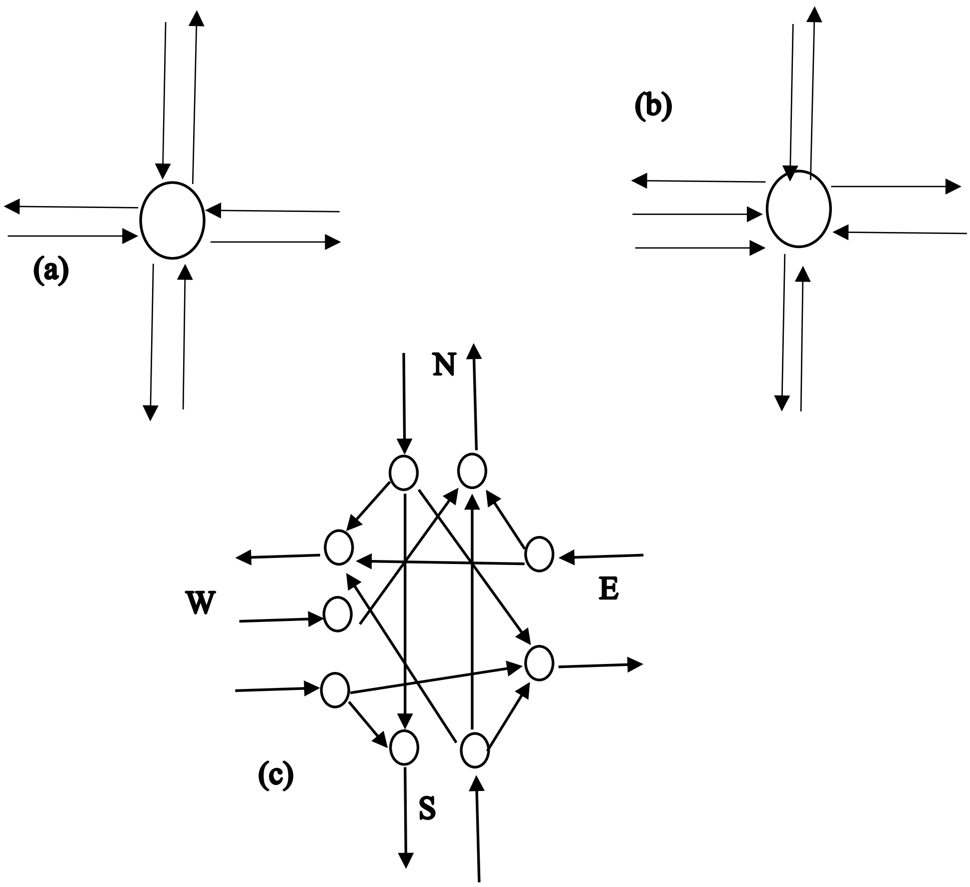


Figure 2.4. Junction representation.

2.2.1. Network capacity

It seems reasonable to assume that every link has a maximum flow that it can carry. If it exceeds this limit, the smooth movement on this link and thus on the whole path, as a result, is referred to be diminished to some extent depending on the value of the volume – capacity ratio it has . When this ratio gets higher then queues of the vehicles get longer and more problematic leading discharges over a stop line are to be designed accordingly M. G. H. Bell (1997). The max-flow min-cut theorem suggests that the capacity for a network with just one origin, a unique destination, and a single user class is equal to the minimum of the cut-set capacities. A technique to discover this capacity was proposed by Ford and Fulkerson (1962). It can be challenging to define capacity for additional broad networks that have several sources and destinations.For instance, from a marketable viewpoint, there is generally a guideline to raise the inflow of one commodity at the cost of another. In other words, it is attainable to delineate the capacity for many commodities to enter. Assuming that connections with finite capacities are linked using the least expensive ways to handle overflows. The highest multiplier that can be used on a trip table could serve as a way of expressing capacity in this case.If the overall number of trips on this route varies, the network capacity will change as well. In particular, while longer passages show a propensity to utilise more links, capacity will likely decrease as the proportion of longer portions rises.The integration of the network's capacity values with actual-life instances of traffic management on urban motorways in a network can also be associated with determining the capacities of ramps on one or more specified links.For a given set of on-ramp-to-off-ramp possibility chances subject to linking capability, the problem in this case is to optimise the total on-ramp outflows of an urban motorway network. The most significant challenge is ultimately determining the maximum amount for each zone's land-use growth that is subject to linking their capacity.Capacity is essential for timing signals at intersections, as it plays an essential role. When all safety and capacity limitations have been taken into account, Allsop (1992) defined the active capacity as the biggest multiple of the rate of arrival for which signal timings can be focused.Nevertheless, there is an opportunity to minimise conflict flows with the objective of increasing capacity for specific flows. More Allsop features were recently added to the networks under equilibrium assignment by Yang and Wong (1995). On each indicate-controlled link, the highest multiple of the trip table is searched for without going over the maximum point of saturation flow. They utilise the term "sensitivities" for stability assignment to repeatedly respond to a bi-level programming problem as an array of linear programming queries.Space-time networks

The time dimension has not yet been included in the flow equation as one of the parties. In reality, qualifications are flexible, and flow moves via the network's links at capped rates. As individuals commute to and from work, morning, afternoon, and nighttime peaks have an impact on the majority of transportation networks. Longer-term fluctuations exist as well, such as the flow leaning to build up in certain areas over the summer break. In addition, there are sporadic athletic events, accidents, religious celebrations, and routine road maintenance that cause erratic variations in flow.The trajectory of a trip through space and time may be illustrated as shown in Fig. 2.5. The timing of events, such as the arrival at the intersections, may affect determinants related to delay and capacity. One approach is to discretize time and include the time dimension in the network. This takes us to a space-time extended network (STEN), where links are specific not just by the locations of their start and end nodes in space but also by their locations in time. By combining the time dimension into the network in this way, it is possible to apply some steady-state network flow programming methods to dynamic situations. A STEN, plotted against space and time axes, is show in Fig. 2.6. The vertical links represent delay. Two paths are show. In the first, they were late for any reason within the network of two periods, before entering link 3. The second path is show to overtake the first by entering link 2 later but entering link 3 earlier; it considered an anomaly from the first in, first-out (FIFO) rule or concept. Ford and Fulkerson (1962) primarily suggested the STEN approach for the study of the dynamic maximal flow problem, where each link has a capacity and a specific traversal time. At each node, trip-makers can either refer to the next link or store for one period. (Zawack and Thompson 1987) adapted the STEN approach for dynamic traffic assignment on urban transportation networks with the terminology of green links for forwarding links and red links for storage links.

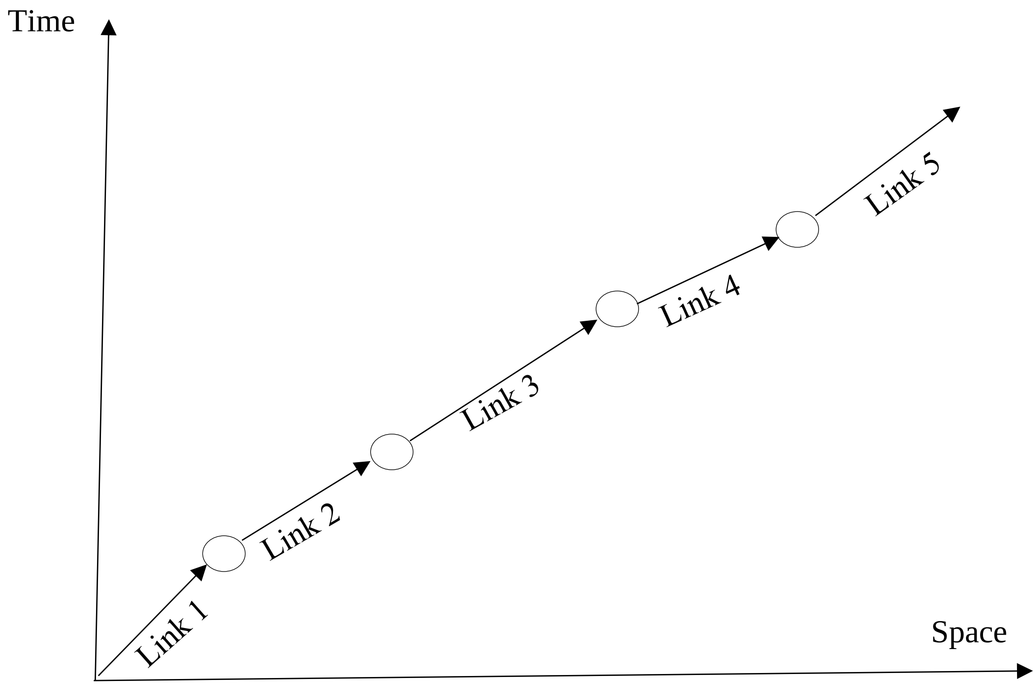


Figure 2.5. Trajectory of a vehicle through space and time

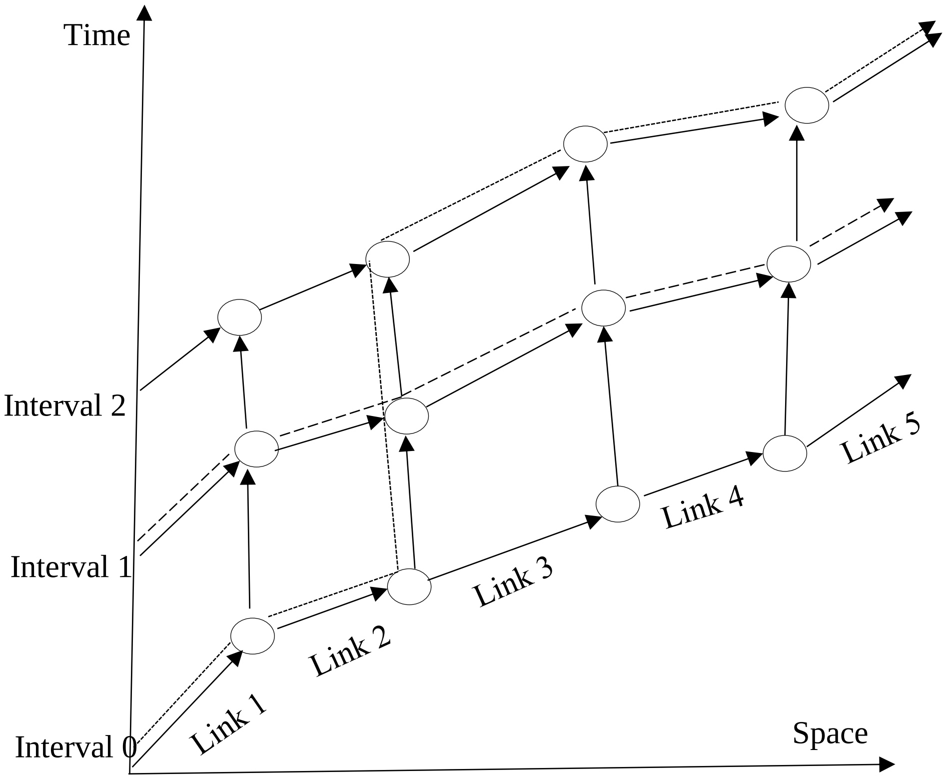


Figure 2.6. An example of STEN network with FIFO.

2.2.2. Analysis methods

There are numerous methods, algorithms, and techniques developed to find solutions for the challenged tasks relating to network flows. Some of these are applicable to all types of transportation networks, while others are specific to particular application domains. Many of these algorithms are carried out in commercial and open-source GIS software, such as GRASS GIS and the Network Analyst extension to Esri ArcGIS.

2.3. Road Transport

At its basic form road transport means the transportation of goods and people from one place to the other on roads rather than railway, seaways or airways. A road is a path between two destinations, which has been either paved or worked on to enable transportation by the way of motorized and non-motorized carriages. Road transport has many advantages that give it preference over other transportation types. Its flexibility allowing vehicles reaching from one point to another one in the networks makes it extremely advantageous over other transportation types. In other words, it can enable door-to-door delivery of people, goods and materials by providing a very cost-effective means of carriage, loading, and unloading operations. The initial investment required in road transport is also generally less disadvantages compared to other modes of transport such as railways and air transport. When comparing the types of transportation infrastructure along with operating and maintaining the system during its service period, one must look at the economic aspect, and certainly, the costs of establishing the system. Despite various merits, road transport has some major limitations, too. For instance, there are more likely to involve accidents and breakdowns making it more unsafe and unreliable compare to other means of transportation. Road transportion has more freedom than other modes of transport, but if this freedom is abused, it turns into something that cannot be controlled. Flow rates for road transportation are also unstable and unequal. The speed of road transport is slow and limited, which is one of the major drawbacks of this system. As for the long distances, especially when it is possible to use another transportation system, the road transport will have a negative impact more than the positive and may be harmful to the environment due to the pollution emanating from the modern roadway transportation. With that sense it may be stated that vehicles emit a lot of pollution in the form of Nitrogen, carbon monoxide, and various harmful air pollutants, including benzene, which have adverse respiratory health effects and a serious threat to global warming. Building roads requires the melting of tar or formulation of concrete, which may harm the associated environment., Hence the improvisation of roads is a serious topic of research. Road transport of the future is planned and designed to include aspects like solar panel roads and cars where solar cells will have replaced asphalt or tar, and there will be vehicles with electric motors reducing emissions.

2.4. Transportation Network Reliability

Various indicators, such as travel times and the level of congestion, can be used to determine if the transportation network's capacity is sufficient. In the absence of direct observations, these metrics can be estimated using a traffic attribution model.Network flows are influenced by abnormal events affecting network characteristics and capacity, like disasters, accidents, construction or repair works. As networks ideally are designed so as to cope with normal fluctuations of the traffic by offering alternative paths, planning for abnormal events requires more difficult tasks. This is mainly stem from the fact that the occurrence time and inpact level of such incidents are extremly hard to evaluate because of the stochastic structure of them. In systems engineering, reliability may be defined as the degree of stability of the quality of service that a system normally offers. In the face of increasing user demands for high levels of service, system reliability is becoming increasingly important in the planning, construction, and operation of transportation networks.In evaluating· network reliability, the flow (of people, vehicles, goods, etc.) may be divided into normal and abnormal states. Moreover, transportation network reliability has basically two major aspects; connectivity and travel time reliability. Connectivity is the probability that traffic can move from an origin to a given destination point without having disconnection problem at all. On the other hand, The possibility that traffic will arrive at a particular location within a certain time is referred to as travel time reliability. Since transportation networks in both urban and rural regions can be extensive and have complex topologies, dependability analysis might require a significant amount of computing. Transportation network reliability analysis differs from normal system reliability evaluation in that path behaviour and choices must be included. Shifting from a shorter route to a significantly longer one in communication networks, for example, normally creates no difficulty, but in transportation networks, customers are anticipated to favour shorter, quicker, or, more broadly, less expensive paths. Du and Nicholson (1995) provide an overview of the informant literature on reliability analysis in systems engineering and transportation networks

2.4.1. Connectivity reliability

A system is a piece of equipment that consists of many interconnected components. A unit is a component or part of a system. In the context of systems engineering, reliability can be defined as an item's ability to perform a required function under specified conditions for a specified period of time (see Pages and Gondran, 1986). It is assumed that units have two modes of operation: function and failure. The unit's reliability is the likelihood that it will be operational for an entire period. The relationships between each unit's reliability in a system of connected units are expressed by the reliability graph. The degree of connectedness between the system's input and output nodes can be identified by graph analysis (Inoue, 1976; Henley and Kumamoto, 1981).This approach to analysis is frequently employed for dependability analysis because of how straightforward it is conceptually and mathematically. An actual link (such as a roadway or railway line) and a link in the reliability graph correspond in the context of transportation networks. Thus, the degree of connectedness between the corresponding two nodes (or centroids) in the reliability graph can be used to describe dependability for a given creation-destination pair, also known as terminal reliability. There are several ways to assess the link's connectivity and reliability. For the sake of simplicity, let's assume that connection dependability equates to the likelihood that the associated physical link will become congested, which happens when link throughput exceeds link capacity. The connection's connectivity or dependability may be 0.5 if 50 out of 100 measurements of the hourly flow on a link are higher than the downstream capacity. Determining the link's dependability, Reliability analysis can be used to determine the connection between a couple of points of beginning and an end point. If this connectivity were, for example, 0.7, then the probability that flow from the stated origin can reach the desired location without getting into congestion, which is estimated to occur 7 times out of 10. This only applies to typical circumstances, not unnatural events like disasters, accidents, and building projects. An alternative strategy must be used in unusual circumstances. Travel time is another way to define link reliability. In this situation, the "probability that trips from a given origin can reach a given destination within a given period during stated hours" could be considered transportation network reliability.

2.5. Travel Time Reliability

The likelihood that a trip will arrive at the desired location within a specified time frame and at a specified time of day is known as travel time reliability. When it comes to commuter travel, for instance, if the likelihood that a commuter can get to his workplace from his residence within a prespecified time interval is 70 times for 100 trips,, then the travel time reliability for those trips is said to be 70%. The stability of travel time is measured by travel time reliability and is therefore quite likely to be affected by fluctuations in traffic flows. The destination can be achieved roughly on time. However Travel time is frequently longer than anticipated when flow variability is significant. The consistency of travel time is going to become more significant for transport users as the level of congestion in transport networks rises. Assume Link1 and Link2 are the two links that make up the path between a given pair of origin and destination nodes. It is possible to determine the distribution of trip times on links 1 and 2 based on previous assessments of flows. Travel time distributions are typically found to be reasonably described by the normal distribution. If the medians and standard deviations for links 1 and 2 are μ1, μ2, σ1 and σ2, parameters of the the normal distributions reperesenting travel times recorded, then it is regarded that the mean and variance of the path travel time distribution, which is likewise normal, are given by the sum of the values of the link means and link variances, respectively.

$$N(\mu_1 + \mu_2, \sigma_1^2 + \sigma_2^2) \tag{2.1}$$

Assuming that the distributions are statistically separate. Let the journey time be on pathways in general. Then.

$$\mathrm{T} \sim \mathrm{N}\left(\sum_{i \in P(S)} \mu_i, \sum_{i \in P(S)} \sigma_i^2\right) \tag{2.2}$$

Noting that the variable

$$X = \left(T - \sum_{i \in P(S)} \mu_i\right) \Big/ \sqrt{\sum_{i \in P(S)} \sigma_i^2} \tag{2.3}$$

an individual normal distribution, the chance that the journey times (travel times) on path "s" are less than a certain threshold may be determined by calculating the integral of the individual normal distribution, as follows:

$$Pr\{T \leq t\} = \varphi\left(\left(t - \sum_{i \in P(S)} \mu_i\right) \Big/ \sqrt{\sum_{i \in P(S)} \sigma_i^2}\right) \tag{2.4}$$

Where $\boldsymbol{\phi}$ (y) is the region under the normal distribution from -∞ to y.

Unlike connectivity reliability, Travel time reliability, as opposed to connection reliability, may be evaluated for individual pathways (Asakura et al., 1989).Travel Time Reliability (TTR) measures help in calculating unexpected delays. The Following measures are the main components of TTR:

2.5.1.1. Travel time index (TTI):

The Travel Time Index (TTI) is the ratio of peak-hour average travel time to free-flow travel time. In other words, the Travel Time Index reflects the average extra time necessary for a trip during peak hours as compared to the same travel duration during non-peak hours. TTI may be stated as follows: "Free flow travel time is calculated by dividing the road length by the highest permissible speed limit of the linked road." TTI can be expressed as follows,

$$TTI = \frac{\text{Average Travel Time}}{\text{Free Flow Travel Time}} \tag{2.5}$$

In this sense, if the average and free-flow travel times are given as 5 and 4 minutes, respectively, then TTI would be 1.25. This value basically expresses the fact that the trip will take 25% longer than with no congestion condition. TTI can be calculated for different temporal grouping schemes such as X-minute intervals, by the time of the day, day of the week, month, and for the entire year. In addition, for each of these groups, TTI could been calculated for weekdays and weekends separately.

2.5.1.2. Buffer index (BI):

Buffer Time is the additional time for unexpected delays that commuters should consider along with average travel time to be on-time 95 percent of the time. Buffer Index calculated as follows:

$$BI = \frac{\text{Travel Time}_{\text{95th percentile}}\text{-Average Travel Time}}{\text{Average Travel Time}} \times 100 \tag{2.6}$$

As Formula 2.6 implies the buffer index is expressed as a percentage value. For example, if BI and average travel time were 30% and 20 minutes, then the buffer time would be 6 minutes. Since it calculated by 95th percentile travel time, it represents almost all worst-case delay scenarios and assures travellers to be on-time 95 percent of all trips.

2.5.1.3. Planning time index (PTI):

The Planning Time Index is the ratio of the 95th percentile of the travel time to the free-flow travel time indicating the total time needed for an on-time arrival in 95 percent of all trips.

$$PTI = \frac{\text{Travel Time}_{\text{95th percentile}}}{\text{Free Flow Travel Time}} \tag{2.7}$$

The difference between Buffer Index and Planning Time Index is that BI represents the additional delay time that should be added to the average travel time, while the PTI points out the total trip time (average travel time + buffer time). A PTI value of 1.5 for a given period suggests that travellers should spend one and a half as much time traveling as the free-flow travel time to reach their destination on time 95% of the time. A PTI is useful because it could be straightaway compared to the travel time index on analogous numeric scales.

2.5.1.4. 90th or 95th Percentile travel times:

These measures are considered as the most accurate values that represent the travel time of the most congested day. These measures are fairly simple and easy to understand by all road users and not limited to researchers. However, the 90th or 95th Percentile measures could not be used to compare different trips because of the difference in length and other characteristics of the links to be travelled within the path. In addition, it is hard to aggregate the trip travel time and report it as a subarea or citywide average.

2.5.1.5. Percentage of travel under congestion (PTC):

The percentage of travel under congestion is defined as the percentage of all vehicles' miles travelled (VMT) under congested conditions in the specified duration. The PTC measure could be aggregated in the similar temporal style described above for TTI.

2.5.1.6. Frequency that congestion exceeds some expected threshold

In order to facilitate the study of traffic and congestion over the course of the day or week, there must be a measure that provides a value close to the real case (percentage) for the days or times when the congestion is higher than the limit that can be controlled. This measure is commonly reported on weekday peak hours.

2.5.2. Travel time

It is a specified period spent in traveling from one point to another one. The time necessary for the people to travel from home to the work place may be referred as an example. Travel time can be directly measured by traversing the route(s) that connects any two or more origin and destination points in network through nodes. Travel time value is equivalent to total value of running time and stopped delay time. While running time refers to the time in which the mode of transport is in motion, stopped delay time refers the time in which the mode of transport is stopped for any reason of delay (all kinds of delay). In some studies if the speed reduces to 5 mph, the time is considered as stopped delay time even if the vehicle is still on move (travel tıme data collectıon handbook,1998). Figure 2.7 below illustrates the concepts of running time and stopped delay time.

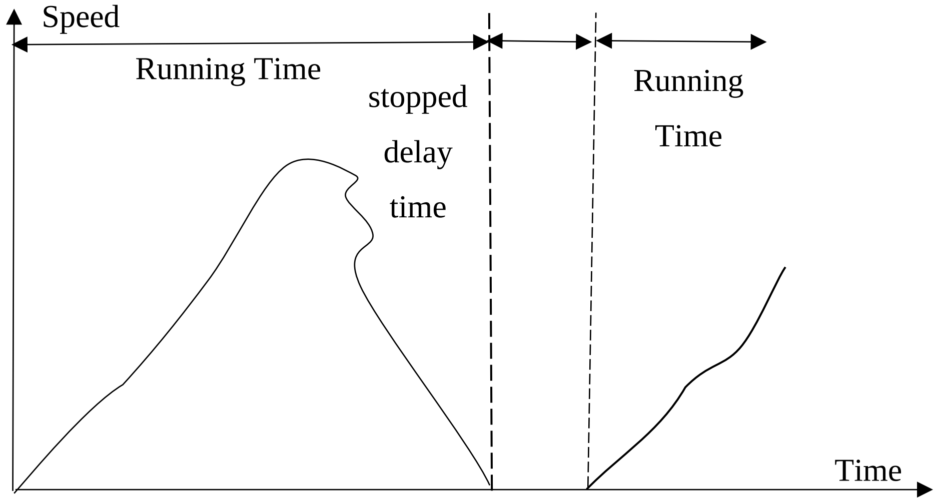


Figure 2.7. The concepts of running and stopped delay time.

Considering the time is one of the most important criteria for the level of road service, it is necessary to know the factors affecting travel time with regard to obtaining the best possible level of service. Trying to reduce or eliminate the impact of these factors is quite important. The following section discusses these factors:

1. Bottlenecks refer to road segments that exhibit reduced traffic capacity when compared to the capacity of upstream road segments. Typical bottlenecks include lane drops, changes in alignment (e.g., horizontal curves), and presence

of merge and weave sections, along with changes in physical road characteristics. Tunnels are perfect example of this case. Motorway-to-motorway interchanges, hills, geometric changes, checkpoint, and access points to residential or commercial developments can be given other types of bottlenecks. Strategies that mitigate the effect of bottlenecks include demand management at upstream locations, efficient signal treatments, provision of real-time traffic information and alternative routes for travellers.

2. Traffic-control devices used to inform, guide, and control the flow of both vehicles and pedestrians` traffic. Malfunctioning problem, ineffective or inefficient traffic-control devices cause intermittent traffic flow disruption, which, in turn, cause delays and unreliable travel times. Common problems with traffic-control devices may include use of improper devices. Proper maintenance and use of traffic-control devices can significantly reduce delays of this type of congestion.
3. Adverse weather conditions such as heavy rain, fog, snow, sandstorm, and wind, as well as seasonal variations such as glare from the position of the sun. These weather conditions interfere with the visibility of traffic-control devices and lane delineations, which can lead to significantly reduced capacity and result in non-recurrent congestion and delays. Weather also affects driver behaviour, for example, on rainy or snowy days, the drivers generally are forced to slow down to avoid skidding and getting involved in accidents.
4. Work zones are the areas where roadway construction activities result in temporary physical changes to the highway environment. Factors that create delays in work zones include lane closures, lane width reductions, lane configurations, type and duration of the work, work intensity, and the length of the work zone. The major works such as building a bridge or widening the road would have a long-term effect. Having said that it should be stated that the long-term works will have less adverse impact than the short-term works on traffic due to the fact that since road users become familiar with the changed traffic pattern, they arrange travel pattern accordingly.
5. Traffic accidents are unexpected events that disrupt the regular flow of traffic, causing a reduction in roadway capacity. These events include crashes, vehicle breakdowns, terrorist attack, spilled loads, and debris. In addition to the direct

damage caused by the accident to the road capacity, which is represented by the road being completely closed, there are collateral damages resulting from drivers who reduce their speed when approaching the accident site to watch or stop to provide assistance to the injured. Time delayed due to accident depends on the number of lanes blocked, duration of the accident and level of travel demand at the time of an accident.

6. Travel demand fluctuations are the daily and seasonal variations in travel demand resulting in increased travel time compared to regular traffic conditions. For example, during holidays and special occasions, at the beginning and end of the school and state institutions, many people start their journeys at the same time and in the same direction. This leads to a significant increase in overcrowding traffic flows. An additional travel demand of more than 6% of the average traffic volume is considering as higher demand than regular traffic. One of the available solutions to this problem may be the promotion and encouragement of public transportation usage instead of private transportation preference.

2.6. Speed

Speed is deem as the vital quality measurement of travel as the drivers and passengers will be concerned more about the speed of the journey than the design aspects of the traffic. Speed is defined as the rate of motion in distance per unit of time like kilometer per hour or mile per hour. Mathematically formula of speed or velocity “v” is given by,

$$v = \frac{d}{t} \tag{2.8}$$

where, “v” is the speed of the vehicle in km/h, “d” is distance travelled in km and time “t” in hour. Speed of different vehicles will vary with respect to time and space. Several types of speed can be defined to illustrate these difference properly. The followings are the most important types of speed used in the analysis of transportation network performances.

2.6.1. Spot speed

Spot speed is the instantaneous speed of a vehicle at a particular location on a certain time during movement or travel. The spot speed is used by transportation engineers responsible for design and management of the networks with regard to location and size of traffic signs, determination of safe speed zone and , design of signals,. Road safety and congestion analysis along with road maintenance are the main fields of traffic engineers who use spot speed data as the basic reference. There are several methods and ways to measure the spot speed. The most common one employs the radar used by the traffic police in the streets. The other methods are recording the traffic flow and dividing the video into equal parts of time (pair frames), and pressure contact tubes.

2.6.2. Running speed

Running speed is the average speed maintained over a particular section of the roadway while the vehicle is moving. It is calculated by dividing the length of the roadway to the time duration in which the vehicle was in motion. This speed doesn’t consider the time during which the vehicle is brought to a stop, or has to wait till it has a clear road ahead. The running speed will always be more than or equal to the journey speed, as delays are not considered in calculating the running speed.

2.6.3. Journey speed

Journey speed the effective speed of the vehicle on a journey between two nodes in the network is the distance between the two nodes divided by the total travel time taken for the vehicle to finish the journey including any stopped time. In most cases running speed is more than the journey speed, this is due to the fact that the vehicle follows a stop-go condition with enforced deceleration and acceleration. The closer the spot speeds are to each other, the more comfortable travels, what drivers generally look for, are available as they do not contain may stops.

2.6.4. Time mean speed and space mean speed

Time mean speed is defined as the average speed of all vehicles that pass through a specific point in a specific time period in an hour for example. Space mean speed is, on the other hand, refers to the average speed of all the vehicles occupying a given section of a highway over some specified time period." Both mean speeds will always be different from each other except in the extremely random case that all vehicles travel at the same speed. Time mean speed measures the speed at a specific point, on the other hand, space mean speed measurement is related to the length of a highway or a lane. Depending on the time mean speed we can get an estimated travel time in certain cases by assuming the average speed at a particular point (spot speed) is constant for a relatively short distance (usually less than 0.8 kilometer). The consistent speeds over a short roadway segment is frequently applicable to continuous flow facilities like motorways or with stable traffic flow patterns. The estimated travel time for any road segment can be calculated using the average spot speed, or time-mean speed through the Equations below.

$$\text{Time-Mean Speed, } \overline{V}_{TMS} = avg.speed = \frac{\sum v_i}{n} = \frac{\sum \frac{d}{t_i}}{n} \tag{2.9}$$

$$\text{ETT} = \frac{\text{Segment Length (km)}}{\text{Time-Mean Speed (km/h)}} \times (3600\ sec/hour) \tag{2.10}$$

$$\text{SMS, } \overline{V}_{SMS} = avg.speed = \frac{\text{distance traveled}}{\text{avg.travel time}} = \frac{d}{\frac{\sum t_i}{n}} = \frac{n \times d}{\sum t_{\text{i}}} \tag{2.11}$$

2.6.5. Average running speeds

Average running speeds can be calculated by using the average running time, which does not include any stopped delay time (Equation 2.12). If there is no stopped delay, the average running speed is equal to the space-mean speed. Running speeds may be suitable if one does not want to include any stopped delays caused by traffic signals or any other factors along a journey.

$$\text{Average Running Speed, } \overline{v_r} = \frac{\text{distance traveled}}{\text{avg. running time}} = \frac{d}{\sum \frac{t_{ri}}{n}} = \frac{n \times d}{\sum t_{ri}} \tag{2.12}$$

2.7. Geometric Design of Roads

The geometric design of roads is the branch of highway engineering concerned with positioning the roadway's physical elements according to standards and constraints. The basic objectives in geometric design are to improve adequacy and safety while minimizing oprational costs and environmental pollution. The geometric design also affects an emerging objective called "livability," which refers to designing roads to great and remarkable development community goals, including providing access to businesses, employment, school, and residences, accommodating a range of travel modes such as walking, bicycling, transit, to minimise fuel use, emissions, and environmental pollution. Geometric roadway design can be divided into three main parts: alignment, profile, and cross-section. Combined, they provide a three-dimensional layout for a roadway.

- The alignment is the route of the road, defined as a series of horizontal tangents and curves.
- The profile is the vertical aspect of the road, including crest and sag curves, and the straight grade lines connecting them.

The cross-section shows the position and number of vehicle, bicycle lanes, sidewalks, and cross slope or banking. Additionally, cross sections display pavement structure, drainage features. The cross section can identify the efficiency of the discharge, pavement structure and other items outside the category of geometric design.

2.7.1. Profile

The profile of a road consists of road slopes, called grades, connected by parabolic vertical curves. In order to allow for a unified transition from one road slope to another, vertical curves are employed in the design of roads.

Sag vertical curves have a tangent slope at the end of the curve that may be higher or lower than that at the beginning of the curve. When driving on a road, a sag curve would appear as a valley, with the vehicle first going downhill before reaching the bottom of the curve and continuing uphill.

Crest vertical curves, however, are those with tangent slopes having positive absolute value in terms of the gebric diferences of the slopes. A crest curve would seem like a small hill when driving on a road with initially uphill movement before coming to the top point of the curve then moving on continuing downhill.

2.7.2. Alignment

Horizontal alignment in road design consists of straight sections of the road, known as tangents, associated by circular horizontal curves. Circular curves are mainly characterised by their radius and deflection angles. The design of a horizontal curve is designed by considering the minimum radius requierd based on design speed of the project, curve length, and objects obstructing the view of the driver.

The utmost concern that a transportation engineer has is to design a road that is safe and comfortable through the valid design standards. If a horizontal curve needs to be designed under high speed and a small radius, then an superelevation (bank) may be required to assure safety. If there is an object obstructing the view around a corner or curve, the engineer must work to ensure that drivers can see far enough to stop to avoid an accident.

2.7.3. Cross section

The cross-section of a roadway can be deemed as representing the configuration of a proposed roadway at right angles to the centerline. It basically express what someone would see when roadway is looked in case that the central line is cut through right angle. In this way the size and positions of trenches, the widths- cross slopes and the number of lanes, as well as the presence or absence of shoulders, curbs, sidewalks, drains and other roadway features can be illustrated. The cross-sectional shape of a road surface across a roadway, in particular in connection to its part in managing runoff, is called "crown".

2.7.4. Lane width

The selection of lane width affects the safety, capacity, and cost of a highway, The suggested set of best at a widths in urban networks are of 3.0 to 3.1 meters where narrow less than 3.0 meter-lanes and widths over 3.1 meter-lanes have higher crash risks. Lanes wider than 3.3~3.4m are also associated with 33% higher speeds and more severe collision. The capacity is also optimal at a width of 3.0 to 3.1 meters both for motor traffic and bicycles. Wider lanes and shoulders are usually used on roads with higher speeds and higher traffic volumes especially with significant numbers of trucks and other large vehicles.

2.8. Classification of Urban Roads and Streets

The following six classes of urban roads and streets have been recommended in the IRC Manual on Planning and Development of Urban Roads and Streets. [6]

● Urban Expressway: An urban expressway is a high-speed regional passenger and goods highway that connects to other intercity highways entering the city at specific points. These have complete access control, divided lanes for high-speed transport, grade separators typically installed at intersections, and service roads on both sides.

● Arterial route: A street or road designated largely for through traffic, typically on an uninterrupted route. Arterial roads facilitate mobility across the city and connect to long-distance destinations within/outside the city while providing safe non-motorised traffic (NMT) facilities. On-street parking is either prohibited or strictly regulated unless a service lane and parking space are available.

● Sub Arterial Road: This road are denoted a a road/street primarily for through traffic usually on a continuous route but offering somewhat lower level of traffic mobility than the arterial road. These are bigger collector roads designed for providing travel through neighborhoods and to connect arterial routes.

● Collector Street: These are the streets used for collecting and distributing traffic from and to local streets along with providing access to arterial/sub arterial roads. They are designed with dedicated footpaths. Various speed reduction measures known as traffic calming may be put into practice to limit vehicle speeds to ensure safety of NMT users.

● Local Street: These are primarily used to get access to residence, business or other abutting properties. Their primary function are to provide access for local activities and properties. Local streets may not have a designated walkway instead they may be planned as a shared space with NMT modes of mobility.Various traffic calming elements may also be employed to ensure that vehicle speeds are safe enough for intermingling with pedestrians, cyclists, and motor vehicles.

● Non-Motorized Transport (NMT) Streets and Greenways: All motorized traffic are be prohibited to access these streets by using barriers and enforcement of regulations to prevent their entry and encroachment to NMT space. These streets provide safe pedestrian and bicycle movement, access to emergency response vehicles, and, hence, are built in accordance with universal accessibility standards.

2.9. Delay

When moving from one place to another, there are determinants governing this transition. While some of them may be known beforehand, some of which may only be guessed and expected making them having non-fixed values. For example, the distance, the permitted speed and the number of intersections may be regarded as the known elements. As for the expected; the time of the trip depending on the speed at which the vehicle will have opportunity to travel under available traffic conditions and remain unstable from day to day and from hour to hour as a result of delay times mainly caused by unforeseeable changes in the traffic and road conditions. There are situations where the road users may know that they will be late, but how long it will be is generally unknown by the reasons explained. The network investigated in this study however, had a specific points where the road users experince extra delays . These points are military checkpoints. These checkpoints are spread throughout all the streets of Iraq in general, and in Baghdad specifically. They turn the number of lanes in the roadway into only one lane causing a great delay for the users. The recent removal of some checkpoints made indeed a huge difference in the delay for these streets indicating their profound impact on the delays that drivers had toexperience. By the virtue of previous studies, it is possible to get an approximate value. Delay causes time losses, financial losses, and sometimes, unfortunately, lives due to the patient's late arrival to the hospital.The delay itself is one of the main factors having biggest influences on the reliability of the travel time. Delays are of several types and for each type there is a suitable unique approach for the solution for it in terms of the impact and cost that they produce. There is no solution that eliminates the delay totally, but solutions might help as much as possible to reduce the delay. The most frequently used forms of delay are defined as follows:

1. Stopped time delay

2. Approach delay
3. Travel time delay
4. Time-in-queue delay
5. Control delay

These delay measures can be completely different, depending on conditions at the intersections. Figure 2.8. shows the differences among stopped time, approach and travel time delay for single vehicle traversing a signalized intersection.

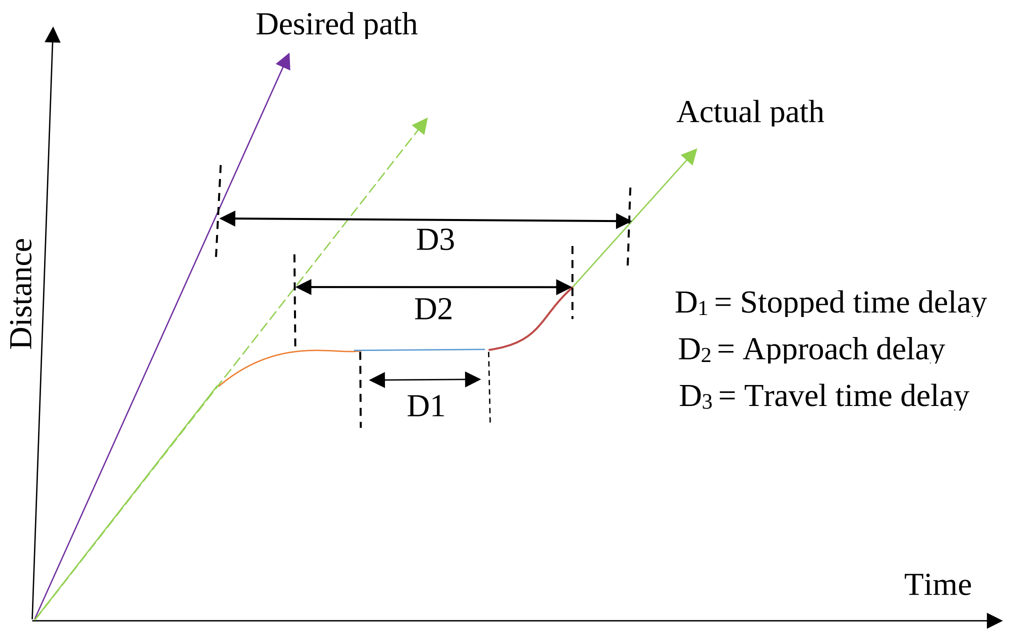


Figure 2.8. Illustration of various types of delay measures.

Note that while the desired path is the path when vehicles travel with their suitable speed the actual path is the path depending on decreased speed, stops and acceleration and deceleration.

2.9.1. Stopped time delay

Stopped-time delay is defined as the time a vehicle is stopped in queue while waiting to pass through the intersection. It begins when the vehicle speed becomes zero and ends when the speed starts to have value away from zero (increase) and approach to the design or operational speed. Average stopped-time delay is the average for all vehicles during a specified time period.

2.9.2. Approach delay

Approach delay includes stopped-time loses but also adds the time loss due to retardation from the approach speed to a stop (deceleration) and the time loss due to reacceleration back to the required speed. It's set up by extending the haste pitch of the approaching vehicle as if no signal was available. Approach delay is the vertical time difference between the extension of the approaching velocity slope and the departure slope after full acceleration is achieved. Average approach delayis the normal process for all vehicles during a specified time period.

2.9.3. Travel time delay

If the expected time for the trip or passing the whole or part of the road becomes less than the real time, then the difference between the two values is Travel Time Delay. This concept of delay is generally used for some planning studies.

2.9.4. Time-in-queue delay

Time- in- queue Delay is the total time from a vehicle reached a crossroad line to its discharge across the stop line on going down from crossroad. Time-in- queue delay can not be effectively determined by using only one vehicle, as it involves joining and departing a line of several vehicles.

2.9.5. Control delay

Control delay is the delay which can be controlled by control device, either a traffic signal or a traffic police. It is nearly the total value of time-in-queue delay + the acceleration + deceleration delay. There are two ways to measure the delay: either all delay values for all vehicles over a specified time period, or the delay for one vehicle and set as an average for all vehicles over a specified time period. The total delay represents the total delay time experienced by all vehicles in the specified time interval. Average individual delay, on the other hand, is generally stated as a delay expressed in terms of seconds per vehicle for a specified time interval.

3. METHODOLOGY

3.1. Overview

As previously mentioned, this study investigates travel time reliability of the network present at the city of Baghdad “Russafa side” through selected different paths for the same origin and destination points.Figure 3.1. shows the research plan for the study. The traffic data was collected on the period from March 14, 2022 to May 12 ,2022. The morning peak period between 7:00 am to 9:00 am, the noon period from 1:00 pm to 3:00 pm ,and the night period from 5:00 pm to 7:00 pm were selected as the time intervals to collect traffic data via probe vehicle travelling from the same origin to the same destination via 3 different routes.The data collected through manually for 34 rounds. The trips for each route to desired destination is made through the same roads for going and returning with the exception the first route. Although the routes for this first route share the same streets and roads to a large extent, it was not possible to make the way to the target destination and return via using exactly the same streets for the trips due to design characteristics of the streets

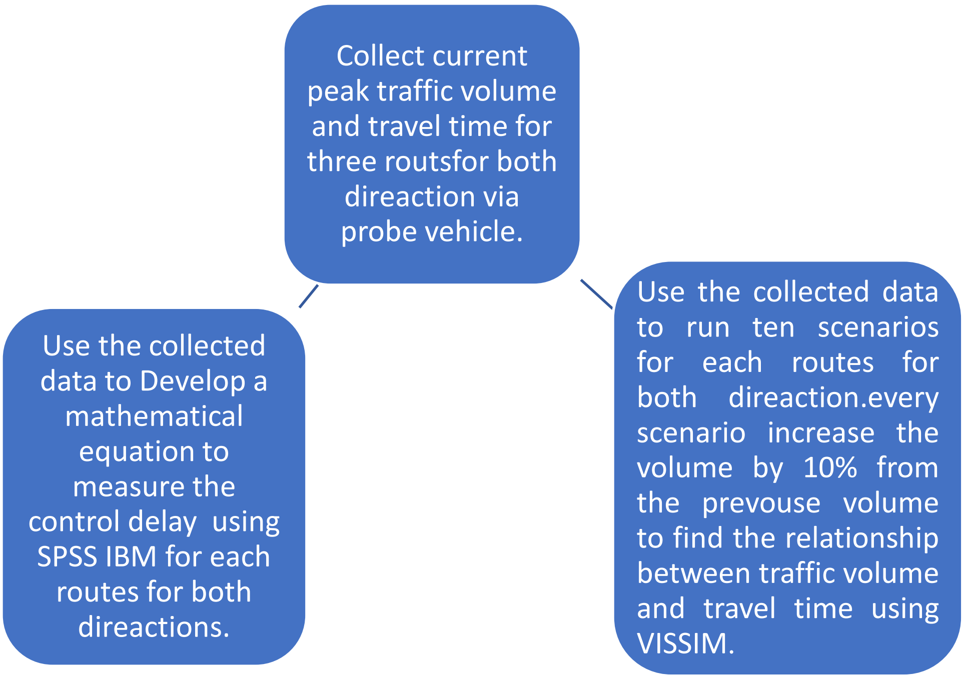


Figure 3.1. Research approach plan.

3.2. Collecting Traffic Data

In order to obtain accurate results, accurate data are needed as inputs. But in engineering studies and analysis there is always possibility that 100% accuracy may not be reached all the time. On the other hand, every effort must be put into practice to get as accurate data as possible. In this study the research area chosen has special characteristics to become attractive for the students, commuters and other road users. For example, the routes start, go through and end at the locations where a high population density and heavy traffic flows govern.

The process of collecting data took place in Baghdad, specifically in the Rusafa region. The data are collected for 3 different paths similar in starting and ending points through three periods; morning, noon and evening departure in the morning and return in the evening). This applies to all paths. Each of these roads has distinguishing features from other roads, as one of them contains many intersections and was chosen to find the extent of their impact on travel time, while the other contains a variety of types of road sections. The following tables represent the physical properties of each of link sections. Each links begins and ends with an intersection except for the first link in all routes, it starts from the starting point and ends with the Nadaa intersection, which takes a relatively long time in order to reach the intersection despite of shortening the distance from the starting point to the intersection. This delay cannot be ignored as it sometimes reaches more than five minutes. Each of the three routes is distinct from the others. In the three tables that follow, we will identify the Link characteristics for each route, such as the length of the links, the number of lanes inside these links, and the roadways. Table 3.1 examines the first road's features, Table 3.2 examines the second road, and Table 3.3 examines the third road. This will assist us in understanding the nature of the road, since traffic is impacted by numerous elements, including the permissible speed and the length of the segment, which will assist us in understanding the findings in the future after analysis and determining how accurate they are in light of the preceding considerations.

Table 3.1. Link characteristics of route 1.

Link	Name	Length (km)	No. of lane (one direction)		Lane width (meter)		Speed limit (km/h)	
			North	South	North	South	North	South
1	Street I[a]	0.655	2	2	3	3	40	40
2	Abo talab I	1.172	3	3	3.2	3.2	60	60
3	Abo talab II	0.874	3	3	3.2	3.2	60	60
4	Street II[b]	11.82	4-3	4-3	3.5	3.5	100	100

a : from origan to the Nadaa int.

Table 3.2. Link characteristics of route 2.

Link	Name	Length (km)	No. of lane (One direction)		Lane width (meter)		Speed limit (km/h)	
1	Street I[a]	0.655	2	2	3	3	40	40
2	Ministry of Labour	1.887	2	2	3.2	3.2	40	40
3	Palestine Street I	1.08	3	3	3.3	3.3	60	60
4	Palestine Street II	0.536	3	3	3.3	3.3	60	60
5	Palestine Street III	2.563	3	3	3.3	3.3	60	60
6	Palestine Street IV	1.56	3	3	3.3	3.3	60	60
7	Palestine Street V	0.911	3	3	3.3	3.3	60	60

a: from origan to the Nadaa int

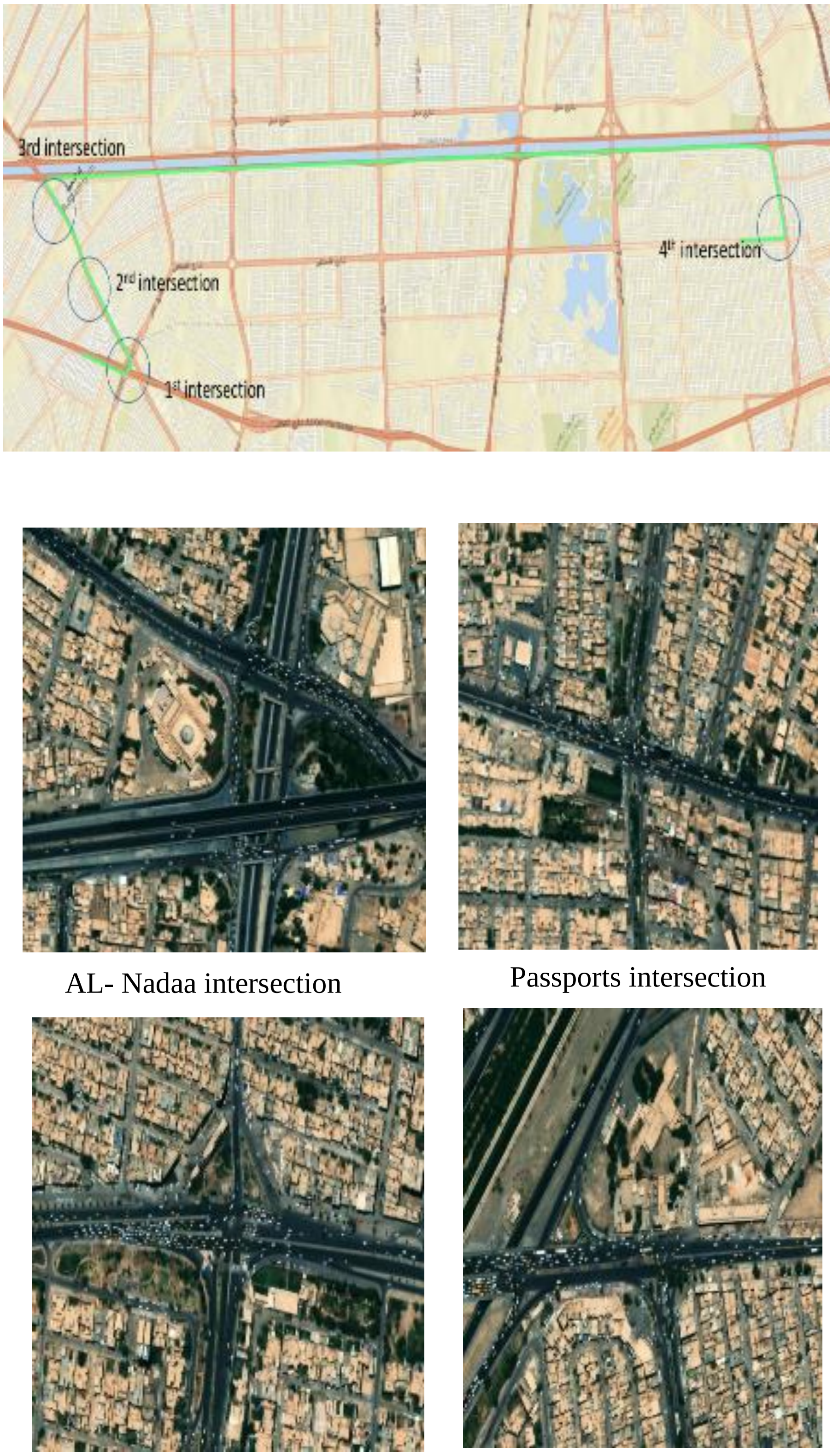
Table 3.3. Link characteristics of route 3.

link	Name	Length (km)	No. of a lane (one direction)		Lane width (meter)		Speed limit (km/h)	
			North	South	North	South	North	South
1	Street I[a]	0.65	2	2	3	3	40	40
2	M.alqasm	8.54	3	3	3.5	3.5	100	100
3	Al-rubiae bir.	0.86	3	3	3.2	3.2	60	60
4	Al-rubiae	1.4	3	3	3.2	3.2	60	60

a : from origan to the Nadaa int.

Since each of these three routes has characteristics that distinguish it from the others, each path was dealth with separately to study traffic and the causes of delays that affect its travel time reliability.

The total length of the first path-route is 15.6 km. It is characterized by a variety of links passing through residential and commercial areas. This path contains a section of Army Canal Motorway (ACM) carrying large vehicles which surely contribute to increase the congestion level on the path. ACM is a strategic and important road in Baghdad to transport commercial and other goods from Baghdad to the provinces and vice versa. Figure 3.2. illustrates the Route 1 and the locations of the intersections available on the path. The green path represents Route 1 consisting of 4 intersections and 3 tunnels. There is also a variation in the speed limits of 40, 60 and 100 km/h which result in a variety of time of transmission in different links.



AL- Nadaa intersection

Passports intersection

Maysalon intersection

popular clinic intersection

Figure 3.2. Topology and location of the intersections of route 1.

Route 2 characterized by the fact that it is intended to be used only by small and medium-sized vehicles. It consists of two important streets in Baghdad, Ministry of Labour and Social Affairs Streets and Palestine Streets. This path was chosen as it is characterized by an abundance of traffic containing the vital intersections in Baghdad on the Rusafa side. Most of the intersections are located closely to very important areas around universities, ministries, military facilities and commercial streets daily visited by many people such as employees, students, soldiers, auditors etc. This generates a large crowd especially in the morning period. This path starts from the al Nidaa intersection and ends at the Rubaie intersection with the length of 10.4 km involving 8 intersections. Since one intersection was crossed by using the bridge, the total number entered in the calculation is 7. As it is shown in Table 3.2 it is divided into several distinguished links different in terms of length, the number of lanes, and road type. Some of the links do not contain side stops making traffic move faster than those that contain side stops allowing waiting for a short period of time but not stopping. The second type, on the other hand, allows both stopping and waiting. As for speed, while the speed limit on Ministry of Labour and Social Affairs Street is 40 km/h,Palestine Street has the speed limit of 60 km/h. Figure 3.3.and Figure3.4. below illustrates the route and the locations of the intersections it contains.

Figure 3.3. Topology and location of the intersections of route 2.

Al Mawail intersection

BabAl Moatham intersection

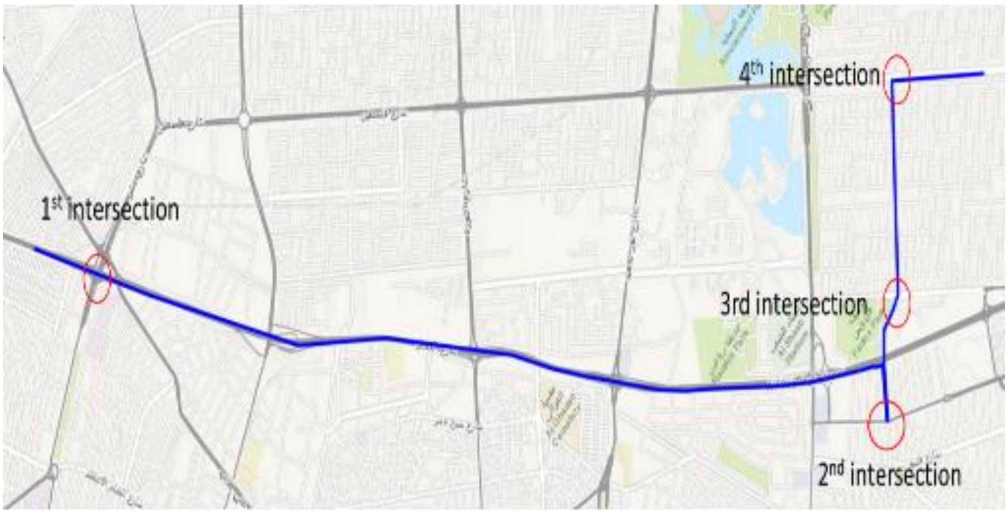
Martyrs' intersections

Al Rubaie intersections

Figure 3.4. Various intersections located on the second route.

Routes 3 has the length of 12.5 km. It contains four intersections. Muhammad Al-Qasim Motorway is part of this route and represents about 60% of the total length of the route. Muhammad Al-Qasim is considered one of the most important highways in the Rusafa region as it passes through the main terminal from which trips depart from Baghdad to the rest of the important cities and areas in Iraq

It also passes through the center of Baghdad connecting industrial, ministrial areas and universities making it very important and used almost daily by the people from different social level of the community. As for the second notable part of this route, Al-Rubaie Street, it is a very important commercial street in Baghdad and crowded most of the time. Given the above, it is crucial to evaluate the reliability of this main artery. Figure 3.5. below illustrates the route and the locations of the intersections it contains



AlNadaa intersection

Al-Rubaie Bridge

Dream city intersection

Al Rubaie intersections

Figure 3.5. Various intersections located on the third route.

The following table represents details of each intersection for all routes.

Table 3.4. Details of each intersection.

NO	Name	Type	location GPS UTM N (m)	location GPS UTM E (m)	Contains bridge	Bridge direction	Located at route
1	Al Nidaa	4 ways	3692876	442839	no	/	1st,2nd, and 3rd
2	Passports	4 ways	3694069	442915	no	/	1st
3	popular clinic	3 ways	3694912	442977	no	/	1st
4	Maysalon	4 ways	3686705	450572	no	/	1st
6	Al Mawail	4 ways	444456	444456.8	yes	E-W	2nd
7	Bab al Moatham	4 ways	445245	445245.8	no	/	2nd
8	Al-Sagrah	4 ways	445644	445644.6	no	/	2nd
9	Martyrs' Square	4 ways	447522	3689566	yes	E-W	2nd
10	Ministry of Youth	4 ways	448699	3688475	yes	E-W	2nd
11	Al-Rubaie Bridge	4 ways	3686304	447688	no	/	3rd
12	Dream city	4 ways	3686812	448361	no	/	3rd
13	Al Rubaie	3 ways	449346	3687860	no	/	3rd and 2nd

3.2.1. Data collection method

Test vehicle techniques (often referred to as “floating car”) are the most common travel time collection methods and consist of a vehicle(s) that is specifically dispatched to drive with the traffic stream for the express purpose of data collection.

Data collection personnel in the test vehicle control the speed of the vehicle according to set driving guidelines and record manually the travel times at designated checkpoints using a clipboard and stopwatch. Because of the development in technology there are mobile applications on the mobile phone to be used for this purpose. The Speed View GPS mobile application in this sense was employed during the field study of each route for data collection. Maximum and minimum speed, average speed, total distance travelled, total trip time, and stopping time for each trip and along the trip are the data collected .Once the speed changes during the trip for any reason, the application recorded the Latitude and Longitude values of the point along with all the above data stated.

3.3. SPSS IBM

SPSS standing for “Statistical Package for the Social Sciences” is an IBM tool launched in 1968. This package is mainly used for statistical analysis of the big and coomplex data. It is mainly used in the areas like healthcare, educational research, survey companies, and many others. It provides data analysis for descriptive statistics, numeral outcome predictions, and identifications of the groups. This software also produces data transformation, graphing and direct marketing features to manage data smoothly. SPSS offers statistical capabilities for analysing the exact outcome. One of the best features why researchers prefer SPSS is that it provides easy access to data with different variable types. [14] SPSS helps researchers to set up model effectively due to its most of the processes being automated. One of the primary benefits of using SPSS is its ability to help researchers make informed decisions, as the software's features enable users to analysis large data sets quickly and accurately. Additionally, it helps to minimize errors and improve accuracy by providing multiple features such as data exploration, standardization and automatic calculation. This helps researchers to save time and money as they can quickly analysis data and draw valid conclusions.

Moreover, it enables users to easily access and share their data, which can be securely stored in the cloud.

3.3.1. Developing a SPSS model

Developing a model using SPSS requires the user to input their data into the program and select the type of analysis to be used. Once the analysis has been selected, the user must specify the dependent and independent variables, as well as any confounders. The next step is to run the model to generate a set of results. The results obtained can then be interpreted and conclusions are drawn. In the broadest sense models are used to analyze data and predict outcomes. For example, a regression model can be used to predict how changes in one variable will affect changes in another one. Models can also be used to calculate probabilities of the occurrence of different secenarios and determine the best course of action. Because of all these benefical features of IBM SPSS Statistics software it has been employed in this study to obtain the statistical model for finding a relationship for the control delay and the explanatory dependent variables; the deceleration, stopped, and acceleration delay. The acceleration, stopping and deceleration delay timeswas introduced in the regression model using stepwise method for the morning and night times of the 34 rounds for each route as shown in Figure 3.6.

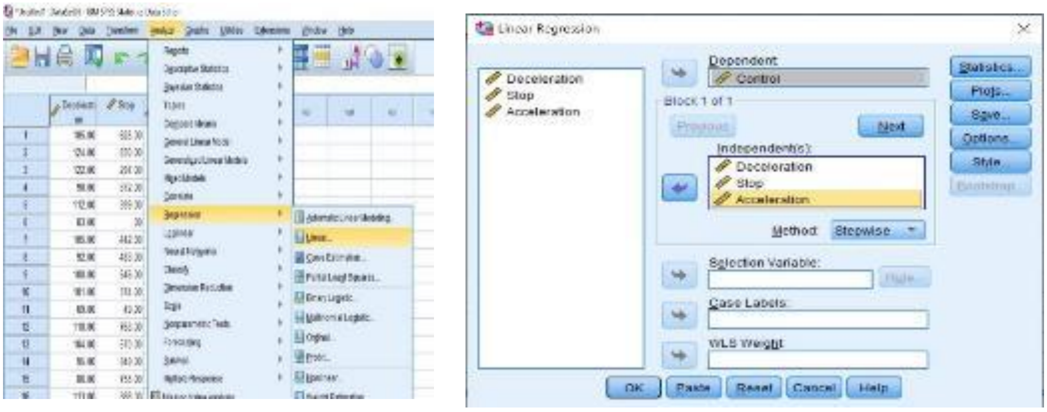


Figure 3.6. SPSS analysis method.

3.4. VISSIM

As a traffic professional, it is truly important to recognize the importance of understanding traffic patterns and how they can be used to make decisions to improve the traffic flow available on the network. However, the sheer volume of data and the complexity of analysis can be overwhelming. This is where a tool like VISSIM comes in. VISSIM is a powerful traffic simulation software that can be used to accurately model and simulate traffic networks. The following section discusses what VISSIM is, the components of a VISSIM network, setting up a VISSIM simulation and interpreting the results.

3.4.1. Introduction to VISSIM

VISSIM is a traffic simulation software created by PTV Group, a German-based software company. It is used by traffic professionals, engineers, and city planners to simulate and analyse traffic on transportation networks. VISSIM allows users to model traffic networks in a virtual environment, simulating the behavior of drivers, vehicles, pedestrians, and other elements of a road users. This makes it possible to analyse the impact of different traffic scenarios and predict the effects on traffic flow.VISSIM is a versatile tool that can be used in a variety of ways. It can be used to design and test new traffic networks, develop traffic signal controllers, and optimize existing road networks. It can also be used to evaluate the impact of new developments or road improvements on traffic flow.

There are many advantages to use VISSIM for traffic simulation as described below.

- The first is that VISSIM is an extremely powerful and flexible tool. It can be used to create highly detailed simulations of complex traffic networks, allowing for a comprehensive analysis of the system.
- VISSIM also features an intuitive user interface and a wide range of features. It includes a library of pre-built components, such as roads, intersections, vehicles, and traffic signals, making it easy to create simulations quickly.
- Another benefit of using VISSIM is that it is relatively easy to learn. The software includes detailed tutorials and documentation to help users get started. And for more complex simulations, there is an active user community where experienced users can provide assistance and advice.
- Finally, VISSIM is relatively affordable. The cost of the software is well within the budget of most traffic professionals.

3.4.2. Overview of VISSIM components

Before beginning to set up a VISSIM simulation, it is needed to understand the components of a VISSIM network. A VISSIM network consists of four main components:

- Road Network: This is the most basic component of a VISSIM network. It consists of the roads, intersections, and any other elements that make up the transportation network.
- Vehicles: This component consists of the vehicles that will be simulated in the network. This includes the type and number of vehicles, as well as the types of drivers that will be driving them.
- Traffic Signals: This component consists of the traffic signals to be be used to control traffic flow in the network.
- Drivers: This component consists of the drivers that will be simulated in the network. This includes the types of drivers and their driving behaviour.

3.4.3. Steps to setting up a VISSIM network

- After basic understanding of VISSIM components, it is time to begin setting up a VISSIM network. The first step is to create a road network. This can be done by either creating a new network from scratch or importing a network from a GIS system.
- Once the road network has been created, the next step is to add the vehicles. This can be done by selecting the type and number of vehicles, as well as the types of drivers that will be driving them.
- The third step is to add the traffic signals. This involves selecting the type of traffic signals and the timing of the signals.
- The fourth step is to add the drivers. This involves selecting the types of drivers and their driving behaviour.
- The fifth and final step is to set the simulation parameters. This includes the time step, the duration of the simulation, and any other parameters that need to be set.

Once all of these steps have been completed, the simulation is ready to be run.

3.4.4. Interpreting VISSIM results

Once the simulation has been run, the next step is to interpret the results obtained. VISSIM produces a variety of reports that can be used to analyze the performance of the simulated traffic network. These reports include traffic flow diagrams, speed profiles, and trip times. The traffic flow diagrams provide an overview of the simulated traffic network, showing the number of vehicles at each intersection and the average speed on each road segment. The speed profiles provide detailed information on the speed of vehicles in the network, showing the average speed and the speed distribution of vehicles. And the trip times reports provide information on the average travel times between two points in the network. These reports can be used to evaluate the performance of the simulated traffic network and identify areas requiring improvement.

3.4.5. Developing a VISSIM model

Once interpretation of the results of the initial simulation are carried out, then more detailed model can be developed. This process involves adding more elements to the simulation, such as different types of vehicles, more traffic signals, and more drivers. It also involves tweaking the parameters of the simulation, such as the time step, the duration of the simulation, and the speed limits. This will allow the analyst to get a more realistic simulation of the traffic network. At the final step, the simulation can be run again to allow the program user to refine the model until it produces the desired results.

3.4.6. Advanced VISSIM modeling

Once the basic understanding of VISSIM is known, there is a possibility to explore more advanced modeling techniques. This includes creating more complex simulations, such as those involving multiple intersections or multiple traffic signals.

It also involves exploring more advanced features of VISSIM, such as the ability to simulate driver behavior, traffic signal optimization, and the ability to simulate dynamic traffic scenarios. This will allow us to create more accurate simulations and gain a better understanding of the traffic network.

3.4.7. Troubleshooting VISSIM simulation

When creating a VISSIM simulation, there are a few common issues that can arise. These include incorrect input data, errors in the network configuration, and errors in the simulation parameters.

If any of these issues are encountered, the first step is to double-check the input data and the network configuration to ensure that they are correct. Then, checking the simulation parameters are performed to make sure they are set correctly. Finally, the simulation results are controlled to ensure that they are accurate.

3.4.8. Applications of VISSIM

VISSIM is a powerful tool that can be used in a variety of applications. It can be used to design and analyse new traffic networks, develop traffic signal controllers, optimize existing road networks, and evaluate the impact of new developments or road improvements.It can also be used to evaluate the performance of existing traffic networks, analyse driver behavior, and simulate dynamic traffic scenarios..

By modeling, it is possible to evaluate the present situation of the network investigated. Afterwards, development and implementation of new strategies that will enable the most suitable solution can be found by investigating the network under various scenarios. The following analyses may be possible to be performed by employing VISSIM software in 2D and 3D [15]:

- Transportation systems (networks) and vehicle movement patterns,

- Traffic and transportation management,

- Rail transportation,

- Control of signaling systems,

- Urban traffic management (one-way applications, pedestrianization, etc.)

- Evaluation and analysis (delay, queuing, density studies etc.)

- Analysis of complex intersections,

The program was employed to find the relationship between travel time and changing traffic volumes to evaluate the fluctuations of the travel times on the related paths. The movement was simulated in each route and the value of travel time, the average vehicle delay and thea average stopping delay were all calculated for each route.

4. RESULTS

As discussed, apart from the collected actual data, the link travel travel times were calculated by combining direct link travel time measurements and link travel times obtained by using VISSIM program. In this chapter, the results of direct travel time measurements are initially introduced for each route. Then, for the control delay and the explanatory dependant variables (the deceleration, stopped, and acceleration delay) regarding each route are analysed statistically to get the correlations and relations. Finally, the simulation results of travel time estimations obtained through VISSIM program are discussed.

4.1. Direct Travel Time Measurement

The results obtained through the test drive during morning, noon, and evening for the route 1 in the northern and southern directions are shown in Figure 4.1. and 4.2. These figures shows the distribution of direct measurement route travel times. Figure 4.1 represents the distribution of travel times for the morning period. While, as shown, the 12th day represents the day with the highest travel time value, the 6th day represents the lowest value of travel time. The day 16 and 17 represents the noon period travel time. Figure 4.2 represents the distribution of travel times acquired for the night time travels. It should be pointed that the starting point of the daytime is the same as the ending point of the night, and the same goes in reverse. As can be seen from the figure, the 8th day represents the day with the highest travel time value. On the other hand, 15th day characterises the lowest value of travel time. 16th and 17th days represents the travel time data for the noon period.

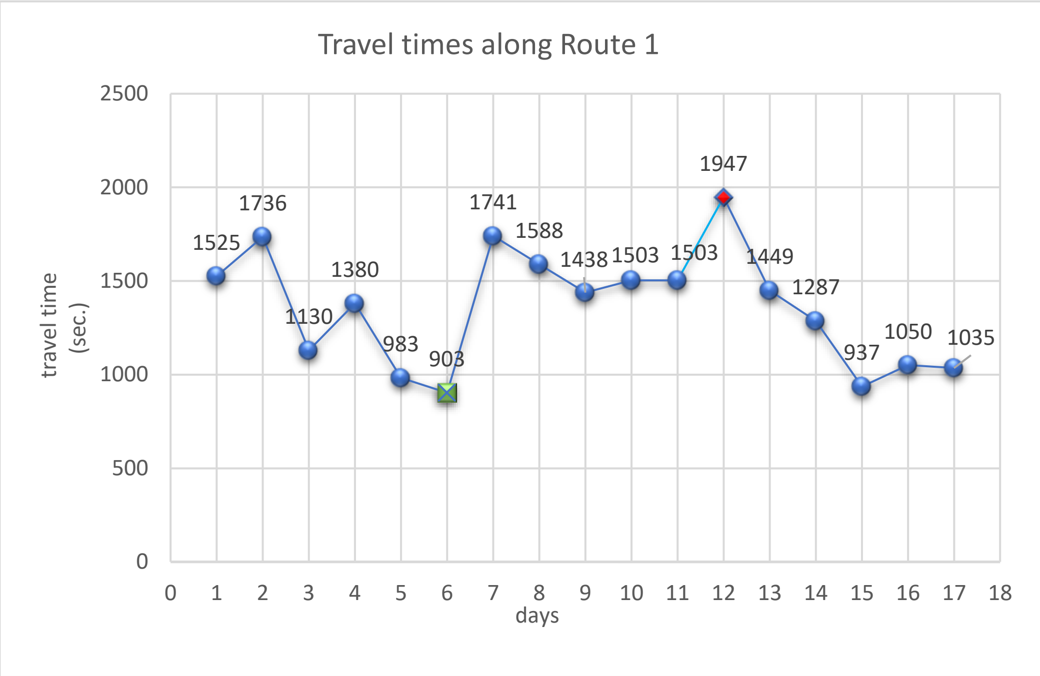


Figure 4.1. Travel time for route 1 for north direction (during morning and noon).

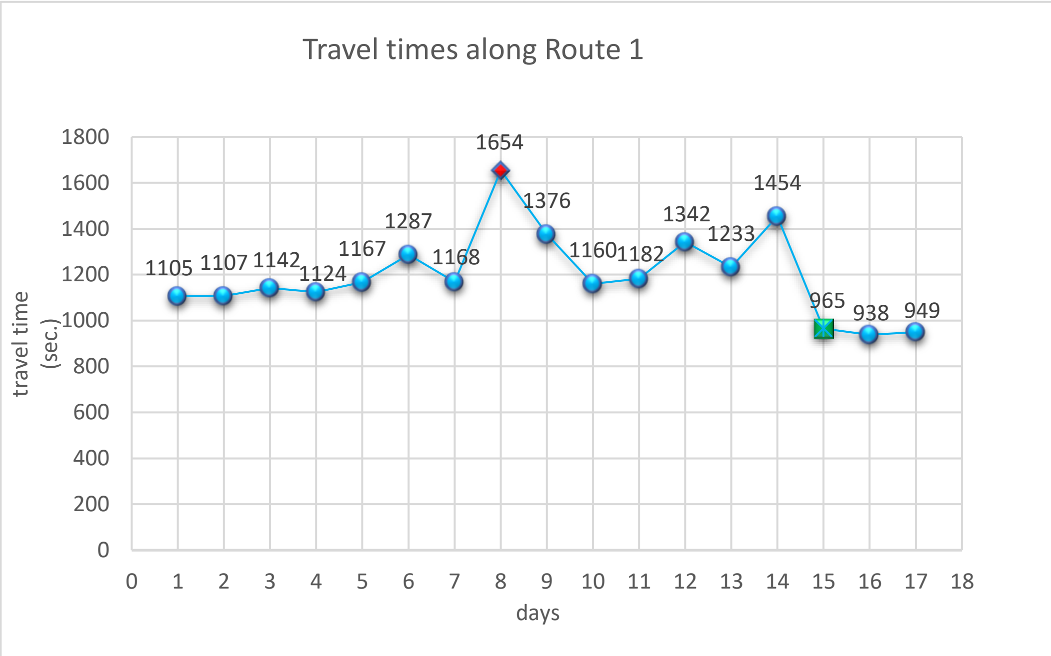


Figure 4.2. Travel time for route 1 for south direction (during night and noon).

It can be seen from Figure 4.1. that there is a significant discrepancy among the values of the travel times, making it difficult to determine the reliability efficiency of the travel. This fluctuations imply that the journey itself may be more challenging or time-consuming than it needs to be. Hence, it is important to consider the effects of this discrepancy when making plans and expectations for a journey. However there is relatively smoother reliability of the data represented in Figure 4.2 where it is observed that the variance of the values is close on all days. These results contribute to the credibility of the collected data. As such, the conclusions can be viewed as valid and accurate by providing a deeper insight into the nature of the analysis of the paths as far as travel time reliability concept is concerned.

Figure 4.3. and 4.4 shows the distribution of direct measurement route travel time for the second route in both northern and southern directions for the time period of morning, noon, and evening. Figure 4.3 illustrates the distribution of travel times obtained in the morning time , and as shown, the 12th day represents the day with the highest travel time value. Furthermore, the sixth day represents the lowest value of travel time. On the other hand, days of 16 and 17 represent the noon period travel time. Figure 4.4.represents the distribution of travel times obtained in the night time with the starting point as the ending point of the morning time, and the same goes in reverse. As shown, the 6th day represents the day with the highest travel time value. While the 11th day represents the lowest value of travel time, travel time. the 16th and 17th days represent the noon period travel time.

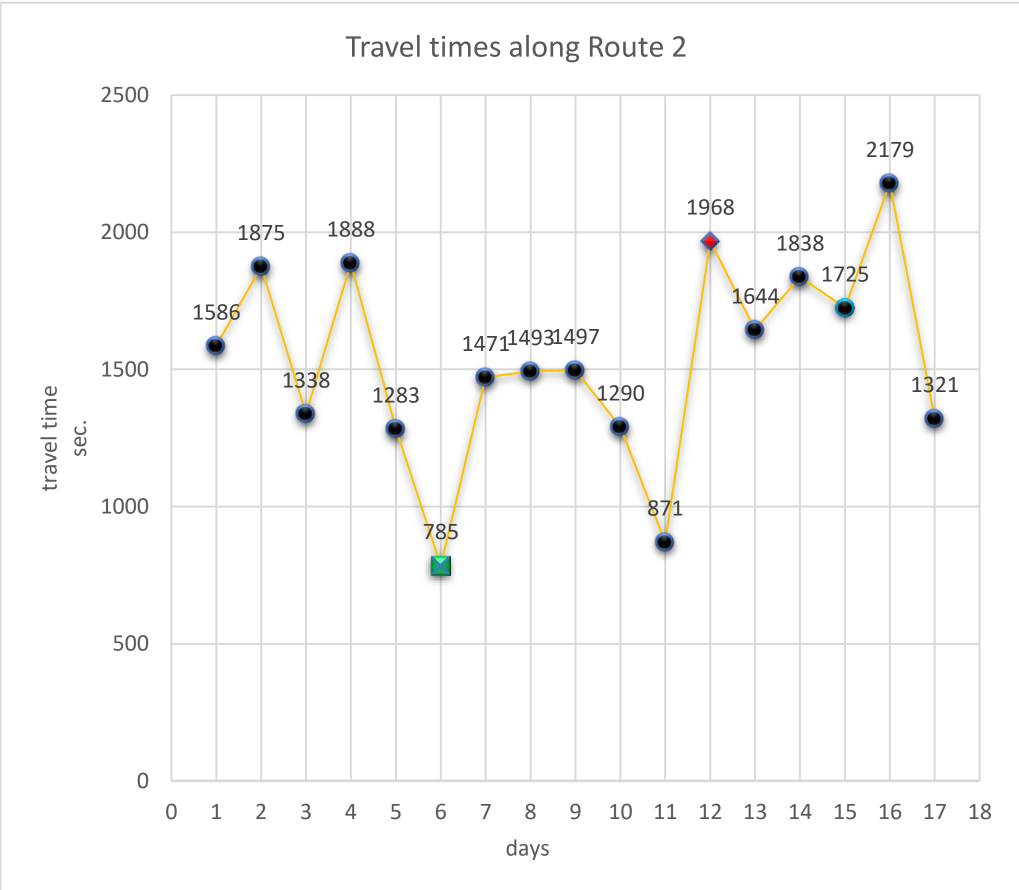


Figure 4.3. Travel time for route 2 for north direction (during morning and noon).

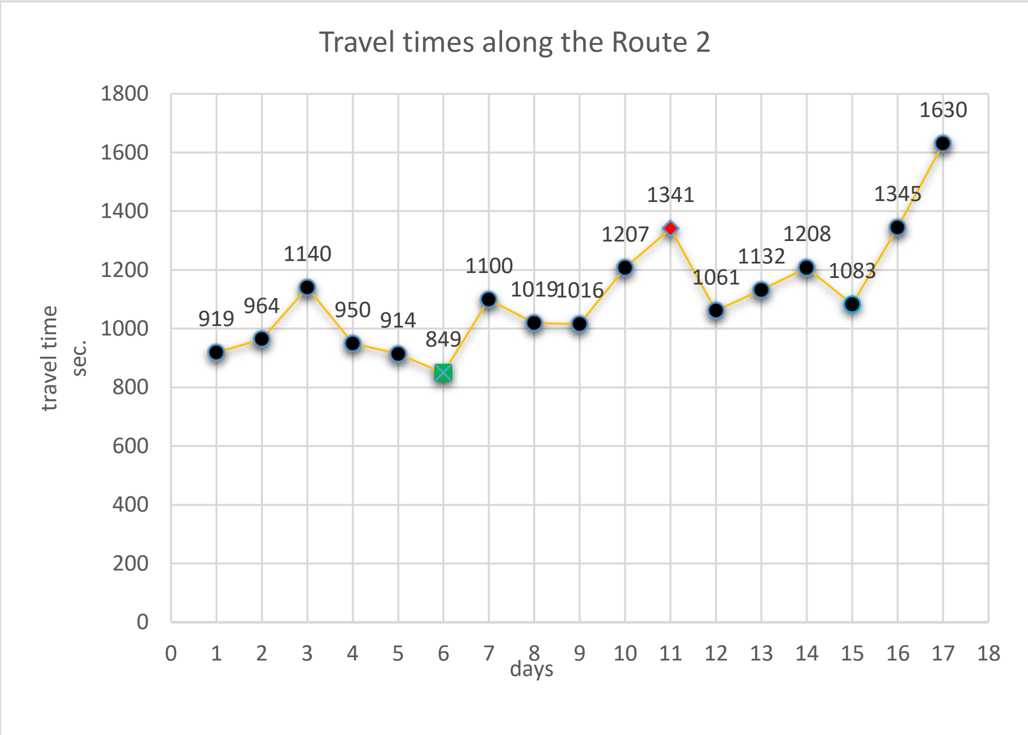


Figure 4.4. Travel time for route 2 for south direction (during night and noon).

Likewise, with regard to the second route, the discrepancy in travel time values is similar to the discrepancy seen in the first route. This means that one should plan for potential delays or changes in the expected travel time when making plans for a journey. Furthermore, the effects of this discrepancy can vary with certain days to be more affected in certain areas than in others. Additionally, it is important to consider the level of reliability for the journey itself, as this can help in providing a better estimation of how long the travel time may take.

For the third route in the northern and southern directions (morning, noon, and evening), the results obtained are shown in Figure 4.5. and 4.6. These figures show the distribution of direct measurement of route travel times. Figure 4.5.represents the distribution of travel times obtained in the morning period. As shown, while the 12th day represents the day with the highest travel time value, 9th day represents the lowest value of travel time. On the other hand, 16th and 17th days symbolise the travel times on noon period. As for Figure 4.6, it represents the distribution of travel time of the trips recorded in the night time having the starting point as the destination point of the morning time trips, the same goes in reverse. The 10th day represented indicates the day with the highest travel time value recorded. The 4th day, on the other hand, represents the lowest value of travel time. The 16th and 17th days represent the travel time values collected on noon.

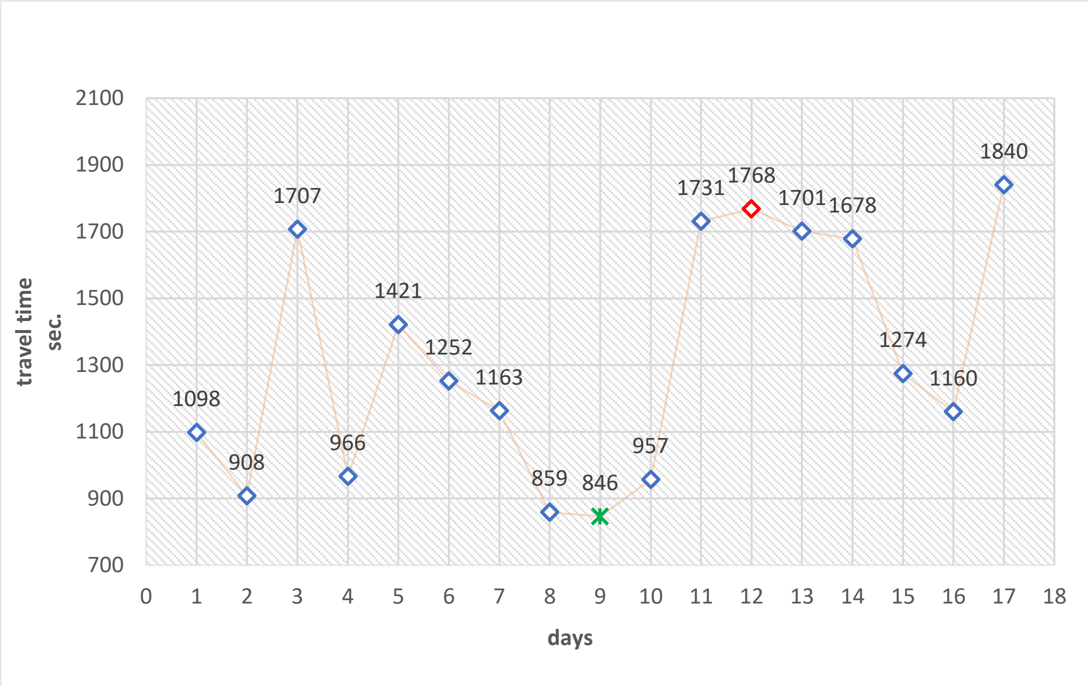


Figure 4.5. Travel time for route 3 for north direction (during morning and noon).

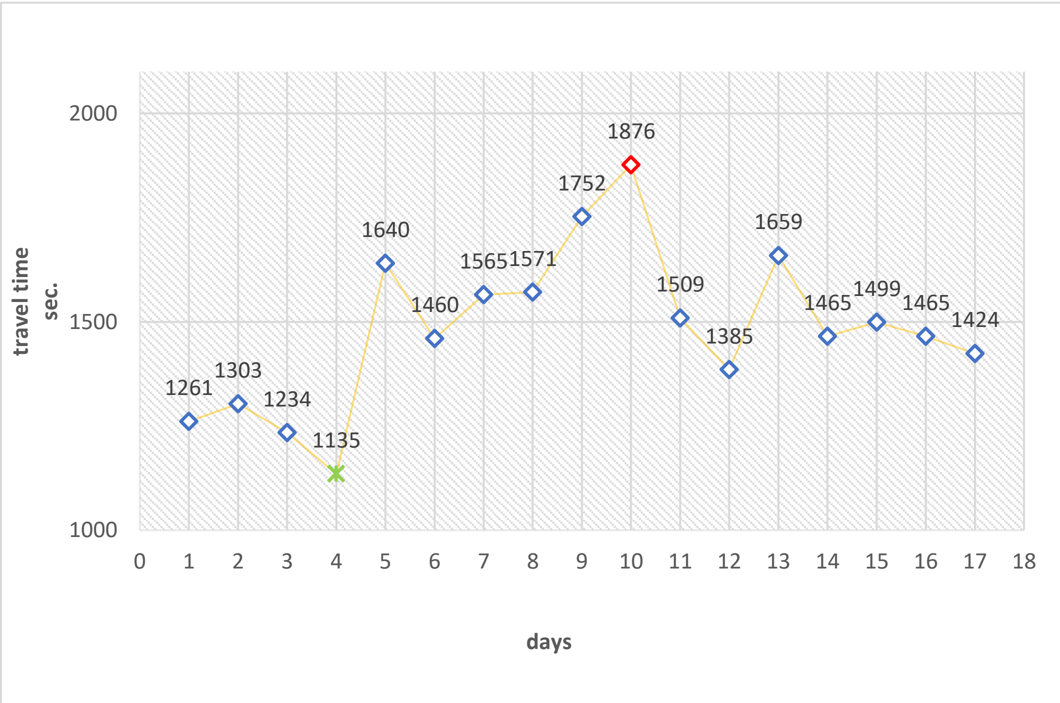


Figure 4.6. Travel time for route 3 for south direction (during night and noon).

It is well established that certain pathways are more frequently used during the morning period than in the evening. This is due to a variety of factors, including the desire to reach a specific location in an efficient manner. Additionally, many people prefer to take certain routes in the morning than in the evening.The factors regarding perceived amount of traffic may be regarded as the major concerns to be taken into consideration.

4.2. Delay

It is well known that delays of any kind can lead to an increase in transportation time, however, in this particular study, we focused on the delays caused by intersections. The three types of delays (deceleration, stop, acceleration) associated with intersections in both directions across all paths were evaluated. In this study, the effect of delays on travel time reliability and how they can be minimized were also investigated. Additionally, potential methods that can be used to reduce congestion at intersections to improve travel time reliability and traffic flow by reducing delays were assessed.

The results obtained for the first route in the northern and southern directions during morning, noon, and evening period are shown in Tables 4.1. And 4.2. in Table 4.1, the while 7th day represents the day with the highest delay, while the 6th day denotes the day with the least delay in the morning period, in the north direction. On the other hand, as for Table 4.2 the 6th day had the lowest delay time while the 13th day had the highest value of the delay for the south direction. Figures 4.7. and 4.8. illustrate the value and type of delay (deceleration, stop, and acceleration) in each day for the north and south direction.

Table 4.1. Delays for the north direction:route 1.

Days	Deceleration (sec.)	Stop (sec.)	Acceleration (sec.)	Total Delay (sec.)
1	35	436	62	533
2	58	564	52	674
3	54	89	65	208
4	69	331	47	447

Table 4.1. (Continued) Delays for the north direction: route 1

Days	Deceleration (sec.)	Stop (sec.)	Acceleration (sec.)	Total Delay (sec.)
5	33	40	43	116
6	30	21	18	69
7	26	627	22	675
8	27	479	36	542
9	41	366	38	445
10	30	373	50	453
11	56	421	52	529
12	66	470	37	573
13	80	267	90	437
14	58	226	48	332
15	41	37	42	120
16	76	18	51	145
17	48	59	53	160

Table 4.2. Delays for the south direction: route 1.

Days	Deceleration (sec.)	Stop (sec.)	Acceleration (sec.)	Total Delay (sec.)
1	35	92	23	150
2	30	74	23	127

Table 4.2. (Continued) Delays for the south direction: route 1.

Days	Deceleration (sec.)	Stop (sec.)	Acceleration (sec.)	Total Delay (sec.)
3	48	62	29	139
4	45	60	30	135
5	31	33	22	86
6	44	20	14	78
7	37	148	28	213
8	21	63	31	115
9	40	93	17	150
10	40	122	19	181
11	37	86	19	142
12	42	46	19	107
13	40	334	32	406
14	25	136	15	176
15	23	323	37	383
16	38	40	18	96
17	24	29	38	91

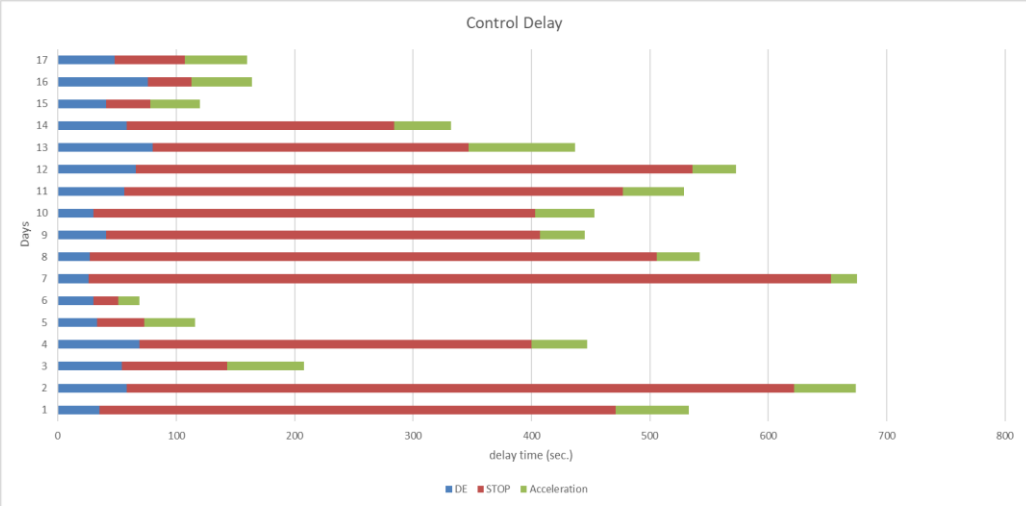


Figure 4.7. The value and type of delay for north direction: route 1.

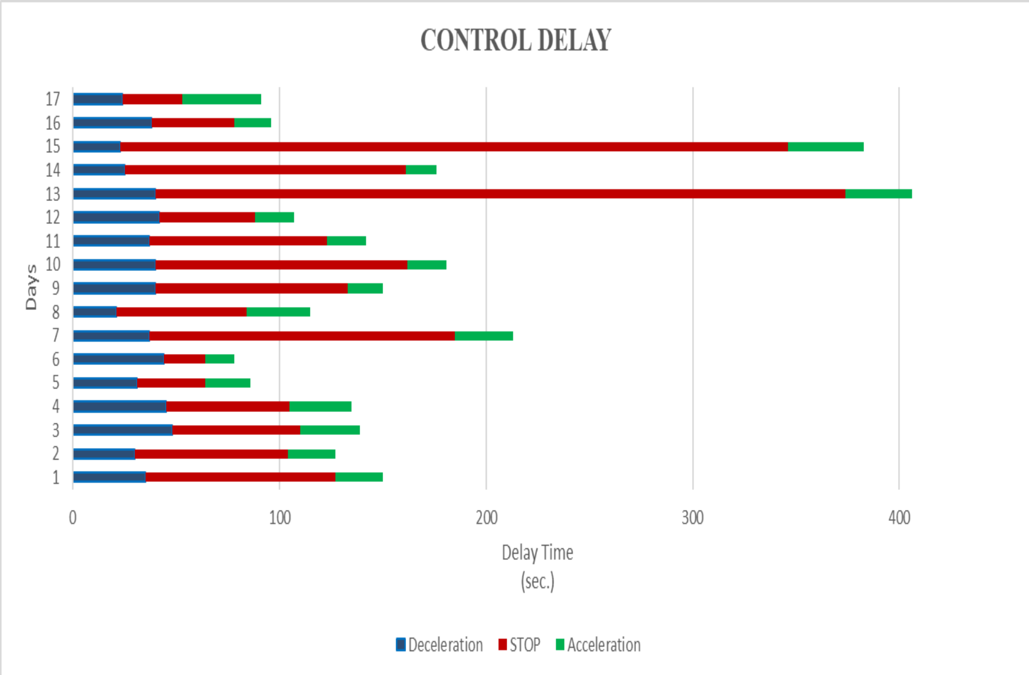


Figure 4.8. The value and type of delay for south direction: route 1.

For the second route in the northern and southern directions (morning, noon, and evening), these results obtained are shown in Tables 4.3. and 4.4. As can be seen from Table 4.3, the 4th day represents the day with the highest delay. The 6th day denotes the day with the least delay in the morning period, in the north direction. On the other hand, Table 4.4. illustrates the fact that the 6th day had the lowest delay time while the 11th day had the highest value of the delay for the south direction. Figures 4.9.and 4.10. illustrate the value and type of delay (deceleration, stop, and acceleration) in each day for the north and south direction.

Table 4.3. Delays for the north direction: route 2.

Days	Deceleration (sec.)	Stop (sec.)	Acceleration (sec.)	Total Delay (sec.)
1	105	625	117	847
2	124	830	113	1067
3	122	297	116	535
4	90	872	114	1076
5	112	399	133	644
6	83	0	100	183
7	105	442	116	663
8	92	483	127	702
9	100	546	127	773
10	101	374	131	606
11	69	49	91	209
12	110	763	132	1005
13	104	570	112	786
14	95	849	116	1060
15	86	755	122	963
16	113	888	86	1087
17	110	389	120	619

Table 4.4. Delays for the south direction: route 2.

Days	Deceleration (sec.)	Stop (sec.)	Acceleration (sec.)	Total Delay (sec.)
1	82	13	99	194
2	74	25	109	208
3	71	191	114	376
4	96	19	115	230
5	64	28	100	192
6	74	13	91	178
7	107	30	94	231
8	91	59	114	264
9	97	21	116	234
10	114	122	86	322
11	91	210	121	422
12	99	60	105	264
13	111	57	116	284
14	115	132	109	356
15	92	131	102	325
16	117	268	111	496
17	97	448	123	668

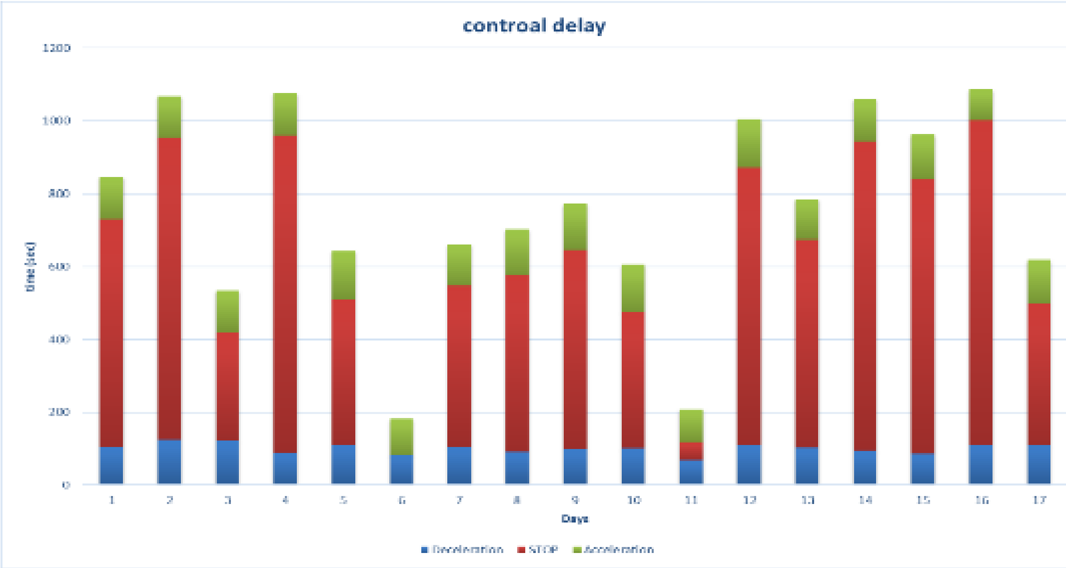


Figure 4.9. The value and type of delay for north direction: route 2.

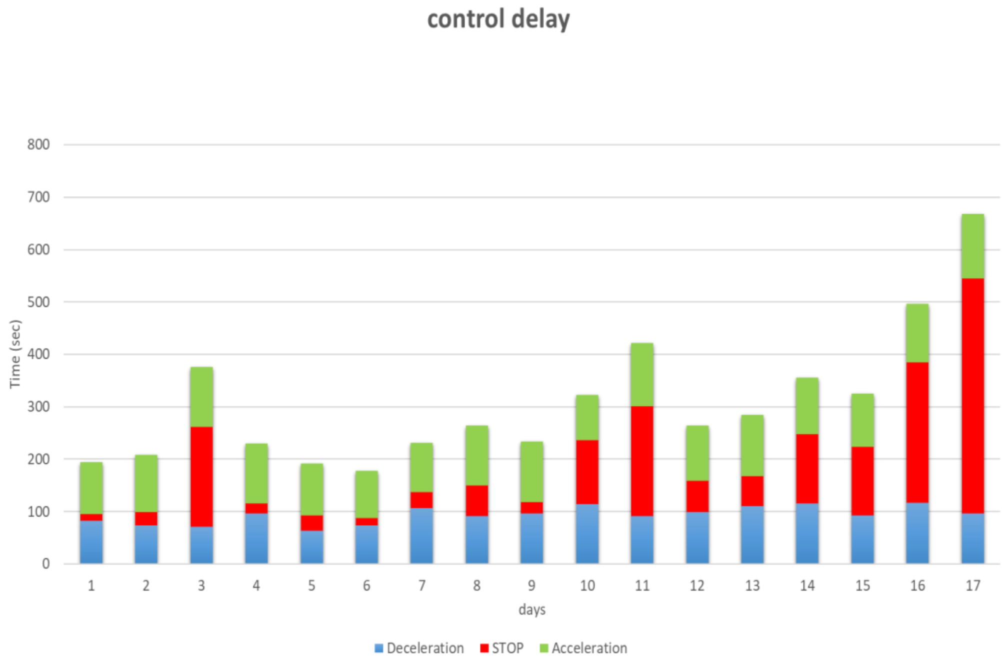


Figure 4.10. The value and type of delay for south direction: route 2.

The results for the third route in the northern and southern directions (morning, noon, and evening) obtained are shown in Tables 4.5 and 4.6, respectively. For Table 4.5, the 5th day represents the day with the highest delay due to the intersections, while the 2nd day denotes the day with the least delay in the morning period, in the north direction. On the other hand for Table 4.6, the 4th day had the lowest delay time while the 6th day had the highest value of the delay for the south direction that due to the intersection. Figures 4.11.and 4.12. illustrate the value and type of delay (deceleration, stop, and acceleration) in each day for the north and south direction.

Table 4.5. Delays for the north direction: route 3.

Days	Deceleration (sec.)	Stop (sec.)	Acceleration (sec.)	Total Delay (sec.)
1	63	88	67	218
2	46	8	54	108
3	53	239	45	337
4	42	23	48	113
5	44	362	53	459
6	42	220	65	327
7	41	187	57	285
8	52	6	50	108
9	55	22	52	129
10	44	50	51	145
11	46	235	53	334
12	53	326	61	440
13	26	261	48	335
14	36	138	71	245
15	29	158	50	237
16	88	145	41	274
17	53	211	51	315

Table 4.6. Delays for the south direction: route 3.

Days	Deceleration (sec.)	Stop (sec.)	Acceleration (sec.)	Total Delay (sec.)
1	63	88	67	218
2	46	8	54	108
3	53	239	45	337
4	42	23	48	113
5	44	362	53	459
6	42	220	65	327
7	41	187	57	285
8	52	7	51	110
9	55	22	52	129
10	44	50	51	145
11	46	235	53	334
12	53	326	61	440
13	26	261	48	335
14	36	138	71	245
15	29	158	50	237
16	88	145	41	274
17	53	211	51	315

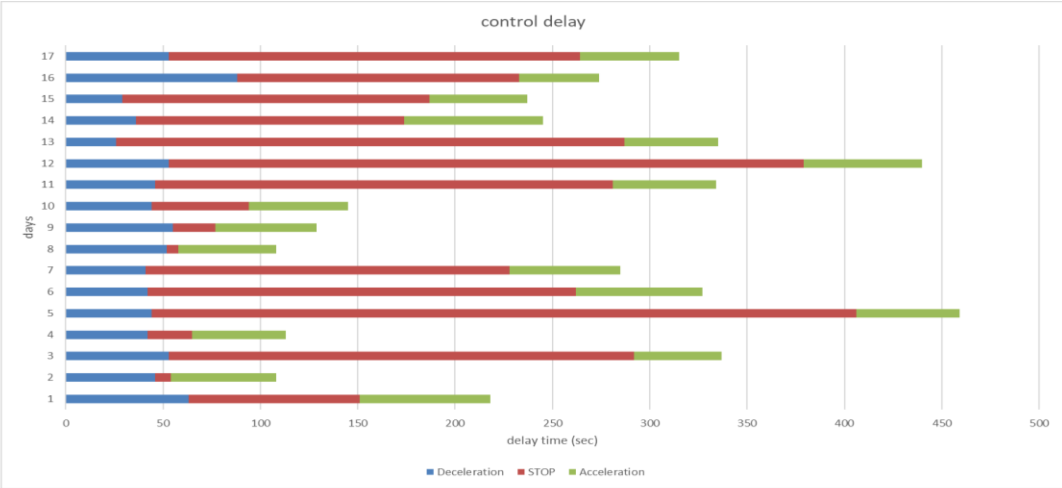


Figure 4.11. The value and type of delays for north direction: route 3.

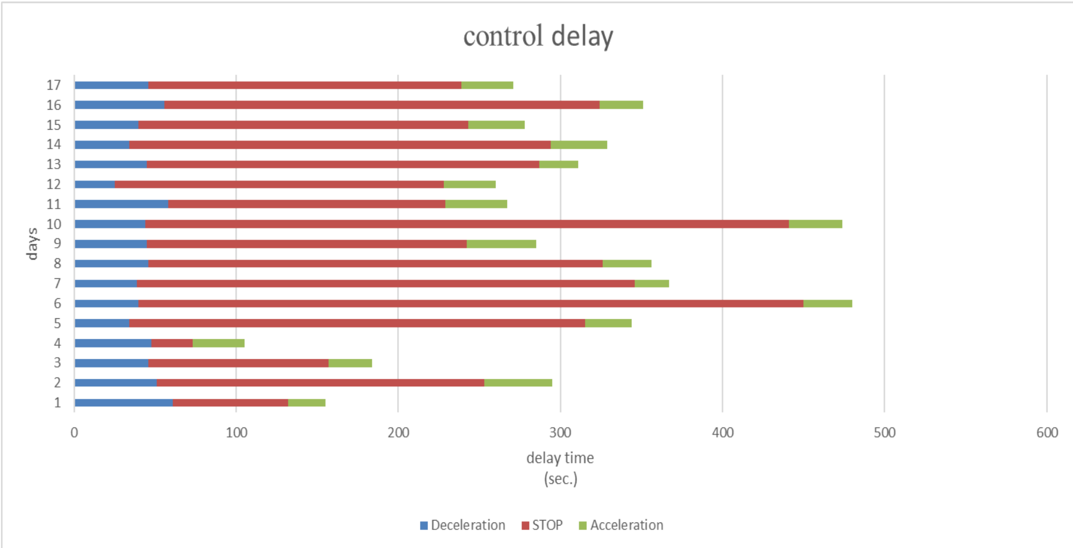


Figure 4.12. The value and type of delays for south direction: route 3.

It is clear that when the delay values were low in the morning on the first and second routes, the delay was still low in the evening hours. However, this was not always the case, as evidenced in the third route. The data suggests that there may not be a clear-cut rule of thumb when it comes to predicting these delays. As a result, it is important to observe the trends in each track individually to get an accurate picture of what is happening. When the transportation time is short, this day has the lowest value in the delay according to the relationship between the value of travel time and the value of delay, which was reached in three tracks. For the first and second routes, this was observed in the morning, while for the third track, it happened in the evening. So let's not forget that junctions are the main compound to blame for the estimated delay. Nonetheless, it can be asserted that if the intersection delays can be cut down, we can improve the reliability of morning traffic in the first and second routes. For the third route, on the other hand,the road itself rather than crossings are the primary sources of the delays.

4.3. Speed

With the delays at intersections under control, it is time to talk about speed. Speed is a key factor for the level of service for a road. Since the delay at intersections is one of the most determining factors for speed, it is paramount to properly manage the speed at intersections. In addition, it is essential to consider speed when reviewing traffic flow characteristics. Speed has an effect on roadways in terms of capacity, safety, and efficiency. Road designers must take into account many variables such as the number of vehicles, their type, the street width, traffic signals, and so on. With this knowledge in hand, they can then design the intersection in a way that will allow a safe and steady flow of traffic, while keeping speed within the desired range.

For the first route on the seventh day and the sixth day, the morning period delays were highest and lowest, respectively. This will undoubtedly have some deep impact on the instantaneous speed in these two days. The same applies to the evening period of the

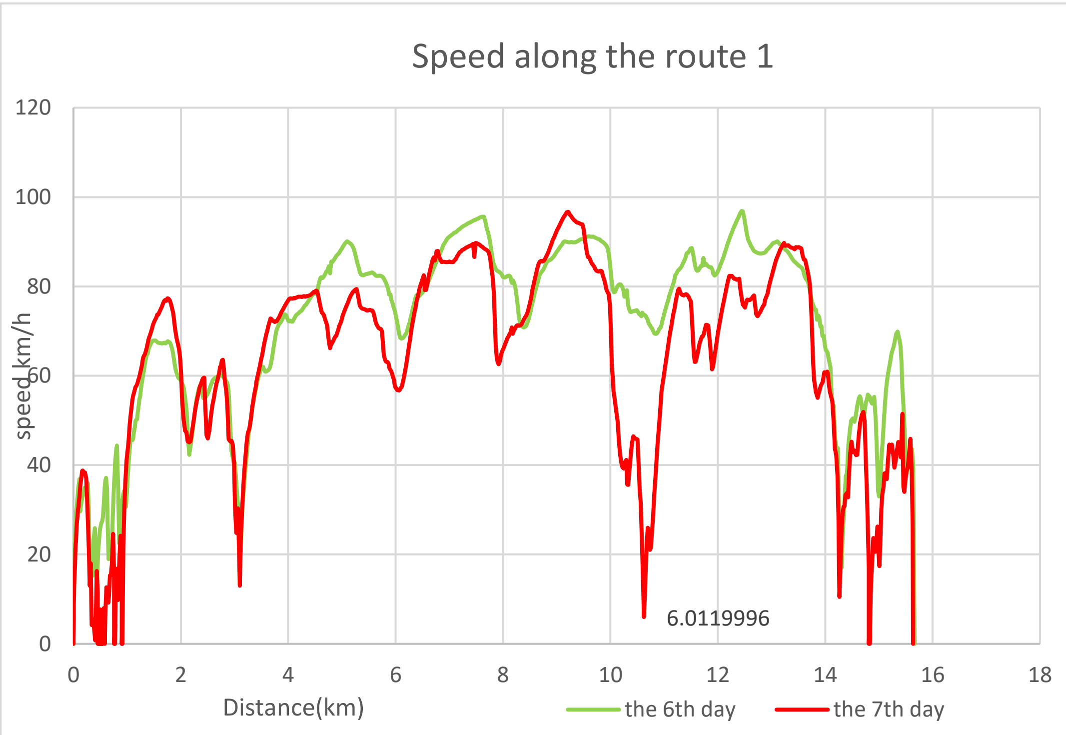


Figure 4.13. Instantaneous speed change of route 1 for the north direction (morning time).

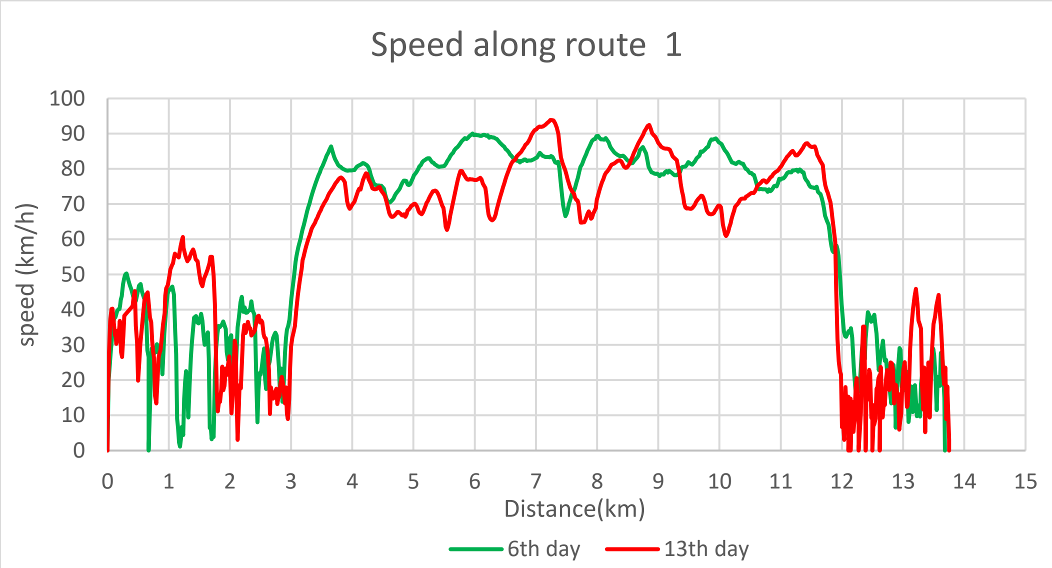


Figure 4.14. Instantaneous speed change of route 1 for south direction (night time).

These two figures illustrate the instantaneous speed changing in both directions along the Route1 for 6th , 7th and 13th day.

The speed fluctuates along the route, as illustrated in figures 4.13 and 4.14, and is influenced by the intersections located at 0.8 km, 2.087 km, 2.961 km, and 14.993 km.

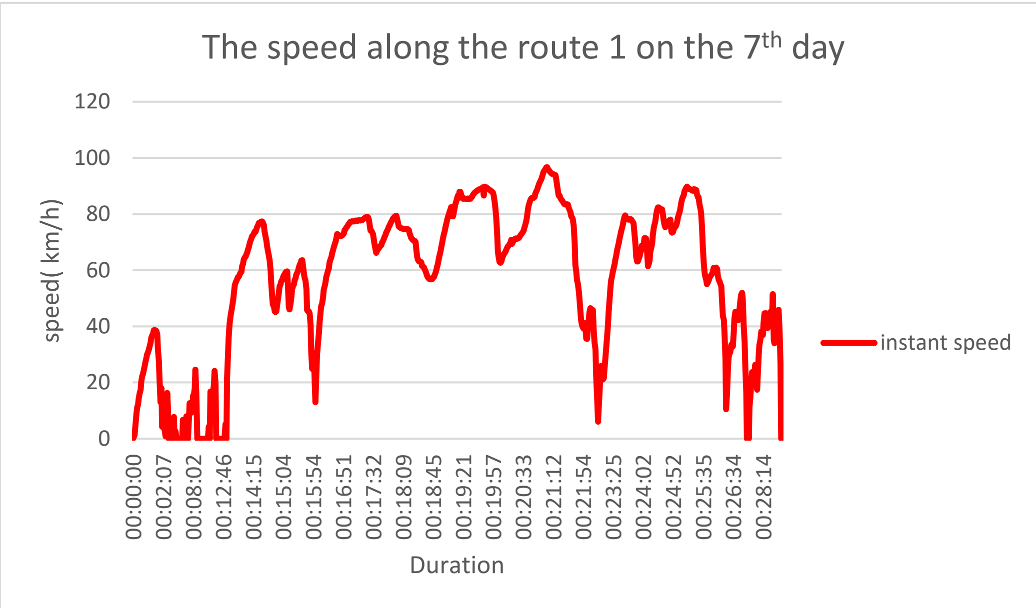


Figure 4.15. Instantaneous speed change for the 7th day (morning time).

This figure clearly illustrates the fact that the junction causes the speed occasionally to drop from the free flow speed to close to zero (stop) for several times (approximately 9 minutes). On the other hand, not for the whole period the vehicle was stopped; instead, it travels for 4 seconds at a speed less than 20 km/h. The vast bulk of it occurred during the first intersection. Thus, junctions in this case cannot be considered the only primary causes of the slowdown. There are other elements at work on the route, such as roadways' geometric layouts. At the 10.3 kilometers, for example, the speed is greatly lowered although there is no intersection at this specific point. This is due to the change in the road geometry. The route has several tunnels causing the speed to decrease. Figure 4.16 depicts the position and speed at tunnels at 5.8, 8.3, and 10.6 kilometers. As can be seen from the figure at kilometer 10.6, the drop at the speed level was remarkable compare to other two tunnel ocations. This is because the road at the tunnel's exit was badly paved. Two of the three accessible lanes would be compelled to slow down, resulting in more traffic and longer travel times.

Figure 4.16. Illustrated the locations for the tunnels.

A comparison of the seventh and sixteenth days reveals that the seventh day has the greatest amount of delay in the morning and the sixteenth day has the greatest amount of delay in the midday (the delay value depends only on the delay in intersections). It is depicted in figure 4.17.

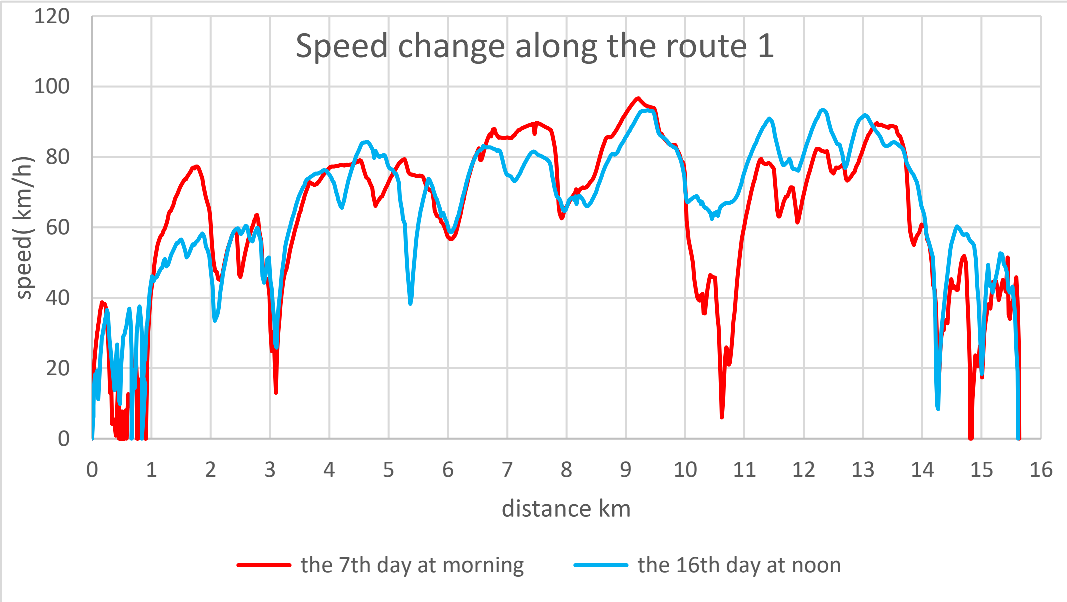


Figure 4.17. Instantaneous speed change for north direction.

As for second route, the speed decreases when approaching the intersection and increases when moving away from as expected because delays are frequently associated with intersections. Since some intersections are relatively close together, and because of the volume of traffic, users are unable to resume their pre-intersection speeds. This situation persists until you are able to leave the intersection area. The figures below represent the speed in the days with the greatest and least amount of delay due to intersections,in both direction as previously mentioned.

Figure 4.18. Instantaneous speed change of route 2 for the north direction (morning time).

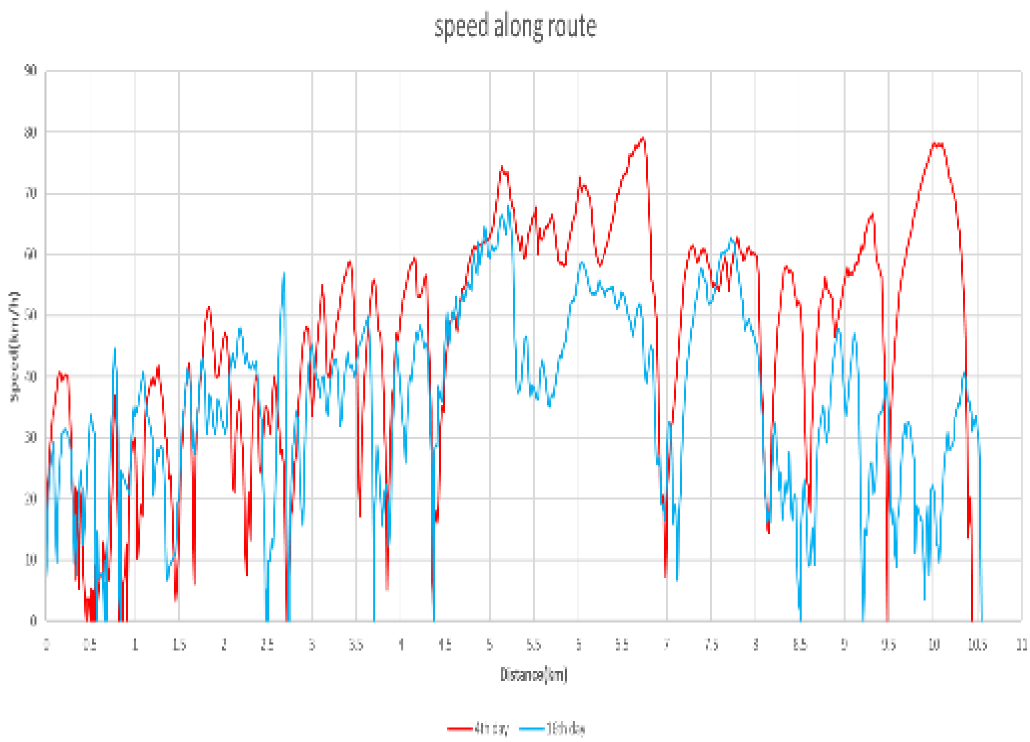


Figure 4.19. Instantaneous speed change of route 2 for north direction (noon time).

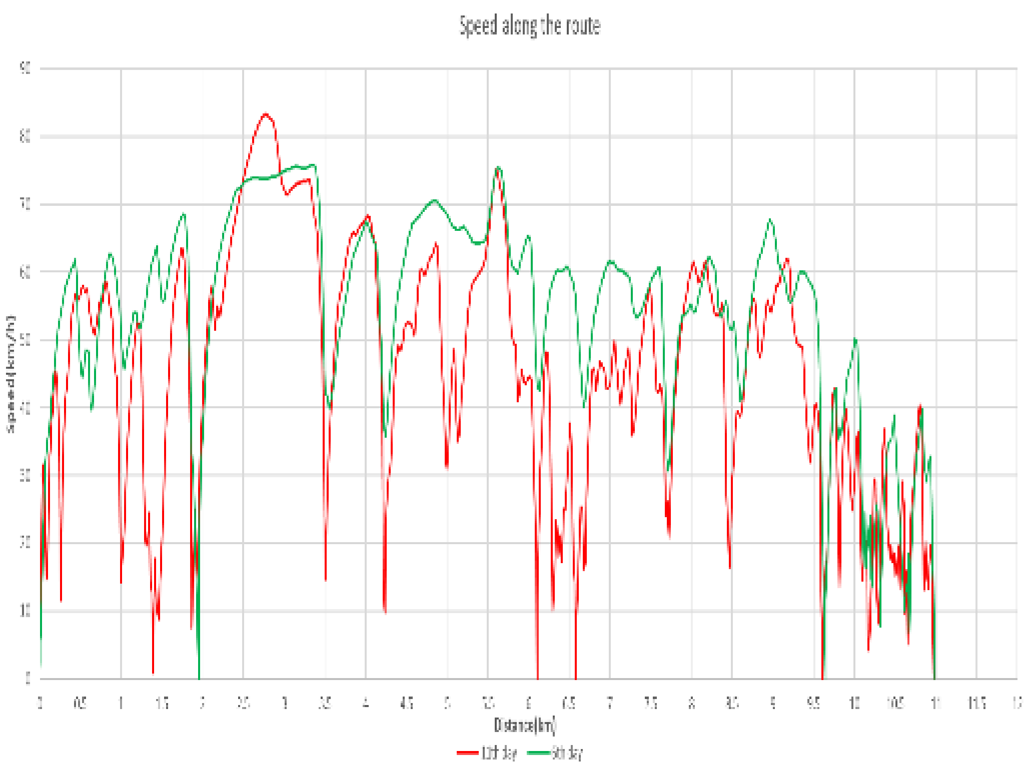


Figure 4.20. Instantaneous speed change of route 2 for south direction (night time).

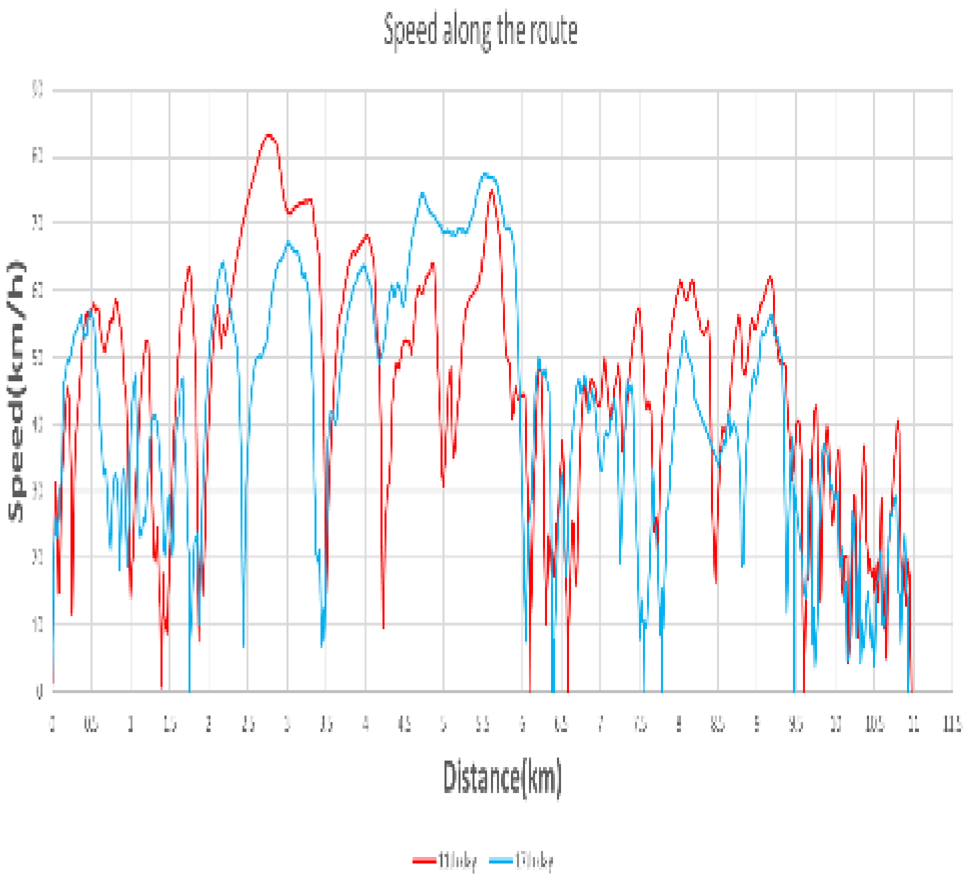


Figure 4.21. Instantaneous speed change of route 2 for south direction (night time).

As illustrated in the figures above, it can be seen in Figures 4.18 and 4.19 that the effect of intersections and traffic volume on the speed change when approaching and moving away from intersections vary between the fourth and sixth day in the morning and the fourth and sixteenth day in the northern direction. The impact of intersections and traffic volume on speed is greater in the afternoon than in the morning as shown in figure 4.19., As for figures 4.20 and 4.21, they represent the speed fluctuation in the southern direction.

For route 3 decelerating and accelerating are not always associated with intersections. As previously stated, some of the causes of delay are related to problems with the road itself. There are sections of the road that, for one reason or another, force the vehicle to travel at a slower speed than the designed or permitted speed. In the north direction, Fig 4.22 in the morning and 4.23 in the noon time represent a comparison between speed fluctuations. For the southern direction, figure 4.24 depicts the night period, whereas figure 4.25 depicts a comparison of the noon and night periods.

Figure 4.22. Instantaneous speed change of route 3 for the north direction (morning time).

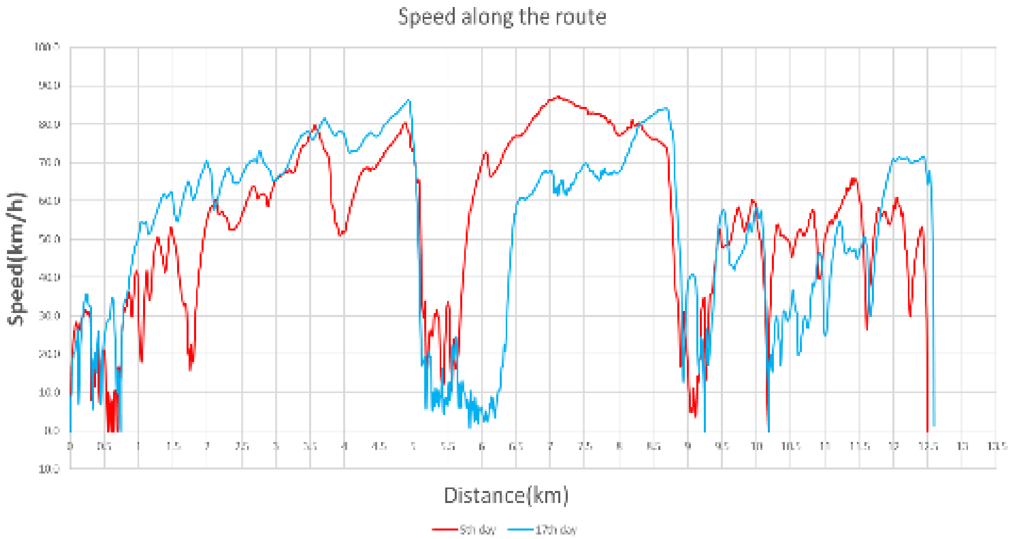


Figure 4.23. Instantaneous speed change of route 3 for north direction (noon time).

Figure 4.24. Instantaneous speed change of route 3 for south direction (night time)

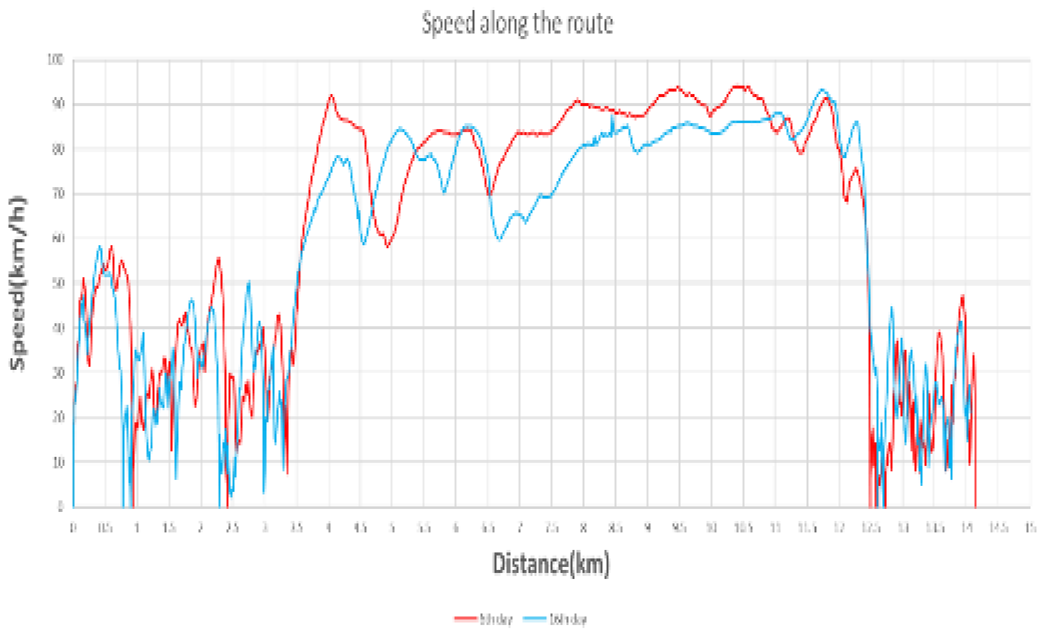


Figure 4.25. Instantaneous speed change of route 3for south direction comparison of the noon and night periods.

This research to some extent aims to analyse the impact of intersection layout and design on traffic flow with resulted travel times. By assessing the number of lanes, the proximity to other roads, and the amount of traffic that the intersection handles, it is possible to determine the effect of the intersections in terms of providing a reliable transportation option. By studying these elements and their effects, it can be concluded that some lanes will experience speed increases and decreases when approaching intersections. If the problem of delay in these intersections is solved, the reliability of transportation on this road will increase, as well as user comfort when choosing this path. Intersections are a key element of any transportation system, and they can be noticeably complex. On the other hand,some routes do not have the same limitations as the intersection-based transportation networks, as they can involve various reasons for delays and slowdowns that must be addressed. This could have to do with external factors; such as weather or traffic, or internal factors; such as maintenance and construction. In order to ensure that the transportation network runs efficiently,and try to keep traffic flowing smoothly, there must be an understanding of the causes of delays and measures to prevent them from occurring. On the other hand, some traffic delays may be caused by other issues such as construction or traffic accidents which cannot be controlled and managed before hand.

4.4. SPSS Analysis

IBM SPSS Statistics was employed to obtain the statistical model for finding a relationship for the control delay and the explanatory dependant variables; the deceleration, stopped, and acceleration delay. The acceleration, stopping and deceleration delay times were introduced in the regression model for the morning and night times for 34 rounds. The following tables represent the summaries of the model for the first route, north direction.

Table 4.7. The predicted single and multi-variables models summary belong route 1 for north direction.

Model Summary						
	Change Statistics					
Model	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1 (single)	0.975a	513.968	1	13	0	
2 (Multi variables)	0.02[b]	52.757	1	12	0	
3 (Multi variables)	.005[c]	.	1	11	.	1.461

a. Predictors: (Constant), Stopping.

b. Predictors: (Constant), Acceleration, stop.

c. Predictors: (Constant), Deceleration, stop, Acceleration.

Table 4.8. Details of the regression models for independent variable control delay and dependent explanatory variables; acceleration, stopping, and deceleration delay times belong route 1 for north direction.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	sig
		B	Std. Error	Beta		
1	(Constant)	95.052	16.22		5.86	0
	Stop	0.996	0.044	0.998	22.671	0
2	(Constant)	16.555	13.02		1.271	0.22
	Stop	1.005	0.02	0.997	50.957	0
	Acceleration	1.616	0.222	0.142	7.26	0
3	(Constant)	-5.6842E-14	0		0	1
	Stop	1	0	0.992	268841716	0
	Acceleration	1	0	0.088	18663874	0
	Deceleration	1	0	0.087	18412975	0

a. Dependent Variable: control delay

Table 4.8. (Continued) Details of the regression models for independent variable control delay and dependent explanatory variables; acceleration, stopping, and deceleration delay times belong route 1 for north direction.

Coefficients[a]					
Model		95.0% Confidence Interval for B		Collinearity Statistics	
		Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	60.012	130.09		
	Stop	0.901	1.091	1	1
2	(Constant)	-11.82	44.931		
	Stop	0.962	1.048	0.996	1.004
	Acceleration	1.131	2.101	0.996	1.004
3	(Constant)	0	0		
	Stop	1	1	0.991	1.009
	Acceleration	1	1	0.608	1.645
	Deceleration	1	1	0.61	1.639

a. Dependent Variable: control delay

Table 4.9. Correlation coefficients between control delay and delay components; acceleration, stopping and deceleration delay times belong route 1 for north direction.

		Control Delay	Deceleration Time	Stopping Time	Acceleration Time
Pearson Correlation	1	0.158	0.988	0.079	0.158
	0.158	1	0.017	0.622	0.988
	0.988	0.017	1	-0.063	0.079
	0.079	0.622	-0.063	1	1
Sig. (1-tailed)		0.287	0	0.390	0.287
	0.287		0.477	0.007	0.000
	0.00	0.477		0.411	0.390
	0.39	0.007	0.411		

These variables were used in the stepwise regression linear method. In this method, the acceleration, stopping and deceleration delay time were introduced in the regression model. After entering the stopping delay time values, the coeeficient of determination, R^2, value obtained as 0.973 , as presented in Table 4.7. This high value obviously states that the model represents the data accurately. Details of regression models for Independent Variable Control Delay and Dependant Explanatory Variables: Acceleration, Stopping and Deceleration Delay Times and their correlations coefficients are presented in Tables 4.8. and 4.9., respectively.From the regression analysis, which is a set of statistical operations to predict the relationships among selected field variables in this research, that is, acceleration, stopping, and deceleration delay time, a travel delay model was developed. A travel delay model was developed shown in equation 4.1 for the north direction of route 1.

$$DC = 16.555 + 1.005T_{st} + 1.616T_{ac} \tag{4.1}$$

where

DC: Control delay time.

T_{st}: Stopping delay time.

T_{ac}: acceleration delay time.

The coeeficient of determination value for the stopping delay time obtained as 0.99 for south direction of route 1 as presented in Table 4.10. Details of regression models for Independent Variable Control Delay and Dependant Explanatory Variables; Acceleration, Stopping and Deceleration Delay Times and their correlations coefficients are presented in Tables 4.11 and 4.12, respectively.

Table 4.10. The summary of predicted single and multi-variables models belong route 1 for south direction.

Model Summary						
	Change Statistics					
Model	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1 (single)	0.991[a]	1363.43	1	13	0	
2 (Multi variables)	0.006[b]	21.058	1	12	0.001	
3 (Multi variables)	0.003[c]	.	1	11	.	1.055

a. Predictors: (Constant), Stopping.

b. Predictors: (Constant), Acceleration, stop.

c. Predictors: (Constant), Deceleration, stop, Acceleration.

Table 4.11. Details of the regression models for independent variables; control delay and dependent explanatory variables; acceleration, stopping, and deceleration delay times belong route 1 for south direction.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardised Coefficients		
		B	Std. Error	Beta	t	sig
1	(Constant)	57.702	4.003		14.416	0
	Stop	1.018	0.028	0.995	36.92	0
2	(Constant)	21.25	8.331		2.551	0.25
	Stop	1.04	0.018	1.017	57.91	0
	Deceleration	0.946	0.206	0.081	4.589	.001
3	(Constant)	0	0			
	Stop	1	0	0.978		
	Deceleration	1	0	0.085		
	Acceleration	1	0	0.071		

a. Dependent Variable: control delay.

Table 4.11. (Continued) Details of the regression models for independent variables; control delay and dependent explanatory variables; acceleration, stopping, and deceleration delay times belong route 1 for south direction.

Coefficients[a]					
Model		95.0% Confidence Interval for B		Collinearity Statistics	
		Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	49.054	66.349		
	Stop	0.958	1.078	1	1
2	(Constant)	3.099	39.401		
	Stop	1.001	1.08	0.926	1.08
	Deceleration	0.497	1.395	0.926	1.08
3	(Constant)	0	0		
	Stop	1	1	0.652	1.53
	Deceleration	1	1	0.921	1.08
	Acceleration	1		0.671	1.49

a. Dependent Variable: control delay.

Table 4.12. Correlation coefficients between control delay and delay components; acceleration, stopping and deceleration delay times belong route 1 for south direction.

		Control Delay	Deceleration Time	Stopping Time	Acceleration Time
Pearson Correlation	Control Delay	1	-0.196	0.995	0.611
	Deceleration Time	-0.196	1	-0.217	-0.215
	Stopping Time	0.995	-0.272	1	0.57
	Acceleration Time	0.611	-0.215	0.57	1
Sig. (1-tailed)	Control Delay		0.242	0	0.008
	Deceleration Time	0.242		0.164	0.221
	Stopping Time	0	0.164		0.013
	Acceleration Time	0.008	0.221	0.013	

Similar to Equation (4.1), the following equation (4.2) was developed through regression analysis for the south direction.

$$DC = 21.250 + 1.040\, T_{st} + 0.946\, T_{de} \tag{4.2}$$

where

DC: Control delay time.

T_{st}: Stopping delay time.

T_{de}: Deceleration delay time.

Furthermore, the following tables represent the summaries of the model for north direction of the second route. The stopping delay time regression analysis gives an R^2 value as 0.994 for the north direction, as presented in Table 4.13. The correlations coefficients and details of regression models for Independent Variable Control Delay and Dependant Explanatory Variables: Acceleration, Stopping and Deceleration Delay Times are presented in Tables 4.14 and 4.15, respectively.

Table 4.13. The predicted single and multi-variables models summary belong route 2 for north direction.

Model Summary						
	Change Statistics					
Model	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1 (single)	0.995[a]	2464.763	1	13	0	
2 (Multi variables)	0.004[b]	43.005	1	12	0	
3 (Multi variables)	0.001[c]	.	1	11	.	2

a. Predictors: (Constant), Stopping.

b. Predictors: (Constant), Acceleration, stop.

c. Predictors: (Constant), Deceleration, stop, Acceleration.

Table 4.14. Details of the regression models for independent variable; control delay and dependent explanatory variables; acceleration, stopping, and deceleration delay times belong route 2 for north direction.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	sig
1	(Constant)	198.475	12.24		16.215	0
	Stop	1.037	0.021	0.997	49.646	0
2	(Constant)	79.466	19.098		4.161	10^{-3}
	Stop	1.013	0.011	0.974	93.837	0
	Deceleration	1.318	0.201	0.068	6.558	0
3	(Constant)	-2.842E - 14	0		0	1
	Stop	1	0	0.962	2.66E+08	0
	Deceleration	1	0	0.052	13707411	0
	Acceleration	1	0	0.041	10486710	0

a. Dependent Variable: control delay

Table 4.14. (Continued) Details of the regression models for independent variable; control delay and dependent explanatory variables; acceleration, stopping, and deceleration delay times belong route 2 for north direction.

Coefficients[a]					
Model		95.0% Confidence Interval for B		Collinearity Statistics	
		Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	172.032	224.918		
	Stop	0.992	1.082	1	1
2	(Constant)	37.85	121.07		
	Stop	0.989	1.036	0.885	1.13
	Deceleration	0.88	1.755	0.885	1.13
3	(Constant)	0	0		
	Stop	1	1	794	1.26
	Deceleration	1	1	0.732	1.36
	Acceleration	1	1	0.674	1.48

a. Dependent Variable: control delay

Table 4.15. Correlation coefficients between control delay and delay components; acceleration, stopping and deceleration delay times belong route 2 for north direction.

		Control Delay	Deceleration	Stopping	Acceleration
Pearson Correlation	Control Delay	1	0.399	0.997	0.481
	Deceleration Time	0.399	1	0.399	0.499
	Stopping Time	0.997	0.339	1	0.43
	Acceleration Time	0.481	0.499	0.43	1
Sig. (1-tailed)	Control Delay		0.71	0	0.035
	Deceleration Time	0.071		0.108	0.029
	Stopping Time	0	0.108		0.055
	Acceleration Time	0.035	0.029	0.055	

The following equation (4.3) was developed through regression analysis for north direction of route 2.

$$DC = 79.466 + 1.013\, T_{st} + 1.318\, T_{de} \qquad (4.3)$$

where

DC: Control delay time.

T_{st}: Stopping delay time.

T_{de}: Deceleration delay time.

The stopping delay time repression analysis resulted in R^2 with the value of 0.933 for south direction of route 2 as presented in Table 4.16. Details of regression models for Independent Variable Control Delay and Dependant Explanatory Variables: Acceleration, Stopping and Deceleration Delay Times and their correlations coefficients are presented in Tables 4.17 and 4.18, respectively.

Table 4.16. The predicted single and multi-variables models Summary belong route 2 for south direction.

Model Summary						
	Change Statistics					
Model	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1 (single)	0.937[a]	194.525	1	13	0	
2 (Multi variables)	0.044[b]	28.813	1	12	0	
3 (Multi variables)	0.018[c]	4.562E+14	1	11	0	1.824

a. Predictors: (Constant), Stopping

b. Predictors: (Constant), Acceleration, stop

c. Predictors: (Constant), Deceleration, stop, Acceleration

Table 4.17. Details of the regression models for independent variable; control delay and dependent explanatory variables; acceleration, stopping, and deceleration delay times belong route 2 for south direction.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	sig
		B	Std. Error	Beta		
1	(Constant)	192.176	7.567		25.398	0
	Stop	1.078	0.077	0.968	13.947	0
2	(Constant)	105.618	16.68		6.332	0
	Stop	1.044	0.044	0.938	23.705	0
	Deceleration	0.969	0.181	0.212	5.368	0
3	(Constant)	-8.527E-14	0		0	1
	Stop	1	0	0.898	139996648	0
	Deceleration	1	.0	0.219	35524514	0
	Acceleration	1	0	0.141	22245986	0

a. Dependent Variable: control delay

Table 4.17. (Continued) Details of the regression models for independent variable; control delay and dependent explanatory variables; acceleration, stopping, and deceleration delay times belong route 2 for south direction.

Coefficients[a]

Model		95.0% Confidence Interval for B		Collinearity Statistics	
		Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	175.8	208.52		
	Stop	0.911	1.245	1	1
2	(Constant)	69.27	141.96		
	Stop	0.948	1.140	0.98	1.02
	Deceleration	0.576	1.363	0.98	1.02
3	(Constant)	0	0		
	Stop	1	1	0.904	1.10
	Deceleration	1	1	0.978	1.02
	Acceleration	1	1	0.922	1.08

a. Dependent Variable: control delay

Table 4.18. Correlation coefficients between control delay and delay components; acceleration, stopping and deceleration delay times belong route 2 for south direction.

		Control Delay	Deceleration Time	Stopping Time	Acceleration Time
Pearson Correlation	Control Delay	1	0.345	0.968	0.386
	Deceleration Time	0.345	1	0.141	-0.008
	Stopping Time	0.968	0.141	1	0.275
	Acceleration Time	0.386	-0.008	0.275	1.000
Sig. (1-tailed)	Control Delay	.	0.104	0	0.077
	Deceleration Time	0.104	.	0.308	0.489
	Stopping Time	0	0.308	.	0.161
	Acceleration Time	0.077	0.489	0.161	.

the following equation (4.4) was also developed through regression analysis for south direction of route 2.

$$DC = 105.618 + 1.044\, T_{st} + 0.969 T_{de} \tag{4.4}$$

Where

DC: Control delay time.

T_{st}: Stopping delay time.

T_{de}: Deceleration delay time.

As for the third route, the following tables represent the summaries of the model for north direction. The stopping delay time value gives the R^2 as 0 .987 for the north direction as presented in Table 4.19. The correlations coefficients and details of regression models for Independent Variable Control Delay and Dependant Explanatory Variables: Acceleration, Stopping and Deceleration Delay Times and are presented in Tables 4.20 and 4.21, respectively.

Table 4.19. The predicted single and multi-variables models summary belong route 3 for north direction.

Model Summary						
	Change Statistics					
Model	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1 (single)	0.987[a]	1007.586	1	13	0	
2 (Multi variables)	0.009[b]	25.819	1	12	0	
3 (Multi variables)	0.004[c]	.	1	11	0	1.556

a. Predictors: (Constant), Stopping

b. Predictors: (Constant), Acceleration, stop

c. Predictors: (Constant), Deceleration, stop, Acceleration

Table 4.20. Details of the regression models for independent variable; control delay and dependent explanatory variables; acceleration, stopping, and deceleration delay times belong route 3 for north direction.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	sig
		B	Std. Error	Beta		
1	(Constant)	101.702	5.994		16.968	0
	Stop	0.988	0.031	0.994	31.742	0
2	(Constant)	46.845	11.35		4.126	10^{-3}
	Stop	1.008	0.019	1.014	53.942	0
	Deceleration	1.153	0.227	0.096	5.081	0
3	(Constant)	2.132E-14	0		0	1
	Stop	1	0	1.006	516711529	0
	Deceleration	1	0	0.083	42158767	0
	Acceleration	1	0	0.065	33749765	0

a. Dependent Variable: control delay

Table 4.20. (Continued) Details of the regression models for independent variable; control delay and dependent explanatory variables; acceleration, stopping, and deceleration delay times belong route 3 for north direction.

Coefficients[a]

Model		95.0% Confidence Interval for B		Collinearity Statistics	
		Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	88.753	114.650		
	Stop	0.920	1.055	1	1
2	(Constant)	22.11	71.582		
	Stop	0.968	1.049	0.952	1.05
	Deceleration	0.658	1.647	0.952	1.05
3	(Constant)	0	0		
	Stop	1	1	0.936	1.07
	Deceleration	1	1	0.918	1.09
	Acceleration	1	1	0.956	1.05

a. Dependent Variable: control delay

Table 4.21. Correlation coefficients between control delay and delay components; acceleration, stopping and deceleration delay times belong route 3 for north direction.

		Control Delay	Deceleration	Stopping	Acceleration
Pearson Correlation	Control Delay	1	-0.363	0.995	0.025
	Deceleration Time	-0.363	1	-0.439	0.048
	Stopping Time	0.995	-0.439	1	-0.04
	Acceleration Time	0.025	0.048	-0.040	1
Sig. (1-tailed)	Control Delay	.	0.092	0	0.465
	Deceleration Time	0.092	.	0.051	0.433
	Stopping Time	0	0.051	.	0.444
	Acceleration Time	0.465	0.433	0.444	.

The following equation (4.5) was developed through regression analysis for the north direction for route 3.

$$DC = 46.845 + 1.008\,T_{st} + 1.153\,T_{de} \tag{4.5}$$

where

DC: Control delay time.

T_{st}: Stopping delay time.

T_{de}: Deceleration delay time.

The R^2 value of t he stopping delay time value was obtained as 0.989 for the south direction, as presented in Table 4.22. Details of regression models for Independent Variable Control Delay and Dependant Explanatory Variables: Acceleration, Stopping and Deceleration Delay Times and their correlations coefficients are presented in Tables 4.23 and 4.24, respectively.

Table 4.22. The predicted single and multi-variables models summary belong route 3 for south direction.

Model Summary						
	Change Statistics					
Model	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1 (single)	0.989	1213.345	1	13	0	
2 (Multi variables)	0.007	20.705	1	12	0.001	
3 (Multi variables)	0.004	9.634E+13	1	11	0	1.034

a. Predictors: (Constant), Stopping

b. Predictors: (Constant), Acceleration, stop

c. Predictors: (Constant), Deceleration, stop, Acceleration

Table 4.23. Details of the regression models for independent variable; control delay and dependent explanatory variables; acceleration, stopping, and deceleration delay times belong route 3 for south direction.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	sig
		B	Std. Error	Beta		
1	(Constant)	84.3			12.4	0
	Stop	0.96	6.798	0.995	34.833	0
2	(Constant)	30.778	0.028		2.459	0
	Stop	0.999	12.519	1.03	51.645	0
	Deceleration	1.026	0.019	0.091	4.55	0
3	(Constant)	-3.55E-14	0.226		0	1
	Stop	1	0	1.036	1.43E+08	0
	Deceleration	1	0	0.089	12296218	0
	Acceleration	1	0	0.062	9611150	0

a. Dependent Variable: control delay

Table4.23. (Continued) Details of the regression models for independent variable; control delay and dependent explanatory variables; acceleration, stopping, and deceleration delay times belong route 3 for south direction.

Coefficients[a]

Model		95.0% Confidence Interval for B		Collinearity Statistics	
		Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	69.614	98.987		
	Stop	0.9	1.02	1	1
2	(Constant)	3.501	58.055		
	Stop	0.956	1.041	0.808	1.24
	Deceleration	0.535	1.517	0.808	1.24
3	(Constant)	0	0		
	Stop	1	1	0.807	1.24
	Deceleration	1	1	0.807	1.24
	Acceleration	1	1	0.997	1

a. Dependent Variable: control delay

Table 4.24. Correlation coefficients between control delay and delay components; acceleration, stopping and deceleration delay times belong route 3 for south direction.

		Control Delay	Deceleration Time	Stopping Time	Acceleration Time
Pearson Correlation	Control Delay	1	-0.363	0.995	0.025
	Deceleration Time	-0.363	1	-0.439	0.048
	Stopping Time	0.995	-0.439	1.000	-0.04
	Acceleration Time	0.025	0.048	-0.04	1
Sig. (1-tailed)	Control Delay	.	0.092		0.465
	Deceleration Time	0.092	.	0.051	0.433
	Stopping Time	0	0.051	.	0.444
	Acceleration Time	0.465	0.433	0.444	.

The following equation (4.6) was developed through regression analysis for the south direction .

$$DC = 30.778 + 0.999\,T_{st} + 1.026\,T_{de} \qquad (4.6)$$

where

DC: Control delay time,

T_{st}: Stopping delay time, T_{de}: Deceleration delay time.

4.5. VISSIM Results

The vissim program was used to perform the modeling of the traffic flow for three routes. To further validate the results, several scenarios were created to evaluate the effects of increasing traffic volume by 10% at each step. These scenarios aimed to observe how changes in traffic volume would affect travel time and delays . The results of the first route in the northern direction are shown in the tables below.

Table 4.25. The results obtained for the actual traffic volume**.**

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1143	2588	1514	1453	1886	1873
V/C	0.846	1.9170	1.121	1.076	1.397	1.387
Travel time (sec.)	49.81	88.32	88.147	70.209	965.16	35.20
Vehicle delay (sec.)	0.92	23.93	14.327	16.68	510.036	1.118
stop delay (sec.)	0	0.56	14.2	2.711	183.85	0
Length (km)	0.41	0.2	1.13	0.82	11.92	0.62

Table 4.26. Results obtained with 10% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1257	2847	1665	1598	2074	2060
V/C	0.93	2.11	1.23	1.18	1.54	1.53
Travel time (sec.)	50.24	91.13	134.93	93.97	1049.85	35.52
Vehicle delay (sec.)	1.22	24.47	61.28	40.57	594.61	1.42
stop delay (sec.)	0	0.66	16.03	9.44	243.41	0
Length (km)	0.41	0.2	1.13	0.82	11.92	0.62

Table 4.27. Results obtained with 20% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1371	3105	1816	1743	2263	2247
V/C	1.02	2.30	1.35	1.29	1.68	1.66
Travel time (sec.)	50.71	94.07	147.07	107.85	1103.70	36.48
Vehicle delay (sec.)	1.58	25.13	73.42	54.49	648.55	2.42
stop delay (sec.)	0.00	0.79	24.71	17.88	265.11	0.00
Length (km)	0.41	0.2	1.13	0.82	11.92	0.62

Table 4.28. Results obtained with 30% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1485	3364	1968	1888	2451	2434
V/C	1.10	2.49	1.46	1.40	1.82	1.80
Travel time (sec.)	51.19	97.10	148.41	109.52	1153.95	39.72
Vehicle delay (sec.)	1.95	25.92	74.81	54.55	698.66	5.65
stop delay (sec.)	0.00	0.94	26.45	19.58	299.51	0.00
Length (km)	0.41	0.2	1.13	0.82	11.92	0.62

Table 4.29. Results obtained with 40% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1600	3623	2119	2034	2640	2622
V/C	1.19	2.68	1.57	1.51	1.96	1.94
Travel time (sec.)	51.67	100.00	153.45	109.87	1189.08	39.73
Vehicle delay (sec.)	2.32	26.83	79.43	54.97	733.78	5.66
stop delay (sec.)	0.00	1.10	31.18	20.04	322.22	0.00
Length (km)	0.41	0.2	1.13	0.82	11.92	0.62

Table 4.30. Results obtained with 50% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1714	3882	2271	2179	2829	2809
V/C	1.27	2.88	1.68	1.61	2.10	2.08
Travel time (sec.)	52.15	103.20	154.00	110.30	1216.	39.75
Vehicle delay (sec.)	2.70	27.91	79.72	55.24	760.72	5.68
stop delay (sec.)	0.00	1.29	31.88	20.86	324.67	0.00
Length (km)	0.41	0.2	1.13	0.82	11.92	0.62

Table 4.31. Results obtained with 60% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1829	4141	2422	2325	3018	299
V/C	1.35	3.07	1.79	1.72	2.24	2.22
Travel time (sec.)	52.65	106.71	154.50	110.79	1249.00	39.77
Vehicle delay (sec.)	3.08	29.08	80.89	56.16	793.89	5.69
stop delay (sec.)	0.00	1.50	32.56	21.17	342.37	0.00
Length (km)	0.41	0.2	1.13	0.82	11.92	0.62

Table 4.32. Results obtained with 70% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1943	4400	2574	2470	3206	3184
V/C	1.44	3.26	1.91	1.83	2.37	2.36
Travel time (sec.)	53.15	110.44	154.73	111.19	1270.00	39.79
Vehicle delay (sec.)	3.47	30.36	81.10	56.20	814.34	5.70
stop delay (sec.)	0	1.72	32.93	21.91	347.94	0
Length (km)	0.41	0.2	1.13	0.82	11.92	0.62

Table 4.33. Results obtained with 80% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	2057.40	4658.40	2725.20	2615.40	3394.80	3371.40
V/C	1.52	3.45	2.02	1.94	2.51	2.50
Travel time (sec.)	53.66	114.30	155.00	111.49	1299.79	39.82
Vehicle delay (sec.)	3.87	31.73	81.70	56.42	844.50	5.72
stop delay (sec.)	0	1.98	33.52	22.70	369.41	0
Length (km)	0.41	0.2	1.13	0.82	11.92	0.62

Table 4.34. Results obtained with 90% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	2171.70	4917.20	2876.60	2760.70	3583.40	3558.70
V/C	1.61	3.64	2.13	2.04	2.65	2.64
Travel time (sec.)	54.17	118.29	155.45	111.59	1317.00	39.83
Vehicle delay (sec.)	4.27	33.29	82.44	57.24	861.33	5.74
stop delay (sec.)	0	2.24	34.43	23.24	380.12	0
Length (km)	0.41	0.2	1.13	0.82	11.92	0.62

Table 4.35. Results obtained with 100% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	2286	5176	3028	2906	3772	3746
V/C	1.69	3.83	2.24	2.15	2.79	2.77
Travel time (sec.)	54.70	122.4	155.72	112.46	1338	39.85
Vehicle delay (sec.)	4.69	35	82.61	57.82	882.43	5.76
stop delay (sec.)	0	2.54	34.97	23.77	403.13	0
Lenghth (km)	0.41	0.2	1.13	0.82	11.92	0.62

The figure below depicts the change in travel time, vehicle delays, and stopping delays. When the volume is increased by 10%, for the first route.

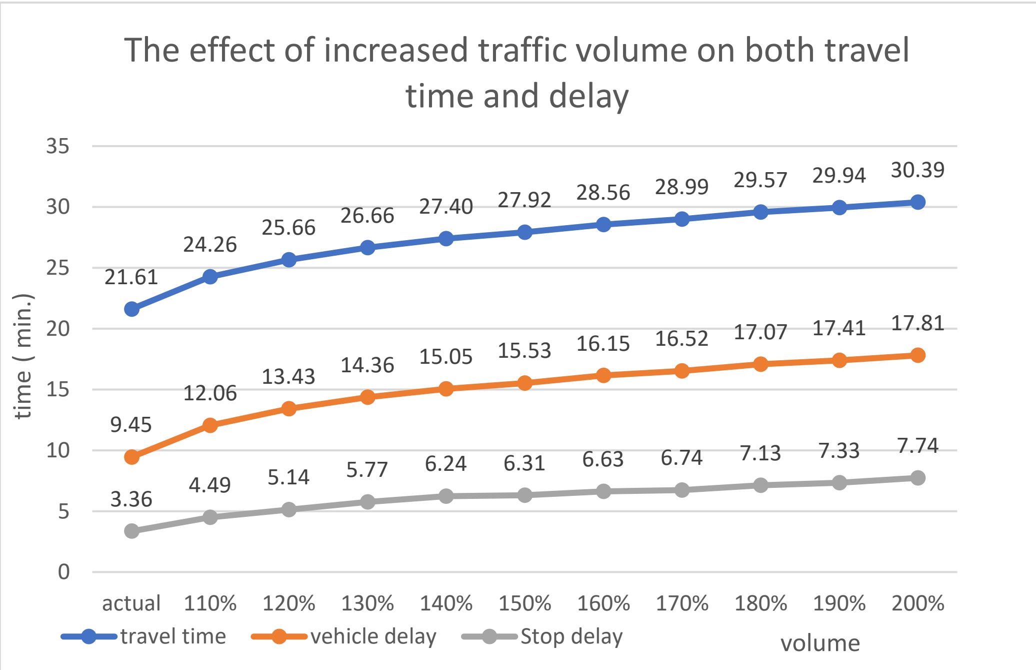


Figure 4.26. The change in travel time and (vehicle and stop) delays with the increase in traffic volume.

The results for the south direction are shown in the tables below.

Table 4.36. The results obtained for the actual traffic volume.

variables	1st link	2nd link	3rd link	4th link
VOL (v/h)	1917	1893	1585	892
V/C	1.42	1.402	1.174	0.66
Travel time (sec.)	140.065	828.416	23.337	196.09
Vehicle delay (sec.)	74.572	352.019	0.14	90.427
stop delay (sec.)	27.127	98.889	0	2.738
Lenghth (km)	0.66	11.39	0.24	0.87

Table 4.37. Results obtained with 10% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link
VOL (v/h)	2109	2082	1744	981
V/C	1.562	1.542	1.292	0.726
Travel time (sec.)	145.565	878.016	24.337	196.941
Vehicle delay (sec.)	79.672	372.319	0.161	90.954
stop delay (sec.)	28.31	109.079	0	3.024
Lenghth (km)	0.66	11.39	0.24	0.87

Table 4.38. Results obtained with 20% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link
VOL (v/h)	2300	2271	1902	1070
V/C	1.704	1.683	1.409	0.793
Travel time (sec.)	152.315	928.756	25.477	197.898
Vehicle delay (sec.)	84.872	392.619	0.203	91.652
stop delay (sec.)	28.97	120.369	0	3.37
Lenghth (km)	0.66	11.39	0.24	0.87

Table 4.39. Results obtained with 30% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link
VOL (v/h)	2492	2461	2061	1159
V/C	1.846	1.823	1.527	0.859
Travel time (sec.)	159.455	980.156	26.767	198.859
Vehicle delay (sec.)	90.272	413.919	0.268	92.478
stop delay (sec.)	30.4	132.759	0	3.722
Lenghth (km)	0.66	11.39	0.24	0.87

Table 4.40. Results obtained with 40% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link
VOL (v/h)	2684	2651	2219	1248
V/C	1.988	1.963	1.644	0.925
Travel time (sec.)	167.925	1032.056	28.217	199.826
Vehicle delay (sec.)	102.172	459.949	0.464	94.514
stop delay (sec.)	31.6	146.269	0	4.079
Lenghth (km)	0.66	11.39	0.24	0.87

Table 4.41. Results obtained with 50% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link
VOL (v/h)	2876	2840	2378	1337
V/C	2.130	2.103	1.762	0.991
Travel time (sec.)	177.605	1085.456	29.847	200.798
Vehicle delay (sec.)	102.172	459.949	0.464	94.514
stop delay (sec.)	32.86	160.879	0	4.441
Lenghth (km)	0.66	11.39	0.24	0.87

Table 4.42. Results obtained with 60% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link
VOL (v/h)	3067	3029	2537	1426
V/C	2.272	2.244	1.879	1.057
Travel time (sec.)	188.105	1140.016	31.717	201.776
Vehicle delay (sec.)	108.502	484.749	0.574	95.802
stop delay (sec.)	33.970	176.569	0	4.809
Lenghth (km)	0.66	11.39	0.24	0.87

Table 4.43. Results obtained with 70% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link
VOL (v/h)	3259	3218	2695	1516
V/C	2.414	2.384	1.996	1.123
Travel time (sec.)	199.745	1195.796	33.657	202.761
Vehicle delay (sec.)	115.032	510.899	0.690	97.103
stop delay (sec.)	35.13	192.359	0.000	5.184
Lenghth (km)	0.66	11.39	0.24	0.87

Table 4.44. Results obtained with 80% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link
VOL (v/h)	3451	3407	2854	1605
V/C	2.556	2.524	2.114	1.189
Travel time (sec.)	213.245	1252.706	35.862	203.755
Vehicle delay (sec.)	121.902	538.309	0.818	98.425
stop delay (sec.)	36.4	208.269	0	5.568
Lenghth (km)	0.66	11.39	0.24	0.87

Table 4.45. Results obtained with 90% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link
VOL (v/h)	3642	3597	3012	1694
V/C	2.698	2.664	2.231	1.255
Travel time (sec.)	228.745	1310.846	38.342	204.758
Vehicle delay (sec.)	129.002	566.939	0.968	99.778
stop delay (sec.)	37.8	225.959	0.000	5.971
Lenghth (km)	0.66	11.39	0.24	0.87

Table 4.46. Results obtained with 100% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link
VOL (v/h)	3834	3786	3171	1783
V/C	2.840	2.804	2.349	1.321
Travel time (sec.)	245.245	1370.446	41.708	205.970
Vehicle delay (sec.)	136.402	597.219	1.160	101.082
stop delay (sec.)	39.7	244.699	0.000	6.403
Lenghth (km)	0.66	11.39	0.24	0.87

The figure below depict the change in travel time, vehicle delays, and stopping delays. When the volume is increased by 10%, for the south direction.

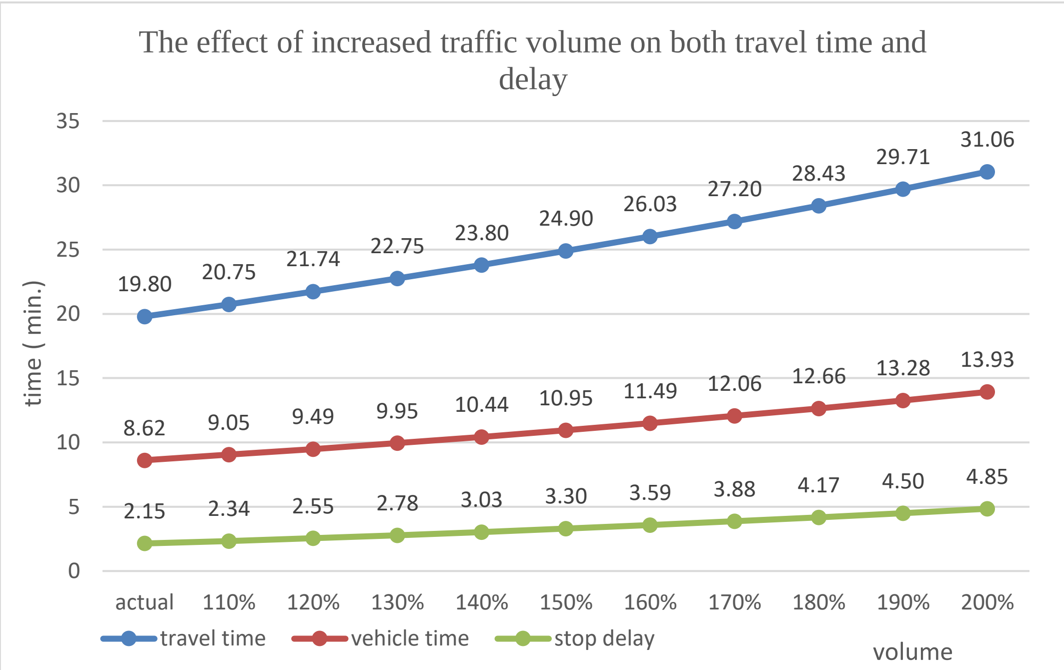


Figure 4.27. The change in travel time and (vehicle and stop) delays with the increase in traffic volume.

The results for the second route in the northern direction are shown in the tables below

Table 4.47. The results obtained for the actual traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	1143	2588	1837	1865	1843	1417	1762	1356	1611
V/C	0.847	1.917	1.361	1.381	1.36	1.05	1.305	1.04	1.19
Travel time (sec.)	49.812	87.325	283.38	135.73	83.25	189.84	214.65	69.45	54.17
Vehicle delay (sec.)	0.92	21.857	103.31	71.16	42.66	22.02	111.08	9.73	1.63
stop delay (sec.)	0	0.48	51.28	22.06	6.39	0.95	36.78	0.32	0
Lenghth (km)	0.41	0.2	1.73	0.94	0.45	2.43	1.41	0.77	0.93

Table 4.48. Results obtained with 10% increase in traffic volume.

variables	1^{st} link	2^{nd} link	3^{rd} link	4^{th} link	5^{th} link	6^{th} link	7^{th} link	8^{th} link	9^{th} link
VOL (v/h)	1257	2847	2021	2052	2027	1559	1938	1492	1772
V/C	0.931	2.109	1.497	1.52	1.502	1.155	1.436	1.105	1.313
Travel time (sec.)	89.937	89.937	298.08	138.63	84.63	259.69	224.03	86.37	54.45
Vehicle delay (sec.)	21.928	21.928	104.41	72.26	138.88	96.22	116.24	30.855	1.97
stop delay (sec.)	0.567	0.567	53.380	22.860	6.74	20.7	37.6	5.640	0
Lenghth (km)	0.41	0.2	1.73	0.94	0.45	2.43	1.41	0.77	0.93

Table 4.49. Results obtained with 20% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	1372	3106	2204	2238	2212	1700	2114	1627	1933
V/C	1.016	2.3	1.633	1.658	1.638	1.26	1.566	1.205	1.432
Travel time (sec.)	50.71	92.692	314.02	142.77	88.25	228.3	233.51	111.48	54.85
Vehicle delay (sec.)	1.585	22.123	106.72	73.57	141.19	170.42	118.44	51.98	2.31
stop delay (sec.)	0	0.662	55.83	23.84	7.12	53.2	38.04	11.39	0
Lenghth (km)	0.41	0.2	1.73	0.94	0.45	2.43	1.41	0.77	0.93

Table 4.50. Results obtained with 30% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	1486	3364	2388	2425	2396	1842	2291	1763	2094
V/C	1.101	2.492	1.769	1.796	1.775	1.365	1.697	1.306	1.551
Travel time (sec.)	51.185	95.549	331.16	148.41	92.07	352.95	242.95	123.21	55.42
Vehicle delay (sec.)	1.95	22.44	110.2	76.05	144.14	185.66	120.46	63.72	2.95
stop delay (sec.)	0	0.787	58.58	25.05	7.515	71.08	38.33	18.36	0
Lenghth (km)	0.41	0.2	1.73	0.94	0.45	2.43	1.41	0.77	0.93

Table 4.51. Results obtained with 40% increase in traffic volume.

Subject	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	1600	3623	2572	2611	2580	1984	2467	1898	2255
V/C	1.185	2.684	1.905	1.934	1.911	1.469	1.827	1.406	1.671
Travel time (sec.)	51.666	98.221	349.52	154.97	96.11	363.43	252.67	126.33	57.83
Vehicle delay (sec.)	2.321	22.826	114.81	79.66	149.5	193.01	120.97	66.79	5.36
stop delay (sec.)	0	0.955	61.4	26.46	7.925	74.6	39.01	18.64	0.15
Lenghth (km)	0.41	0.2	1.73	0.94	0.45	2.43	1.41	0.77	0.93

Table 4.52. Results obtained with 50% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	1715	3882	2756	2798	2765	2126	2643	2034	2417
V/C	1.27	2.876	2.041	2.072	2.048	1.574	1.958	1.507	1.79
Travel time (sec.)	52.152	101.2	369.58	163.23	100.85	337.63	264.05	127.47	61.62
Vehicledelay (sec.)	2.697	23.2	119.63	83.48	158.67	191.98	121.13	68	9.17
stop delay (sec.)	0	1.128	64.29	28.07	8.340	74.66	39.29	18.75	1.49
Lenghth (km)	0.41	0.2	1.73	0.94	0.45	2.43	1.41	0.77	0.93

Table 4.53. Results obtained with 60% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	1829	4141	2939	2984	2949	2267	2819	2170	2578
V/C	1.355	3.067	2.177	2.21	2.184	1.679	2.088	1.607	1.909
Travel time (sec.)	52.647	104.49	391.03	173.21	105.98	368.95	275.77	129.24	62.16
Vehicle delay (sec.)	3.079	23.528	126.04	87.79	168.41	195	121.4	69.76	9.74
stop delay (sec.)	0	1.323	67.24	29.87	8.764	77.8	40.030	19.97	1.61
Lenghth (km)	0.41	0.2	1.73	0.94	0.45	2.43	1.41	0.77	0.93

Table 4.54. Results obtained with 70% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	1943	4400	3123	3171	3133.1	2409	2995	2305	273
V/C	1.439	3.259	2.313	2.349	2.321	1.784	2.219	1.708	2.029
Travel time (sec.)	53.149	107.996	414.13	184.51	111.76	360.28	287.65	129.85	62.43
Vehicle delay (sec.)	3.468	23.69	133.51	93.36	178.41	201.81	121.75	70.42	10
stop delay (sec.)	0	1.532	70.95	31.91	9.234	79.81	42.78	20.96	1.79
Lenghth (km)	0.41	0.2	1.73	0.94	0.45	2.43	1.41	0.77	0.93

Table 4.55. Results obtained with 80% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	2057	4658.4	3307	3357	3317	2551	3172	2441	2900
V/C	1.524	3.451	2.449	2.487	2.457	1.889	2.349	1.808	2.148
Travel time (sec.)	53.658	111.615	438.33	197.4	117.64	359.16	299.97	130.27	62.95
Vehicle delay (sec.)	3.866	23.85	141.42	99.27	188.94	204.61	121.76	70.83	10.53
stop delay (sec.)	0	1.772	75.75	34.21	9.734	84.46	43.180	21.48	2.21
Lenghth (km)	0.41	0.2	1.73	0.94	0.45	2.43	1.41	0.77	0.93

Table 4.56. Results obtained with 90% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	2172	4917	3490	3544	3502	2692	3348	2576	3061
V/C	1.609	3.642	2.585	2.625	2.594	1.994	2.48	1.908	2.267
Travel time (sec.)	54.173	115.364	463.69	211.66	127.68	369.29	314.35	131.32	63.53
Vehicle delay (sec.)	4.273	23.803	150.83	106.68	200.04	196.32	121.86	71.84	11.1
stop delay (sec.)	0	2.052	81.4	36.71	10.304	86.41	45.77	23.24	2.87
Lenghth (km)	0.41	0.2	1.73	0.94	0.45	2.43	1.41	0.77	0.93

Table 4.57. Results obtained with 100% increase in traffic volume.

variables	1^{st} link	2^{nd} link	3^{rd} link	4^{th} link	5^{th} link	6^{th} link	7^{th} link	8^{th} link	9^{th} link
VOL (v/h)	2286	5176	3674	3730	3686	2834	3524	2712	3222
V/C	1.693	3.834	2.721	2.763	2.73	2.099	2.61	2.009	2.387
Travel time (sec.)	54.697	119.173	490.69	226.86	143.36	371.83	330.738	132.03	66.12
Vehicle delay (sec.)	4.689	27.048	160.94	114.79	213.74	202.02	124.56	72.54	13.7
stop delay (sec.)	0	2.371	89.31	39.51	11.114	91.55	45.84	25.17	4.79
Lenghth (km)	0.41	0.2	1.73	0.94	0.45	2.43	1.41	0.77	0.93

The figure below depict the change in travel time, vehicle delays, and stopping delays when the volume is increased by 10% at each step for the north direction.

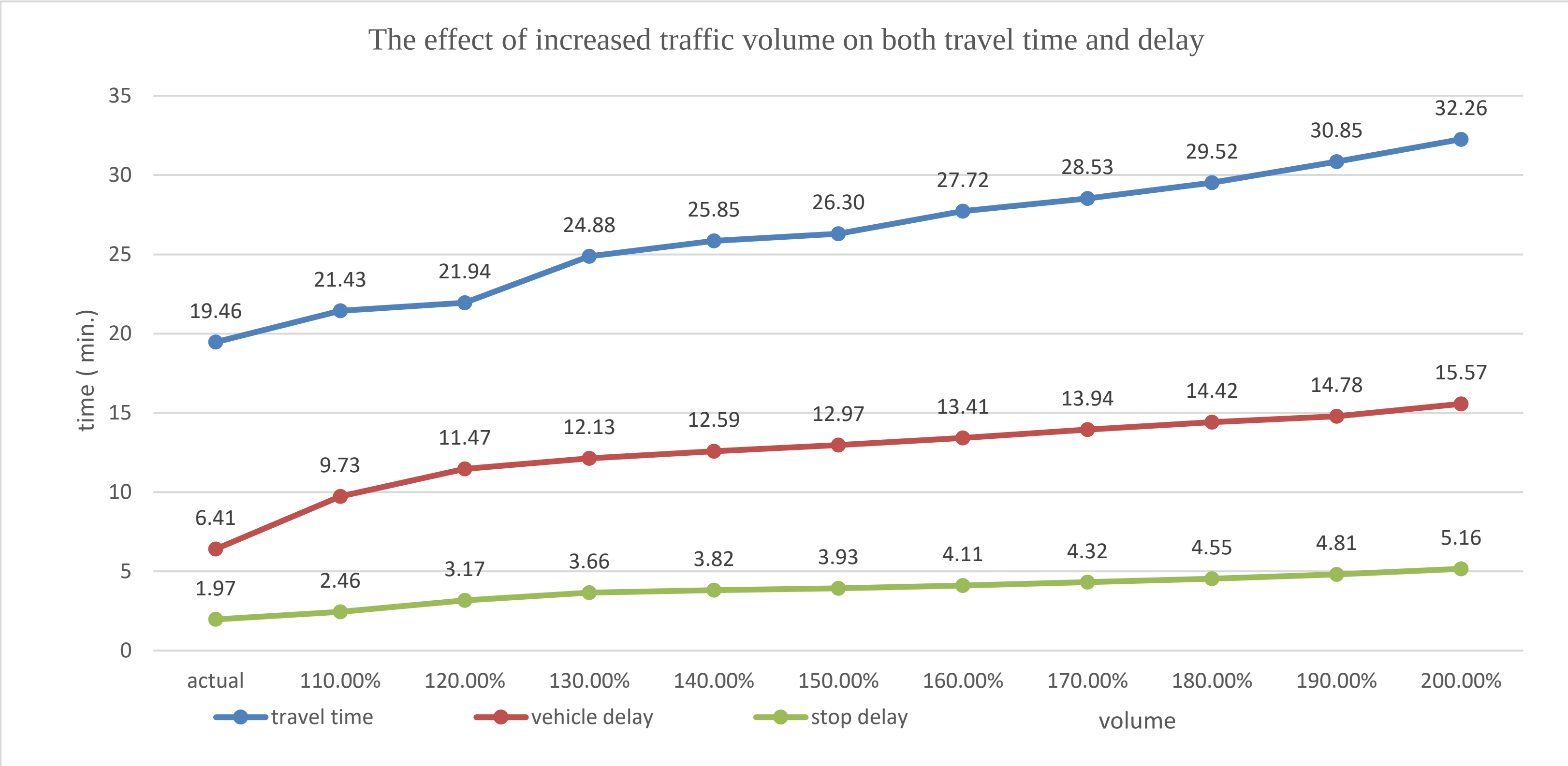


Figure 4.28. The change in travel time and (vehicle and stop) delays with the increase in traffic volume.

The results for the second route in the southern direction are shown in the tables below.

Table 4.58. The results obtained for the actual traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	1750	1742	709	1488	1865	1841	1076.	1585	892
V/C	1.296	1.29	0.525	1.102	1.381	1.364	0.797	1.174	0.66
Travel time (sec.)	144.81	127.28	107	195.75	74.91	153.91	191.17	23.337	196.09
Vehicle delay (sec.)	78.32	66.34	3.61	39.74	38.7	77.82	4.68	0.14	90.427
stop delay (sec.)	22.32	16.11	0	36.51	8.85	19.43	0	0	2.738
Lenghth (km)	0.93	0.77	1.41	2.433	0.45	0.94	1.73	0.24	0.87

Table 4.59. Results obtained with 10% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	1925	1916	780	1637	2052	2025	1184	1744	981
V/C	1.426	1.419	0.578	1.212	1.52	1.5	0.877	1.292	0.726
Travel time (sec.)	152.95	133.62	112.8	285.84	80.51	164.51	192.39	24.337	196.941
Vehicle delay (sec.)	80.4	70.21	4.08	130.21	39.02	81.18	5.64	0.161	90.954
stop delay (sec.)	22.69	19.02	0	46.31	9.6	20.63	0	0	3.024
Lenghth (km)	0.93	0.77	1.41	2.433	0.45	0.94	1.73	0.24	0.87

Table 4.60. Results obtained with 20% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	2100	2090	851	1786	2238	2209	1291	1902	1070
V/C	1.556	1.548	0.630	1.323	1.658	1.636	0.956	1.409	0.793
Travel time (sec.)	162.3	141.07	118.8	322.06	86.18	175.41	195.07	25.477	197.898
Vehicle delay (sec.)	82.56	75.42	4.49	166.48	39.5	84.46	7.98	0.203	91.652
stop delay (sec.)	23.02	19.02	0	63.45	10.14	21.44	0	0	3.37
Lenghth (km)	0.93	0.77	1.41	2.433	0.45	0.94	1.73	0.24	0.87

Table 4.61. Results obtained with 30% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	2275	2264	922	1934.	2425	2393	1399	2061	1159
V/C	1.685	1.677	0.683	1.433	1.796	1.773	1.036	1.527	0.859
Travel time (sec.)	172.8	149.57	125.7	332.43	91.89	186.61	202.35	26.767	198.859
Vehicle delay (sec.)	83.9	79.65	5.06	176.82	40.12	88.1	15.31	0.268	92.478
stop delay (sec.)	23.72	19.05	0	70.4	10.62	21.57	1	0	3.722
Lenghth (km)	0.93	0.77	1.41	2.433	0.45	0.94	1.73	0.24	0.87

Table 4.62. Results obtained with 40% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	2450	2439	993	2083	2611	2577	1506	2219	1248
V/C	1.815	1.807	0.735	1.543	1.934	1.909	1.116	1.644	0.925
Travel time (sec.)	184.5	159.27	133.3	336.48	97.65	198.21	221.83	28.217	199.826
Vehicle delay (sec.)	85.04	83.93	5.64	180.8	40.43	92.2	34.71	0.464	94.514
stop delay (sec.)	24.23	19.32	0	72.03	11.1	25.5	8.38	0	4.079
Lenghth (km)	0.93	0.77	1.410	2.433	0.45	0.94	1.73	0.24	0.87

Table 4.63. Results obtained with 50% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	2625	2613	1064	2232	2798	2762	1614	2378	1337
V/C	1.944	1.936	0.788	1.653	2.072	2.046	1.196	1.762	0.991
Travel time (sec.)	197.35	169.12	141.6	341.32	103.42	210.01	263.5	29.847	200.798
Vehicle delay (sec.)	87.8	87.08	6.43	185.79	41.25	96.3	55.33	0.464	94.514
stop delay (sec.)	25.2	19.42	0	72.75	11.79	25.79	32.14	0	4.441
Lenghth (km)	0.93	0.77	1.41	2.433	0.45	0.94	1.73	0.24	0.87

Table 4.64. Results obtained with 60% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	2800	2787	1134	2381	2984	2946	1722	2537	1427
V/C	2.074	2.065	0.84	1.764	2.21	2.182	1.275	1.879	1.057
Travel time (sec.)	211.14	179.81	150.1	342.27	109.21	222.41	279.83	31.717	201.78
Vehicle delay (sec.)	89.75	92.31	7.74	186.69	42.41	101.02	76.67	0.574	95.802
stop delay (sec.)	25.63	19.92	0	78.56	12.03	25.84	44.17	0	4.809
Lenghth (km)	0.93	0.77	1.41	2.433	0.45	0.94	1.73	0.24	0.87

Table 4.65. Results obtained with 70% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	2975	2961	1205	2530	3171	3130	1829	2695	1516
V/C	2.204	2.194	0.893	1.874	2.349	2.318	1.355	1.996	1.123
Travel time (sec.)	225.79	191.46	158.9	344.03	115.01	235.01	287.38	33.657	202.761
Vehicle delay (sec.)	92.14	97.39	9.59	188.34	43.82	106	93.03	0.69	97.103
stop delay (sec.)	26.5	21.2	0.24	78.75	13.25	25.94	47.42	0	5.184
Lenghth (km)	0.93	0.77	1.41	2.433	0.45	0.94	1.73	0.24	0.87

Table 4.66. Results obtained with 80% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	3150	3135	1276	2678	3357	3314	1937	2854	1605
V/C	2.333	2.323	0.945	1.984	2.487	2.455	1.435	2.114	1.189
Travel time (sec.)	241.26	203.33	168.6	346.74	120.82	247.91	289.81	35.862	203.755
Vehicle delay (sec.)	96.65	102.63	12.48	191.12	45.45	111.46	100.53	0.818	98.425
stop delay (sec.)	26.81	21.6	0.24	78.75	13.45	28.02	51.42	0	5.568
Lenghth (km)	0.93	0.77	1.41	2.433	0.45	0.94	1.73	0.24	0.87

Table 4.67. Results obtained with 90% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	3325	3310	1347	2827	3544	3498	2044	3012	1694
V/C	2.463	2.452	0.998	2.094	2.625	2.591	1.514	2.231	1.255
Travel time (sec.)	257.47	215.54	178.8	347.78	126.632	262.51	293.39	38.342	204.758
Vehicle delay (sec.)	100.45	107.98	18.82	192.21	48.53	117.62	103.22	0.968	99.778
stop delay (sec.)	26.81	22.69	1.97	79.85	13.71	30.57	55.42	0	5.971
Lenghth (km)	0.93	0.77	1.41	2.433	0.45	0.94	1.73	0.24	0.87

Table 4.68. Results obtained with 100% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link	7th link	8th link	9th link
VOL (v/h)	3500	3484	1418	2976	3730	3682	2152	3171	1783
V/C	2.593	2.581	1.05	2.204	2.763	2.727	1.594	2.349	1.321
Travel time (sec.)	274.94	229.01	189.7	347.92	132.832	279.4	293.63	41.708	205.97
Vehicle delay (sec.)	108.6	115.75	29.5	192.35	52.61	126.18	106.87	1.16	101.082
stop delay (sec.)	29.32	22.85	3.07	82.32	14.3	34.47	63.63	0	6.403
Lenghth (km)	0.93	0.77	1.41	2.433	0.45	0.94	1.73	0.24	0.87

The figure below depict the change in travel time, vehicle delays, and stopping delays. When the volume is increased by 10% at each step for the south direction.

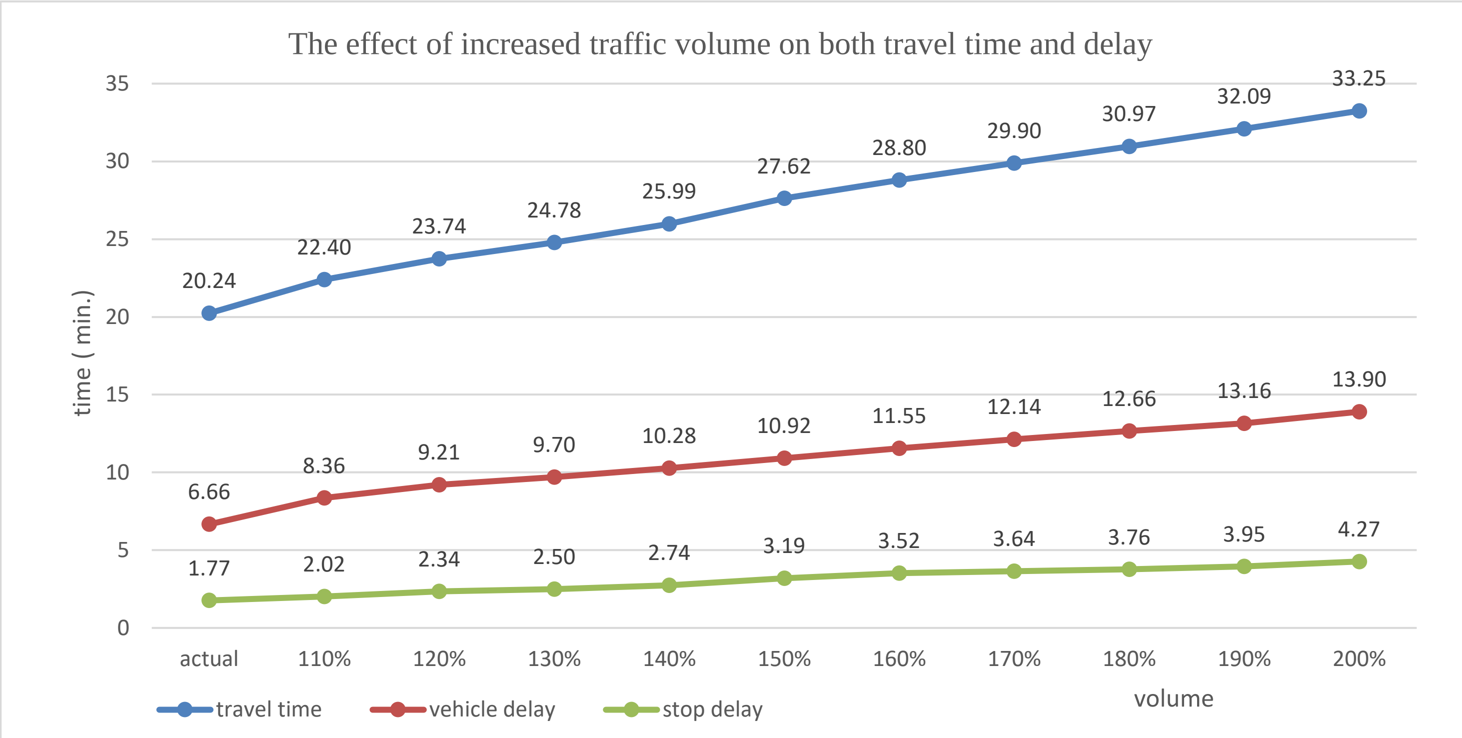


Figure 4.29. The in travel time and (vehicle and stop) delays with the increase in traffic volume.

The results of the third route in the northern direction are shown in the tables below.

Table 4.69. The results obtained for the actual traffic volume.

Variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1143	2588	2313	1762	1851	1419
V/C	0.847	1.917	1.713	1.305	1.371	1.051
Travel time (sec.)	49.812	81.725	1104.41	131.2	208	53.92
Vehicle delay (sec.)	0.92	20.992	796	70.24	120.57	1.26
stop delay (sec.)	0	0.981	341.37	20.57	38.61	0
Lenghth (km)	0.41	0.2	8.51	0.77	1.33	0.93

Table 4.70. Results obtained with 10% increase in traffic volume.

Variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1257	2846	2544	1938	2036	1561
V/C	0.931	2.109	1.885	1.436	1.508	1.156
Travel time (sec.)	50.24	83.344	1197.641	134.43	218.22	54.11
Vehicle delay (sec.)	1.224	21.323	860	73.74	125.67	1.42
stop delay (sec.)	0	1.021	388.64	21.47	40.81	0
Lenghth (km)	0.41	0.2	8.51	0.77	1.33	0.93

Table 4.71. Results obtained with 20% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1372	3106	2776	2114	2221	1703
V/C	1.016	2.3	2.056	1.566	1.645	1.261
Travel time (sec.)	50.71	85.06	1294.911	139.32	229.74	54.39
Vehicle delay (sec.)	1.585	21.707	940	77.54	131.07	1.65
stop delay (sec.)	0	1.091	422.28	22.67	43.31	0
Lenghth (km)	0.41	0.2	8.51	0.77	1.33	0.93

Table 4.72. Results obtained with 30% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1486	3364	3007	2291	2406	1845
V/C	1.101	2.492	2.227	1.697	1.782	1.366
Travel time (sec.)	51.185	86.831	1392.911	145.76	242.36	54.63
Vehicle delay (sec.)	1.95	22.186	1020	81.74	136.87	1.87
stop delay (sec.)	0	1.208	462	24	46.04	0
Lenghth (km)	0.41	0.2	8.51	0.77	1.33	0.93

Table 4.73. Results obtained with 40% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1600	3623	3238	2467	2591	1987
V/C	1.185	2.684	2.399	1.827	1.920	1.472
Travel time (sec.)	51.666	88.388	1492.911	153.08	256.08	54.93
Vehicle delay (sec.)	2.321	22.771	1097	86.54	143.27	2.16
stop delay (sec.)	0	1.366	525.740	25.42	48.76	0
Lenghth (km)	0.41	0.2	8.51	0.77	1.33	0.93

Table 4.74. Results obtained with 50% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1715	3882	3470	2643	2777	2129
V/C	1.27	2.876	2.57	1.958	2.057	1.577
Travel time (sec.)	52.152	90.191	1594.911	161.6	270.85	55.48
Vehicle delay (sec.)	2.697	23.285	1170	92.24	150.57	2.7
stop delay (sec.)	0	1.524	575.17	26.96	51.6	0
Lenghth (km)	0.41	0.2	8.51	0.77	1.33	0.93

Table 4.75. Results obtained with 60% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1829	4141	3701	2819	2962	2270
V/C	1.355	3.067	2.741	2.088	2.194	1.682
Travel time (sec.)	52.647	92.304	1699.911	170.92	286.82	56.39
Vehicle delay (sec.)	3.079	23.722	1240	98.14	158.07	3.63
stop delay (sec.)	0	1.697	625.4	28.63	54.57	0
Lenghth (km)	0.41	0.2	8.51	0.77	1.33	0.93

Table 4.76. Results obtained with 70% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	1943	4400	3932.	2995	3147	2412
V/C	1.439	3.259	2.913	2.219	2.331	1.787
Travel time (sec.)	53.149	94.568	1805.911	181.14	303.84	63.87
Vehicle delay (sec.)	3.468	23.957	1289	104.84	166.37	11.18
stop delay (sec.)	0	1.875	670	30.45	57.69	1.87
Lenghth (km)	0.41	0.2	8.51	0.77	1.33	0.93

Table 4.77. Results obtained with 80% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	2057	4658	4163	3172	3332	2554
V/C	1.524	3.451	3.084	2.349	2.468	1.892
Travel time (sec.)	53.658	96.959	1914.911	192.56	321.56	64.55
Vehicle delay (sec.)	3.866	24.166	1350	112.64	175.77	11.85
stop delay (sec.)	0	2.065	713.55	32.55	61.09	1.95
Lenghth (km)	0.41	0.2	8.51	0.77	1.33	0.93

Table 4.78. Results obtained with 90% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	2171.7	4917.2	4395	3348	3517	2696
V/C	1.609	3.642	3.255	2.48	2.605	1.997
Travel time (sec.)	54.173	99.483	2022.911	205.03	340.78	64.15
Vehicle delay (sec.)	4.273	24.128	1410	121.04	185.77	11.45
stop delay (sec.)	0	2.048	755.75	35.72	65.56	2.87
Lenghth (km)	0.41	0.2	8.51	0.77	1.33	0.93

Table 4.79. Results obtained with 100% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link	6th link
VOL (v/h)	2286	5176	4626	3524	3702	2838
V/C	1.693	3.834	3.427	2.61	2.742	2.102
Travel time (sec.)	54.697	102.26	2126.911	218.48	361.38	64.4
Vehicle delay (sec.)	4.689	27.422	1468	130.64	196.529	11.71
stop delay (sec.)	0	2.145	801	38.95	71.16	4.7
Lenghth (km)	0.41	0.2	8.51	0.77	1.33	0.93

The figure below depicts the change in travel time, vehicle delays, and stopping delays. When the volume is increased by 10% at each step for the north direction.

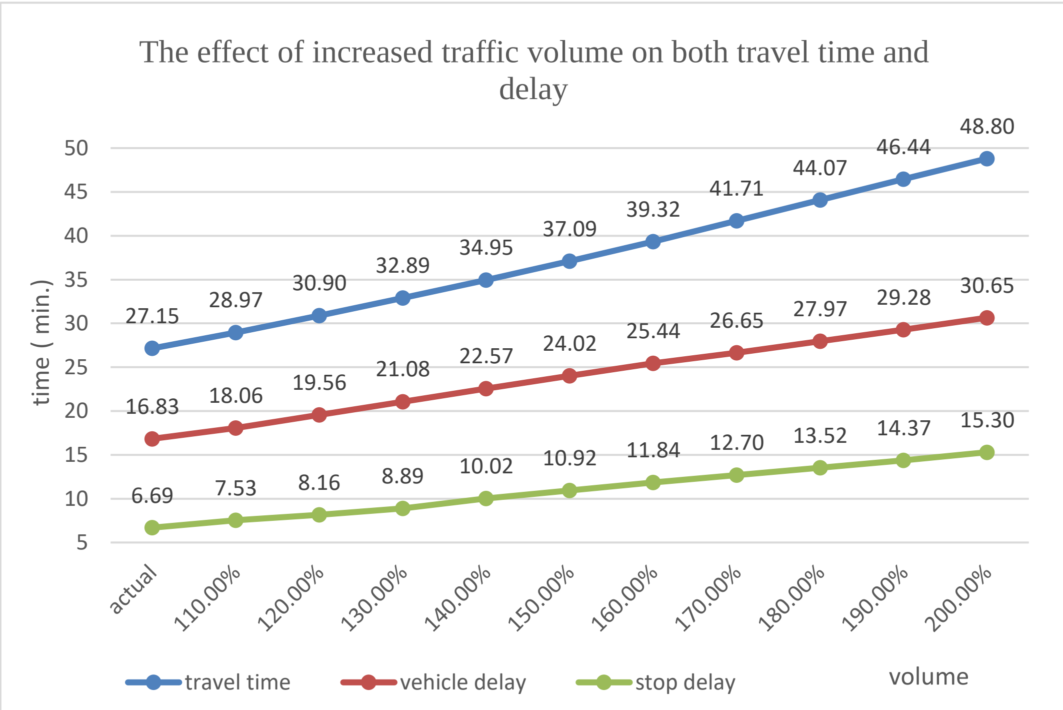


Figure 4.30. The change in travel time and (vehicle and stop) delays with the increase in traffic volume.

The results for the southern direction are shown in the tables below.

Table 4.80. The results obtained for the actual traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link
VOL (v/h)	1985	2569	1895	1585	892
V/C	1.47	1.903	1.404	1.174	0.66
Travel time (sec.)	100.607	183.398	740.557	23.337	196.09
Vehicle delay (sec.)	53.589	95.366	531.797	0.14	90.427
stop delay (sec.)	12.395	34.268	207.239	0	2.738
Lenghth (km)	0.93	1.33	10.28	0.24	0.87

Table 4.81. Results obtained with 10% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link
VOL (v/h)	2184	2826	2085	1744	981
V/C	1.617	2.093	1.544	1.292	0.726
Travel time (sec.)	105.387	197.698	798.459	24.337	196.941
Vehicle delay (sec.)	57.089	102.866	554.397	0.161	90.954
stop delay (sec.)	12.614	38.514	221.839	0	3.024
Lenghth (km)	0.93	1.33	10.28	0.24	0.87

Table 4.82. Results obtained with 20% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link
VOL (v/h)	2382	3083	2274	1902	1070
V/C	1.764	2.284	1.684	1.409	0.793
Travel time (sec.)	110.587	212.498	827.463	25.477	197.898
Vehicle delay (sec.)	60.789	110.766	578.497	0.203	91.652
stop delay (sec.)	13.075	40.17	237.039	0	3.37
Lenghth (km)	0.93	1.33	10.28	0.24	0.87

Table 4.83. Results obtained with 30% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link
VOL (v/h)	2581	3340	2464	2061	1159
V/C	1.911	2.474	1.825	1.527	0.859
Travel time (sec.)	116.387	227.498	958.787	26.767	198.859
Vehicle delay (sec.)	64.679	119.166	604.707	0.268	92.478
stop delay (sec.)	14.1	42.9	252.639	0	3.722
Lenghth (km)	0.93	1.33	10.28	0.24	0.87

Table 4.84. Results obtained with 40% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link
VOL (v/h)	2779	3597	2653	2220	1248
V/C	2.059	2.664	1.965	1.644	0.925
Travel time (sec.)	122.787	242.798	1003.787	28.217	199.826
Vehicle delay (sec.)	68.779	128.066	631.307	0.464	94.514
stop delay (sec.)	14.9	45.064	268.689	0	4.079
Lenghth (km)	0.93	1.33	10.28	0.24	0.87

Table 4.85. Results obtained with 50% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link
VOL (v/h)	2978	3854	2843	2378	1337
V/C	2.206	2.854	2.106	1.762	0.991
Travel time (sec.)	129.887	258.498	1054.787	29.847	200.798
Vehicle delay (sec.)	73.129	137.186	659.327	0.464	94.514
stop delay (sec.)	15.67	47.12	284.889	0	4.441
Lenghth (km)	0.93	1.33	10.28	0.24	0.87

Table 4.86. Results obtained with 60% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link
VOL (v/h)	3176	4110	3032	2537	1427
V/C	2.353	3.045	2.246	1.879	1.057
Travel time (sec.)	137.637	274.598	1118.287	31.717	201.776
Vehicle delay (sec.)	77.739	146.416	687.947	0.574	95.802
stop delay (sec.)	16.324	48.810	301.229	0	4.809
Lenghth (km)	0.93	1.33	10.28	0.24	0.87

Table 4.87. Results obtained with 70% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link
VOL (v/h)	3375	4367	3222	2695	1516
V/C	2.5	3.235	2.386	1.996	1.123
Travel time (sec.)	146.061	291.298	1187.287	33.657	202.761
Vehicle delay (sec.)	82.369	155.656	717.362	0.69	97.103
stop delay (sec.)	17.648	51.4	317.839	0	5.184
Lenghth (km)	0.93	1.33	10.28	0.24	0.87

Table 4.88. Results obtained with 80% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link
VOL (v/h)	3573	4624	3411	2854	1605
V/C	2.647	3.425	2.527	2.114	1.189
Travel time (sec.)	154.675	308.398	1257.287	35.862	203.755
Vehicle delay (sec.)	87.019	165.016	747.712	0.818	98.425
stop delay (sec.)	18.76	54.8	335.029	0	5.568
Lenghth (km)	0.93	1.33	10.28	0.24	0.87

Table 4.89. Results obtained with 90% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link
VOL (v/h)	3772	4881	3601	3012	1694
V/C	2.794	3.616	2.667	2.231	1.255
Travel time (sec.)	163.575	325.698	1341.287	38.342	204.758
Vehicle delay (sec.)	91.689	174.426	778.922	0.968	99.778
stop delay (sec.)	19.23	56.21	352.329	0	5.971
Lenghth (km)	0.93	1.33	10.28	0.24	0.87

Table 4.90. Results obtained with 100% increase in traffic volume.

variables	1st link	2nd link	3rd link	4th link	5th link
VOL (v/h)	3970	5138	3790.	3171	1783
V/C	2.941	3.806	2.807	2.349	1.321
Travel time (sec.)	173.653	343.498	1425.172	41.708	205.97
Vehicle delay (sec.)	96.35	183.849	809.042	1.16	101.082
stop delay (sec.)	20.255	59.6	369.929	0	6.403
Lenghth (km)	0.93	1.33	10.28	0.24	0.87

The figure below depicts the change in travel time, vehicle delays, and stopping delays. When the volume is increased by 10% at each step for each link for the south direction.

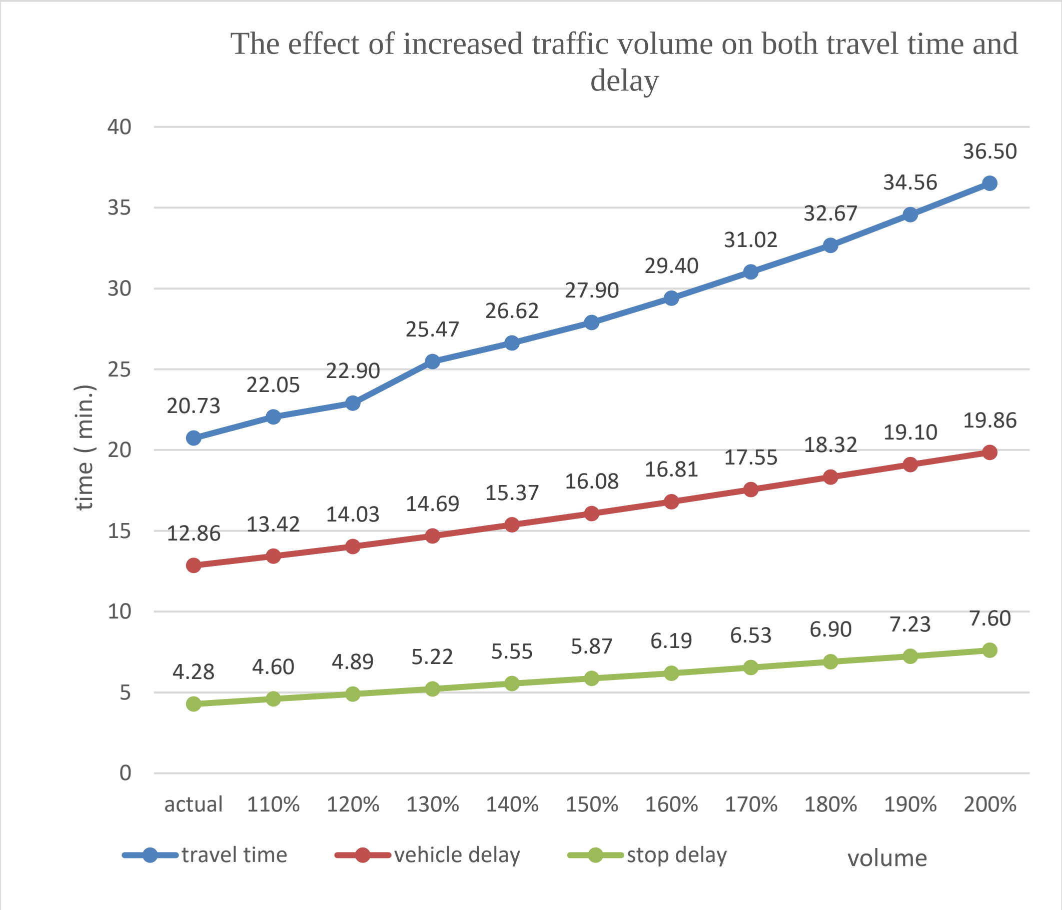


Figure 4.31. The change in travel time and (vehicle and stop) delays with the increase in traffic volume.

The previous tables depict the results of the modeling done to compare the results among different levels of traffic volume. The results of the simulation in the northern and southern directions of the all route showed that there was a significant change in travel time as the traffic volume increased. The results also showed that the increase in traffic volume led to an increase in delays as well, though the effects on travel time were more pronounced than the effects on delays. This is because fewer gaps are available between vehicles and more vehicles are in the same lane leading to longer travel times. These results provide further evidence of how changes in traffic volumes can have significant impacts on traffic flow characteristics.To evaluate the effects of delays of any kind on travel time reliability, we will go over the Buffer Index and Planning Time Index in both directions as illustrated in the table below.

Table 4.91. The values of Buffer Index and Planning Time Index for all routes.

Route number/Direction	Buffer Index	Planning Time Index
First /north	10.24%	2.68
First/south	21.03%	2.79
Second /north	20.21%	2.75
Second/south	19.87%	2.78
Third /north	27.06%	5.02
Third/south	26.15%	3.1

Although it is difficult to get the absolute true delay value, Buffer Index and Planning Time Index values of the three routes provide an idea of the extent of the delay.

5. CONCLUSIONS AND DISCUSSIONS

These results of this thesis were obtained by, first, calculating the travel times with the probe vehicle method for three different routes for the time period of morning, noon and night time for both directions, and then determining the types of delays and creating a mathematical model with an SPSS program to evaluate the delays. In this way, these findings were used to analyse the travel time reliability of the transportation network available in the city of Baghdad. In addition, the VISSIM program was used to simulate the road in various scenarios. Afer all these analysis process, the outcomes acquired can be summarised as follows:

- The analysis of transportation network in terms of travel time reliability with regard to all routes in both directions (morning and evening periods) indicates that the reliability for the morning period of the three routes is uneven as compared to the night period. Overall, these discrepancies show that there is a need for careful planning when it comes to travel time.
- The expected travel time may not match the actual travel time. It is well established that certain pathways are more frequently used during the morning period than in the evening. In the first route, the proportion of days when the actual time surpassed what was expected was 66% in the morning, and the same in the second route, while in the evening, the percentage of the second route was 53%. This is due to a variety of factors, including the desire to reach a specific location in an efficient manner. One of the most important reasons for this is that the majority of individuals who work prefer to arrive at their destination between 8 and 8:30 a.m., which is the start time for most institutions and colleges. When it comes to returning to work, the hours span from 14:00 to 17:00. The reason for utilizing this path differs from person to person.
- It is clear that when the delay values were low in the morning on the first and second routes, the delay was still low in the evening hours. However, this was not always the case, as evidenced in the third route. The data suggests that there may not be a clear-cut rule of thumb when it comes to predicting these delays.

- it is important to observe the trends in each route individually to get an accurate picture of what is happening. When the travel time is short, the related day has the lowest value in the delay according to the relationship between the value of travel time and the value of delay, which was reached in three routes. While it happened in the morning for the first and second routes, for the third track, it occurred during the evening period. So let's not forget that junctions are the main reason for the increased delay.Nonetheless, it can be asserted that if the intersection delays can be cut down, the travel time reliability of morning traffic in the first and second routes can be improved. For the third route, on the other hand, it should be stated that the road itself rather than intersections are the primary sources of the delays.
- The stop delay had the highest percentage of the delay across all routes with the ratios in terms of to the total delay encountered for the first route for the north and south directions, respectively, 74.69% and 63.46%. This means that the stop delay by itself constitute the total delay experienced by the drivers. The ratios for the north and south directions of the second route were 71.19% and 34.83%, respectively. And for the third route, the north and south directions had the following ratios: 60.76% and 74.74%, respectively.

  As for the deceleration and acceleration ratios, the following table illustrates the related the ratios for each route.

Table 5.1. The deceleration and acceleration ratios for each route.

Route	north direction		south direction	
	deceleration	acceleration	deceleration	acceleration
First	12.82%	12.48%	21.62%	14.92%
Second	13.42%	15.38%	30.36%	34.8%
Third	18.44%	20.8%	14.83%	10.43%

- The intersections are the primary causes of delays and speed deceleration along with acceleration on these routes, but there are also factors related to the road itself. The factors relating to the road itself are reflected by a lack of interest in the streets, as the streets require regular maintenance, and the absence of upkeep has a negative impact on vehicle flow, increasing congestion.

- Congestion can be caused by the sort of road users. For example, preventing heavy trucks from passing through by assigning lanes of the roadway reserved for them at specified times lowers congestion.
- The reason why some routes having higher acceleration delay time than the deceleration delay time at the intersections may be attributed to the long queue lengths of vehicles and weak driver behaviour.
- The travel delay models developed are :

first route north direction DC= 16.555 + 1.005 T_{st} +1.616T_{ac}

first route south direction DC= 21.250 + 1.040 T_{st} +0 .946 T_{de}

second route north direction DC= 79.466+ 1.013 T_{st} + 1.318 T_{de}

second route south direction DC= 105.618 + 1.044 T_{st} +0 .969 T_{de}

third route north direction DC= 46.845+ 1.008 T_{st} + 1.153 T_{de}

third route south direction DC= 30.778 + 0.999 T_{st} + 1.026 T_{de}

There predicted delay model can offer relatively accurate estimation of the actual field values of control delay.

- Roads with no side stopping points controlled by the authorities (especially by military officers) were observed to have faster traffic than roads with the ones. The stopping applications may be either allow waiting without stopping, or allows both cases, the second type, having a significant negative impact on traffic flow.
- Congestion is greater at intersections with a checkpoint close to the intersection than at intersections with controls that are relatively far away or not present at all. The checkpoints cause three or two lanes to be reduced to one only.
- There was a significant change in travel time as the traffic volume increased leding to an increase in delays as well.
- To evaluate the delays of any kind, and hence the travel time encountered, the Buffer Index and Planning Time Index in both directions ,When the Buffer index is modest, it indicates that the route's efficiency is adequate, and this is

true for the first route in the northern direction The ratio to the rest of values for other routes is taken into account, which suggests that the preceding criteria have a considerable influence on traffic on these roads, As for the value of the Planning Time Index, the first road in the northern direction needs to be spent 2.68 as much time traveling as the free-flow travel time While in the south direction the value is 2.79, In terms of the values for the remaining routes in both directions, are shown in the table 5.2.

Table 5.2. The value of buffer index and planning time index for all routes.

Route number/Direction	Buffer Index	Planning Time Index
First /north	10.24%	2.68
First/south	21.03%	2.79
Second /north	20.21%	2.75
Second/south	19.87%	2.78
Third /north	27.06%	5.02
Third/south	26.15%	3.1

- The study of the level of service alone is insufficient to determine whether the road performs the function expected.There are several considerations and points that can be considered to determine whether the road is in good condition or not. These points, whether or not they exist, are spatially, geometrically, and functionally associated with the road itself. They might have negative impact on road traffic performance.
- From what was previously noted, preventing illegal on-side parking, encouraging people to use public transportation and distributing various activities in separate areas within the city, all of these proposals are thought to help significantly improve the traffic situation in the city of Baghdad.

- GPS provides an effective tool to accurately measure intersection delay, composed of deceleration delay, stopped delay, and acceleration delay for oversaturated traffic conditions. We can determine the changes that occur in the car during the trip using this way. When the speed changes for whatever reason, it will be added to the schedule as a new point that includes the time, coordinates, and speed in this place. We can determine the cause of the reduction in speed by using map applications. Knowing the vehicle's position and speed, if the speed begins to reduce as it reaches the intersection, this is due to the intersection. If it's distant, it's because of traffic or anything else other than the intersection, and the delay has nothing to do with the kinds connected with the aforementioned intersection as shown in figure 5.1.

Date	Time	Duration	Speed(km/h)	Distance(km)	Latitude	Longitude
3/24/2022	17:20:00	00:00:00	0	0	33.32382109	44.46181478
3/24/2022	17:20:01	00:00:01	7.3799996	0.007650698	33.32379013	44.46187815
3/24/2022	17:20:02	00:00:02	14.724	0.011227437	33.32376019	44.46191495
3/24/2022	17:20:03	00:00:03	18.396	0.016497072	33.32374312	44.46195616
3/24/2022	17:20:04	00:00:04	20.592	0.021723613	33.32371601	44.46199901
3/24/2022	17:20:05	00:00:05	23.363998	0.027725423	33.32368125	44.46204803
3/24/2022	17:20:06	00:00:06	23.4	0.03441773	33.32364236	44.46210921
3/24/2022	17:20:07	00:00:07	24.947998	0.041280173	33.32360241	44.46216516
3/24/2022	17:20:08	00:00:08	26.208	0.048894314	33.32356351	44.46222603
3/24/2022	17:20:11	00:00:11	23.147999	0.06951344	33.32344841	44.46240171
3/24/2022	17:20:13	00:00:13	25.567999	0.08356565	33.32336346	44.46251642
3/24/2022	17:20:14	00:00:14	28.692	0.09156771	33.32331134	44.46257513
3/24/2022	17:20:15	00:00:15	30.636	0.0999948	33.32326245	44.46263916
3/24/2022	17:20:16	00:00:16	30.995998	0.108765416	33.32320913	44.46271803
3/24/2022	17:20:19	00:00:19	21.132	0.12917006	33.32308471	44.46288464
3/24/2022	17:20:25	00:00:25	24.156	0.16200548	33.32289827	44.46313589

Figure 5.1. data acquired from using GPS method.

6. SUGGETIONS AND RECOMMENDATIONS

Congestion on existing roads is difficult to solve in many cases, but there are always possible solutions to releave the problem to some extent.When attempting to solve the problem, a scientific methodology should be considered to get the various solutions differing in some ways. The solutions to be employed will basically are related to the cost of investment and type of technology used. Whatever the solutions are to be developed to reduce traffic congestion and its adverse consequences they seek to maximize the use of existing roads in their circumstances.The cost factors of improvements made on existing roads in order to reduce congestion, including raising traffic levels and improving traffic performance may not produce the expected results. This is mainly due to the fact that these new investments may play a role for the improved road and trafficconditions to induce the road users to use the network even more and frequently. Hence, the planning and application strategies related to enhance the public transportation services must be always a creative alternative to get more robust transportation networks as far as travel time reliebility is concerned. In the case of city of Baghdad, it has to be stated that common military check points play extreme negative effect on the travel times experienced by the road users through reducing the capacity of the roadways significantly due to the closure of the lanes to be used by the traffic. Another point to be mentioned is regarding the managament strategies of the intersections. If the intersections in the network investigated in this reserach are operated through vehicle actuated control systems it is believed that a remarkable improvement may be obtained to reduce the delays resulting in better networks providing higher travel time reliability for the users.

6.1.1. Improvements at the level of the road itself

There are strategies that can be worked out in order to deal with congestion, and increase the travel time reliability. They include;

- The idea behind controlling highway entrances is to limit the number of vehicles that can enter the roads during peak times. Although intermittent regulation of traffic entering the arterial route may increase the relative delay for the vehicles at the entrance point, it keeps the highway's capacity at its best depending on the volume of traffic on the arterial. This strategy improves the effectiveness of road operation performance. With that regard, putting pre-signals at the entrance may be considered to control the entering traffic.

- Adding marked and regulated parking areas, thus preventing random stopping, particularly on arterial and commercial streets, such as Palestine Street and Al-Rubaie Street, would greatly reduce congestion and help to get much smoother movement of the flow.
- Continuing to monitor the phsical condition of the roads (periodic maintenance) regularly and repairing them at degraded points to avoid road capacity shortage.
- Reconfiguration of sidewalks based on pedestrian density and utilization of wide sidewalks for parallel parking. The proper design of sidewalks will not only increase the capacity of the roadways but also will provide safer traffic environment for the pedestrians.
- Encouraging people to use public transportation instead of private transportation for the benefits of not only reducing congestion and saving time, but also for environmental and pollution reasons.People can be encouraged not to use their own private vehicles by developing public transportation having modern and safe stops, as well as possibly providing special lanes allocated only for public transportation usage through the laws legislating legal status of them to restrict the intervention of private usage.
- One of the main suggestion of this research is to advice the local authorities to remove unimportant checkpoints. As illustrated these points have a deeply negative effect increasing the travel times remarkebly by reducing the capacity of the roadways, hence searched paths. Their removal will certainly reduce overcrowding compared to their presence.
- Opening subsidiary roads that link to arterial roads will releave the density of the main paths by providing different access points to merge the roadways. These subsidiary roads may not be an effective alternative to the main roads among the origin and destination points, but diperse the traffic and reduce the density on the paths.

6.1.2. Intersection improvements

This proposal is related to operational management of the existing *Rocaded Junction* without interfering with the configuration, such as widening roads, adding lanes,.. etc.

- Approaching roads should be organized by splitting them into various lanes based on the amount of traffic on each road.
- Traffic signals should replace the traffic officers to increase the capacity of the junction. The signalisation should include new phases to service the specific turning movements with a reasonably high traffic volume. Any turning movements with a relatively high directional traffic flow without being served by a phase should have their own phases being proportional to the volume of directed traffic.
- Redesigning the layout of the the intersection in terms of viewing angles, curves, widths and diameters.
- Redistribute lane groupings based on directional traffic volumes.

6.2. Summary

Previously, the recommended remedies to the congestion problem were to build new roads or broaden them to increase the capacity while retaining the same management style. These implemented remedies, however, are effective and may produce desired results for only in the short term. On the other hand, they may become a financial, operational, and environmental burden in the long term. It is known that a substantial amount of traffic flow is caused either by a lack of traffic management or poor vehicle driving. That is, it is tied to human factors as either user or operator. As the analysed paths are part of main national road that crosses the city center from east to west, there always a potential to have heavy demand on these roads. This should urge the transportation authorities to determine the delay causing factors and their potential impacts on travel time reliability. The outcomes of this research provide valuable imformation to improve level of service in terms of traffic flows, capacity and delays. The sources of the problem, lack of level of service, traffic culture of the users, phyical condition of the roaad geometry and intersection lay out etc, were all clarified and pointed out to manage the traffic congestion and enhance road traffic performance with more reliable transportation networks.

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