THE 13TH INTERNATIONAL CONFERENCE ON QiR
(QUALITY in RESEARCH)

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PROCEEDING

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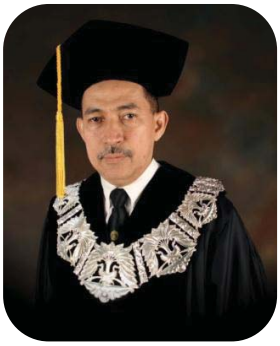
WELCOME FROM THE RECTOR OF UNIVERSITAS INDONESIA



It is both a pleasure and honor for me to welcome you all to the 13th International Conference on QiR (Quality in Research) 2013. In this globalization era, mankind's competitive explorations to find new and better ways to enhance their life has often resulted in sacrificing the environment for their convenience. To preserve the environment for our future generations, steps must be made to ascertain that development and innovation of mankind must be more sustainable, balancing both mankind's' effort in enhancing their quality of life and fulfilling their needs, with its harmony with nature.

Today, scientists and experts, in particular, people in engineering, architecture and design are looking to develop new environmentally friendly technologies, or eco-technologies. Innovation in eco-based multidisciplinary knowledge and skills becomes the important key, and this central issue should be encouraged for the motivation of current and future development. Eco-technology can help protect, conserve and even restore our precious shared environment. To develop this technology, we need to combine engineering, scientific or technological approaches, with ecology, economics and the social sciences and humanities. The eco-innovation field is now wide open and offers exciting new territories to explore and develop. Creative thinking by our top technical and scientific researchers is giving us a more and more treasures of new workable ideas.

However, innovations require more than just brilliant ideas. Innovations require resources, skills, technology, knowledge, tools, techniques and so much more. But most of all, innovations require people. People are the driving force behind every need of change, changes that are aimed to improve mankind's quality of life, to enhance their living conditions or to simply make life easier and more comfortable. This conference is about learning of the fundamental aspects which can transform the world and society, thinking ahead to possible challenges facing the globe, discovering innovations related to opportunities for industry, and most importantly, this conference is about bringing together interdisciplinary people to accelerate activities in many areas simultaneously. This is what makes the conference exceptional this year in terms of potential impact from this networking.

I extend my sincere thanks to the Faculty of Engineering Universitas Indonesia, supporting parties and institutions for their participation and contributions in QiR 2013. I would also thank the people of Yogyakarta for their gracious support and hospitality. Additionally, I extend a hearty thank you to the members of the organizing committees for dedicating their valuable time so that each one of us enjoys an exceptional conference program over the next several days. May we have a successful, stimulating, fruitful and rewarding conference.

Prof. Dr. Ir. Muhammad Anis M.Met.
Rector
Universitas Indonesia

WELCOME FROM THE DEAN OF FACULTY OF ENGINEERING UNIVERSITAS INDONESIA

Welcome to the 13th International Conference on QiR (Quality in Research) 2013. The Faculty of Engineering Universitas Indonesia is thrilled that, together with our co-hosts IST-Akprind and Gadjah Mada University, we are able to present an international conference of this magnitude. This two-day conference speaks to the importance of fostering relationships among national and international front liners, thinkers, academics, executives, government and business officials, practitioners and leaders across the globe in an effort to share knowledge and best practices as part of a worldwide network.

The quest for knowledge has been from the beginning of time but knowledge only becomes valuable when it is disseminated and applied to benefit humankind. It is hoped that QiR 2013 will be a platform to gather and disseminate the latest knowledge in engineering, architectural design and community services. Academicians, scientist, researchers and practitioners of these fields will be able to share and discuss new findings and applications of their expertise. It is envisaged that the intellectual discourse will result in future collaborations between universities, research institutions and industry both locally and internationally. In particular it is expected that focus will be given to issues on innovations for the enhancement of human life and the environment.

In accordance to this year's theme, this conference will cover a wide range of sustainable design and technology issues, especially state of the art information and knowledge of new innovations, ideas, creative methods or applications which can be implemented to enhance the human life and also our environment. The itinerary of the conference over the two days has been carefully planned to ensure a lively exchange of ideas and the development of innovative strategies and there will be many opportunities for everyone in attendance to share their expertise with, and learn from, peers from around the world.

We urge you to spend the next two days in interesting discussions and exchanging ideas among yourselves. We foresee more and more challenges in our future. Challenges in how to improve our life, how can we enhance our society, how can we make our lives and the lives or our society better? These challenges should be answered together by developing collaborations for future research in various engineering and design areas. It is our hope and aim that this conference would be able to provide an international media for exchange of the knowledge, experience and research as well as the review of progress and discussion on the state of the art and future trend of prospective collaboration and networking in broad field of eco-based technology development.

My deepest appreciation to our sponsors, supported parties and various contributors for their never ending supports of this conference. I would also like to convey my humblest thankfulness to all of our distinguished speakers for making the time to share their knowledge with us. To our fellow researchers and/or practitioners from Indonesia and overseas, welcome and enjoy your stay in this amazing historical city, Yogyakarta. I would also like to invite all participants in expressing our appreciation to all members of the QiR 2013 organizing committee for their hard work in making this conference another success.

Prof. Dr. Ir. Bambang Sugiarto, M.Eng.
Dean Faculty of Engineering
Universitas Indonesia

WELCOME FROM THE QiR 2013 ORGANIZING COMMITTEE

Welcome to the 13th International Conference on QiR (Quality in Research) 2013. It is a great pleasure for Faculty of Engineering Universitas Indonesia to be co-hosting this biennial event with IST-Akprind and Gadjah Mada University, in the spirit of strengthening of cooperation and mutual growth to be world class institution. For the first time, the QiR 2013 is held in one of the most historical city in Indonesia – Yogyakarta. It is with our utmost pleasure to hold this year's QiR 2013 in conjunction with the 2nd International Conference on Civic Space (ICCS 2013) and introducing the International Symposium on Community Development 2013 as a forum to share experience on engaging community for a better life and environment.

The aim of this International Conference with our selected theme, "Exploring Innovation for Enhancement of Human Life and Environment", is to provide an international forum for exchanging knowledge and research expertise as well as creating a prospective collaboration and networking on various fields of science, engineering and design. We hope this conference can be a kick-off for the strengthened action and partnerships on creating a platform for us; national and international thinkers, academics, government officials, business executives and practitioners, to present and discuss the pivotal role of engineers in innovative products which will reduce environmental impacts, applications in sustainable planning, manufacturing, architecture, and many more to grow and ensure the rising prosperity of our society going into the future. Under this theme, the conference focuses on the innovative contributions in science, engineering and design as well as their market perspectives to the existing and future enhancement of human life and environment quality.

Over the period of 15 years, this biennial conference has become an important place of encounter between scholars and practitioners from different countries, cultures and backgrounds discussing contemporary engineering and design issues dealt in their hometown, country or even region. Serving as a platform for an engineering and design dialogue, this conference will have 16 invited speakers and has gathered more than 500 papers from more than 20 countries all over the world:
92 papers on International Symposium on Civil and Environmental Engineering
51 papers on International Symposium on Mechanical and Maritime Engineering
97 papers on International Symposium on Electrical and Computer Engineering
111 papers on International Symposium on Materials and Metallurgy Engineering
31 papers on International Symposium on Architecture, Interior and Urban Planning
57 papers on International Symposium on Chemical and Bioprocess Engineering
71 papers on International Symposium on Industrial Engineering
25 papers on International Symposium on Community Development

My deepest gratitude to all of our speakers, participants and contributors who have given this conference their generous support. I would also like to thank all members of the Organizing Committee and our distinguished International Board of Reviewers for all of their support and advice. Our thanks to all of our sponsors, supporters, exhibitors, and professional associations for their great support and encouragement through committed funding and any other form of help and support. We also owe our success to the full support of the Rector of Universitas Indonesia and the Dean of Faculty of Engineering. Thank you to IEEE Indonesia Section that has supported QiR 2013 to be approved as IEEE Conference. Last but not least, a special thanks to our co-hosts, IST-Akprind and Gadjah Mada University for all of their immense supports in making this conference a success.

Allow me to wish all of you a meaningful and rewarding conference. We wish you a pleasant and memorable stay in Yogyakarta. Thank you and we hope to see you again at the QiR 2015.

Prof. Dr. Ir. Bondan T. Sofyan, M.Si.
Chairman of QiR 2013 Organizing Committee

Table of Contents

Symposium A

Proceeding of the 13th International Conference on QIR (Quality in Research)
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Traffic Control of Road Closure on Saturated Two Way Two Lane Roads

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ABSTRACT

The objective of the study is to develop a signal-control strategy and its application for road closure area on two way two lanes roads which is treated as an isolated intersection during severe over saturation.
The study developed a method which introduces a ratio between cumulative departure and cumulative arrival (R). With the same arrival and saturation flow data, the method introducing in this study has a better performance results comparing amongst the Discrete Minimal Delay Model and the Maximum Throughput Model.
The simulation results show that the optimum arrival detection period is 240 seconds and the optimum cycle time is 240 seconds. The study indicates the percentage of increasing total delay, decreasing of average throughput and decreasing of over saturation period if there is a change of cycle time from 240 seconds to less than 240 seconds and the maximum road closure length that can be accommodated by signalized traffic control in over saturation traffic condition based on total Degree of Saturation (DS), average speed on lane closure area (Sw).

Keywords

signalized traffic control, road closure areas, oversaturated.

1. INTRODUCTION

Road activity which requires the closure of one of the two ways two lane roads need a special effort to maximize the capacity of bottleneck areas, especially on over saturation traffic condition. To overcome the problem arises on an oversaturated two way two lane road closure areas, this study developed a two steps of green time planning method which is introducing a ratio between cumulative departure and cumulative arrival (R) on its signalized traffic control strategy.

2. RESEARCH OBJECTIVE

The objective of the research is to evaluate the application of a ratio of vehicle's cumulative departure to cumulative arrival (R) value as a switch over point parameter on oversaturated two way two lane road closure areas (RCA) as a signalized traffic control strategy with the speeds on RCA are 20 km/h and 30 km/h.

3. ROAD CLOSURE AREA (RCA) TRAFFIC CONTROL

Portable traffic signals use of the red clearance interval, or "all red" period to allow vehicles that have entered a RCA under a green or yellow indication to safely pass through and exit the one-lane RCA. The factor that determines duration of the red clearance interval is the speeds at which motorists will drive through the one lane RCA. The lay out of signalized traffic control on two way two lane RCA installation is shown on Figure 1, whereas Figure 2 displays the time needed in both directions to clear the road closure areas.

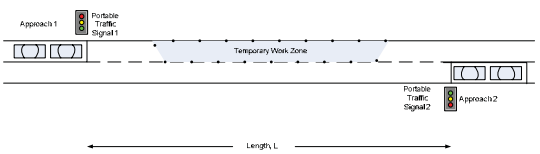


Figure 1: Portable Traffic Signal Installation for Road Closure Area Control

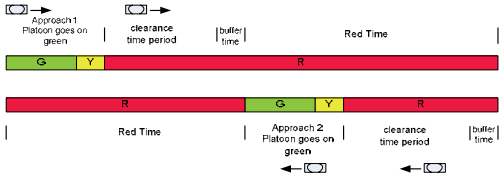


Figure 2: Complete Signal Cycle for Portable Traffic Signal Installation

Maximum Wait Time (each direction) = $2Y + 2R + 2B + G_{nax}$ (2)

where

Y = yellow clearance time (applies to both directions), seconds
R = red clearance time (applies to both directions), seconds
B = buffer time (applies to both directions), seconds
$G_{\max}$ = maximum green time in the opposing direction, seconds

Ginger et al [3] indicates that the maximum wait time (i.e., before driver confusion and possible violation) is approximately four minutes.

4. SIGNALIZED TRAFFIC CONTROL ON OVERSATURATED TRAFFIC FLOW

4.1. Previous Studies

The previous studies of signalized traffic control on oversaturated traffic flow were conducted by Chang and Lin [1] and Talmor and Mahalel D [6] which is summarized on Table 1.

Table 1: The Previous Studies Of Signalized Traffic Control On Oversaturated Traffic Flow

	Chang TH and Lin JT (2000).	**Talmor I and Mahalel D, (2007),**
Objective	minimize the total delay on the intersection during the oversaturated period by deriving a basic discrete minimal delay model and a performance index model	to maximize the average throughput of the intersection during the oversaturated period
uniqueness	Appication of bang-bang like control, by which signals are operated alternatively and sequentially, with minimal maximal green time, significantly outperforms conventional equal timesharing dispersion control; and not all provided cycle lengths are applicable to oversaturation control, since some may fail to meet the warrant of simultaneous dispersion indicated by Gazis	Application of discharge-flow functions instead of saturation-flow functions. Maximum throughput is achieved, based on the best balance between the decrease in discharge flows and the saving in lost time.
conclusions	The discrete type performance index model, which results in bang-bang like control, is quite appropriate for oversaturation control. The performance of this model is rather robust even when the input data appear to be slightly biased. The proposed model can also determine the optimal cycle length and the optimal assigned green time.	Control based on the maximization of throughput enables an optimization of traffic operations as long as congestion persists, without the need for any further knowledge of existing or future demand. This capability is important and significant, since congestion is often random and may occur without any prior information of its existence or duration.

4.2. Demand and Service Approach

The traffic signal service equation is describing the service rate from the beginning until the end of the oversaturated period. The curve of cumulative arrival of vehicle and service of traffic signal control at oversaturated period presented at Figure 3. Beginning of oversaturated period happened at the time of T=0 and oversaturated period end at the time of T=$n.c$. (n=total number of cycle time and c= cycle time).

At $T = n.c,\ Q = G$

$-(a_1 + a_2).t^2 + (b_1 + b_2).t = (\gamma_1 + \gamma_2)t$

t=$n.c$, then

$-(a_1 + a_2).(n.c)^2 + (b_1 + b_2).(n.c) = (\gamma_1 + \gamma_2).(n.c)$ (5)

$\gamma_1 = \frac{g_1 s_1}{c}$, $\gamma_2 = \frac{g_2 s_2}{c}$ and $g_1 + g_2 = c$

$\gamma_1 = \frac{(c - g_2).s_1}{c}$

$-(a_1 + a_2).(n.c)^2 + (b_1 + b_2).(n.c) = \frac{(c - g_2)s_1 + g_2 s_2}{c}.(n.c)$

$-(a_1 + a_2).n.c + (b_1 + b_2) = \frac{(c - g_2)s_1 + g_2 s_2}{c}$ (6)

where

G = Total Cumulative service function, pcu

$G_{1,2}$ Total Cumulative service function of movement 1 and 2, respectively, pcu

$\gamma_{1,2}$. = Service rate (throughput) of movement 1 and 2 respectively, pcu/hour

$a_{1,2}$, $b_{1,2}$ = Constants of the polynomial functions

c is an input value, whereas the value of $a_1, a_2, b_1, b_2, s_1, s_2$ is determined based on field data. If the equation fulfill the equation $g_1 + g_2 = c$, the value of n, T and γ can be calculated. . Based on the assumption that that both approaches disperse the queues at the same cycle, hence the value of γ_1, γ_2, g_1 and g_2 also can be calculated.

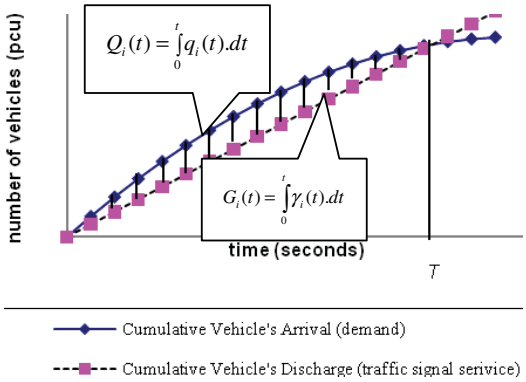
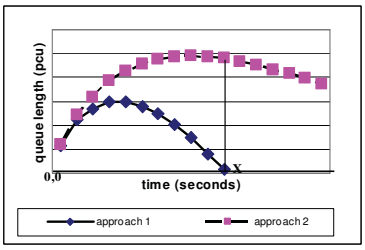


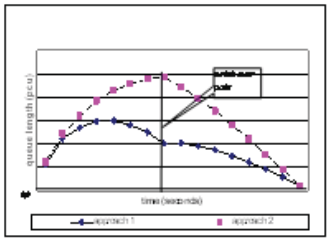
Figure 3: Vehicle's Cumulative Arrival and Cumulative Service of Traffic Signal Control at Oversaturated Period

5. SWITCH OVER POINT APPROACH

Figure 4 show the queue length in an intersection with 2 phase signalized traffic control along the oversaturated period. The first phase serves the movement from the left of RCA (will be termed as first movement) and the second phase serves the movement from the right of road closure area (will be termed as second movement). As shown on Figure 4a, the traffic signal control on oversaturated period with single green time often cannot disperse the queue at both approaches concurrently. It can be seen that at T=X, the all queue at 1st movement has been discharged, but at the 2nd movement the queues still exist. To overcome this, the two step green time method with switching of green time at certain point has been developed. This point is called as switch over point (Figure 4b).



(a) Without Green Time Switch Over



(b) With Green Time Switch Over

Figure 4 : Queue Discharge on Oversaturated Signalized Traffic Control

5.1. Ratio Of Cumulative Vehicle Arrivals to Cumulative Vehicle Discharge

As already mentioned above, the study developed a parameter to determine the switch over point named *R*, which is defined as ratio of cumulative vehicle arrivals to cumulative vehicle discharge.

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Performance parameter calculated at any cycle time (iteration) is :

1. Vehicle discharge on the *i*th of green and *j*th iteration ($VD_{i;j}$)

$$VD_{i;j} = \frac{s_m}{3600} XG_i(m) \qquad m = 1,2 \tag{7}$$

where

$VD_{i;j}$ = Vehicle discharge on the *i*th of green and *j*th iteration *j* , pcu

$s_m \ m = 1,2$ = Saturation flow of approach 1,2 pcu/hour

$G_i(m)$ = Green time of approach m on the i th green time , $i = 1,2$ (1 for before switching and 2 for after switching)

2. Queue length on the *i*th of green time and *j*th iteration ($Q_{i;j}$)

$$Q_{i;j} = CA_{i;j} - CA_{i;j-1} + Q_{i;j-1} - VD_{i;j} \tag{8}$$

3. Ratio of cumulative vehicle arrivals to cumulative vehicle discharge on the *i*th of green time and *j*th iteration ($R_{i,j}(m)$)

$$R_{i,j}(m) = \frac{CD_{i;j}}{CA_{i;j}} \tag{9}$$

where

$Q_{i;j}$ = queue length on the *i*th of green time and *j*th iteration, pcu

$CA_{i;j}$ = cumulative vehicle arrivals on the *i*th of green time and *j*th iteration, pcu

$CD_{i;j}$ = cumulative vehicle discharge on the *i*th of green time and *j*th iteration, pcu

Switch over point will be done if the value of $R_{i,j}(m)$ at one of the two approaches has already achieved the determined value of $R_{i,j}(m)$. Which its value is in the range of zero to one ($0 < R_{i,j}(m) < 1$)

5.2. Simulation Scenario

5.2.1. R Value

The simulation was done on the various value of $R_{i,j}(m)$ as follows:

$R_{i,j}(m) \geq$ 0,1; 0,4; 0,5; 0,65; 0,75; 0,85; 0,9; 0,95; 0,97

The example of Chang and Lin [1] and Talmor and Mahalel D [8] is applied in the simulation as shown on Table 2. The example assumed an intersection of two one way streets with a two-phase signal control. One street is denoted as approach 1, and the other street as approach 2. No left turn is considered. Approach 1 has a saturation flow of 1400 vehicle/hour and approach 2 has a saturation flow 1000 vehicle/hour. In this study the saturation flow was converted into 1400 pcu/hour and 1000 pcu/hour, respectively. The cycle time is 150 seconds. In order to compare with the other model, the simulation was done with the value of zero in the length of RCA.

Table 2:Input Data

Cumulative time period (second)	Cumulative vehicle arrival (pcu)	Arrival flow (pcu/hour)	Saturation flow (pcu/hour)	Degree of Saturation	Cumulative vehicle arrival (pcu)	Arrival flow (pcu/hour)	Saturation flow (pcu/hour)	Degree of Saturation
Approach 1					Approach 2			
300	121	1452	1400	1.04	86	1032	1000	1.03
600	205	1008	1400	0.72	147	732	1000	0.73
900	268	756	1400	0.54	192	540	1000	0.54
1200	318	600	1400	0.43	227	420	1000	0.42
1500	359	492	1400	0.35	257	360	1000	0.36
1800	396	444	1400	0.32	283	312	1000	0.31
2100	430	408	1400	0.29	307	288	1000	0.29
2400	462	384	1400	0.27	330	276	1000	0.28
2700	492	360	1400	0.26	352	264	1000	0.26
3000	523	372	1400	0.27	373	252	1000	0.25
3300	552	348	1400	0.25	394	252	1000	0.25
3600	582	360	1400	0.26	415	252	1000	0.25
3900	611	348	1400	0.25	436	252	1000	0.25
4200	640	348	1400	0.25	457	252	1000	0.25

Source :[1] & [8]

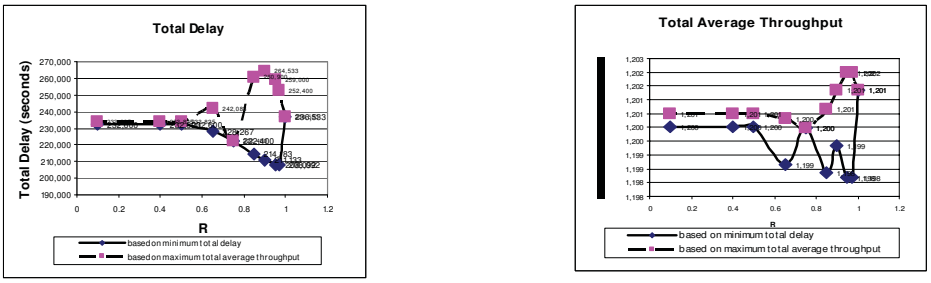
5.2.2. Simulation on RCA

To accommodate various variation of lane width, this study applied the total Degree of Saturation (DS) value to substitute the values of saturation flow and passenger car equivalent of each vehicle type. DS is sum of ratio of arrival flow to saturation flow on each movement or each approach. Therefore, the research's simulation scenario is as follows:

a. Variation of vehicle arrival is represented by total Degree of Saturation and the Degree of Saturation (DS) of each approach.
b. The observation time of the vehicle's arrival is 1 hour (3600 seconds) and the over saturation period is assumed happen on the first 300 seconds. The vehicle's arrival after the first 300 seconds is assumed as unsaturated flow, with the value of total Degree of Saturation is 0.71.
c. The variation of DS on the first 300 seconds are as follows:
   - 1 < DS < 1.5 (representes by DS=1.44)
   - 1.5 < DS < 2 (representes by DS=1.86)
   - 2 < DS < 2.5 (representes by DS=2.26)
   - DS > 2.5 (representes by DS=2.76)
d. The simulation applies at various length of RCA, speed at RCA and cycle time as follows:
   - Length of RCA : 10, 15, 25, 50, 75, 100, 125, 150, 175, 200 meter
   - Speed at RCA: 20 km/tour
   - Cycle time: 120, 150, 180, 210, 240 seconds
   - Vehicle's Detection Period : 120, 180, 240, 300 seconds

6. PERFORMANCE INDICATOR AND R VALUE

The simulation results on Table 3 and Figure 4 show that the various of R do not give a significant trend of both average throughput and total delay. The simulation results also show that although average throughput has a maximum value on the value of R≥ 0.95, but the difference is very small. The two performance indicators, those are average throughput and total delay, do not have any special trend in result regarding with the difference of the R value. The first simulation results show that green time determination has a significant difference if be chosen based on the minimum total delay value. The minimum total delay was happened on the value of R ≥ 0.95.



(a) (b)

Figure 4: Total Delay and Total Average Throughput of Various R Values

Table 3 shows the performance results of the study and the two other methods, i.e. Discrete Minimal Delay Model [1] and Maximum Throughput Model [6] based on the same input data. The results then compared to the based result, which is Minimal Delay Model [1]. The difference in percentage to the based result was done also presented in this Table.

Comparing with Discrete Minimal Delay Model [1], this study has improved some of performance indicators of signalized traffic control, those are 5,88% better in length of over saturation period, 1.46% in average *throughput*, 13,57% in number of vehicles in the queue and 12,80% in total delay. This performance also better than Maximum Throughput Model [6]

Table 3: Performance Results

Performance Indicator	Discrete Minimal Delay Model	Maximum Throughput Model	Research, R=0,95
Over saturation period (second)	2550.00	2434.80	2400.00
throughput (pcu/hour)	1181	1195	1198
Number of vehicles in the queue (pcu)	1609	1566	1391
total delay (second)	238,625	233,035	208,092
Comparison to Discrete Minimal Delay Model			
Over saturation period (second)	-	4.52%	5.88%
throughput (pcu/hour)	-	1.16%	1.16%
Number of vehicles in the queue (pcu)	-	2.69%	13.57%
total delay (second)	-	2.34%	12.80%

Source : Talmor I & Mahalel D [8] & Result of the Study (2009)

Evaluations of the first simulation are as follows:

- Green time determination has a significant difference if be chosen based on the minimum total delay value.
- The minimum total delay was happened on the value of $R \geq 0.95$.
- The ratio of vehicle's cumulative departure to cumulative arrival (R) value as a switch over point parameter could be applied on a two phase oversaturated signalized traffic control strategy.
- The research method, which was applied a ratio of vehicle's cumulative departure to cumulative arrival (R) value of 0.95, has improved the performance of the previous methods, i.e. the Discrete Minimal Delay Model and the Maximum Throughput Model.
- The research method could be applied to oversaturated two way two lane road closure areas signalized traffic control strategy by inputting the length of road closure area and the average journey speed in the road closure area.

6.1. Optimum Detection Period

The simulation results show that minimum total delay is achieved when the detection period is more than 240 seconds. When DS < 2 the minimum total delay is 300 seconds, but at DS>2 the minimum total delay of 240 seconds and 300 seconds vehicle's detection period has the same value of minimum total delay. The percentage of increasing total delay comparing to 240 seconds of detection period at cycle time 240 seconds is shown on Table 4.

Table 4 Total Delay on Various Detection Periods Comparing to Detection Period of 240 seconds= 240 Seconds

DS	Lw	Total Delay (seconds)				oversaturated period	average throughput	% comparing to detection period of 240 seconds			
		detection period (seconds)						detection period (seconds)			
	meter	120	180	240	300	seconds	pcu/hr	120	180	240	300
1<DS<1.5	10	47,675	35,835	27,995	27,803	960	1626	70%	28%	0%	-1%
	25	52,200	40,360	32,520	32,328	960	1591	61%	24%	0%	-1%
	50	61,740	49,900	42,060	41,868	1,200	1,527	47%	19%	0%	0%
	75	76,225	64,385	56,545	56,353	1,440	1,464	35%	14%	0%	0%
	100	99,667	87,827	79,795	79,795	1,920	1,400	25%	10%	0%	0%
	125	144,802	132,962	125,122	124,930	2,880	1,336	16%	6%	0%	0%
1.5<DS<2	10	111,468	95,788	85,548	85,836	1,440	1,626	30%	12%	0%	0%
	25	120,353	104,673	94,433	94,721	1,680	1,591	27%	11%	0%	0%
	50	145,382	129,702	119,462	119,750	1,920	1,527	22%	9%	0%	0%
	75	180,750	165,070	154,830	155,118	2,400	1,464	17%	7%	0%	0%
	100	239,326	223,646	213,406	213,694	3,120	1,400	12%	5%	0%	0%
2<DS<2.5	10	197,899	179,019	167,179	167,179	1,920	1,626	18%	7%	0%	0%
	25	215,633	196,753	184,913	184,913	2,160	1,591	17%	6%	0%	0%
	50	257,734	238,854	227,014	227,014	2,640	1,527	14%	5%	0%	0%
	75	323,688	304,808	292,968	292,968	3,120	1,464	10%	4%	0%	0%
2.5<DS<3	10	341,670	318,310	304,230	304,230	2,640	1,626	12%	5%	0%	0%
	25	373,560	350,200	336,120	336,120	2,880	1,591	11%	4%	0%	0%
	50	449,914	426,554	412,474	412,474	3,360	1,527	9%	3%	0%	0%

6.2. Optimum Cycle Time

The simulation results of cycle time variation. are as follows:

a. Cycle time of 240 seconds resulting the smallest total delay at most of variations, except on the following scenarios, which the smallest total delay occurred on cycle time of 210 seconds:
   - Length of RCA 10 meter and 25 meter on $1 \leq DS \leq 1.5$
   - Length of RCA 25 meter on $1 \leq DS \leq 1.5$ and $2 \leq DS \leq 2.5$.

b. Cycle time of 240 seconds resulting the largest total average throughput at all variations.
c. Cycle time of 240 seconds resulting the smallest oversaturated period at all variations.

Based on the simulation results mentioned above, the cycle time of 240 second is chosen as the optimal cycle time. Total delay, total average throughput and oversaturated period on Various Cycle Time Comparing to Cycle Time of 120 seconds is shown on Table 5.

Table 5: Total Delay, Total Average Throughput and Oversaturated Period on Various Cycle Time Comparing to Cycle Time of 120 Seconds

Length of RCA	Cycle time	Total Delay	average throughput	Length of RCA	Cycle time	Total Delay	average throughput	Length of RCA	Cycle time	Total Delay	average throughput
meter	second	second	pcu/hour	meter	second	second	pcu/hour	meter	second	second	pcu/hour
	120	37,436	1555.58		120	106,240	1357.60		120	-	-
	150	32,270	1583.87		150	67,584	1425.48		150	-	-
	180	28,539	1602.72		180	53,249	1470.73		180	-	-
	210	27,096	1616.19		210	45,841	1503.06		210	105,605	1357.60
10	240	27,995	1626.29	50	240	42,060	1527.30	100	240	79,795	1400.03
	120	100%	100%		120	100%	100%		120	-	-
	150	86%	102%		150	64%	105%		150	-	-
	180	76%	103%		180	50%	108%		180	-	-
	210	72%	104%		210	43%	111%		210	100%	100%
	240	75%	105%		240	40%	113%		240	76%	103%
	120	51,060	1484.88		120	-	-		120	-	-
	150	41,190	1527.30		150	139,031	1323.66		150	-	-
	180	36,176	1555.58		180	85,648	1385.88		180	-	-
	210	33,283	1575.79		210	66,056	1430.33		210	-	-
25	240	32,520	1590.94	75	240	56,545	1463.66	125	240	125,122	1336.39
	120	100%	100%		120	-	-		120	-	-
	150	81%	103%		150	100%	100%		150	-	-
	180	71%	105%		180	62%	105%		180	-	-
	210	65%	106%		210	48%	108%		210	-	-
	240	64%	107%		240	41%	111%		240	100%	100%

6.3. Prediction Of Delay, Throughput And Oversaturation Period

The simulation results show that the length of RCA (Lw) that could be accommodated by a signalized traffic control on two way two lane RCA at oversaturated period is limited and depend on the value of the total Degree of Saturation (DS) of the two approach. The approaching model of total delay and length of RCA relationship is an exponentials equation, while for the total average throughput and length of RCA relationship is a linier equation.
The equations to predict the total delay and average throughput based on the value of DS and the length of RCA on observation period 240 seconds and cycle time 240 seconds are shown on Table 6. The value of oversaturated period is presented on Table 7.

Table 6 Equation of Total Delay and Average Throughput Prediction

DS	equation		Lw can be accommodated
	total delay	throughput	
	second	pcu/hour	meter
1≤DS≤1.5	$y = 23286\ e^{0.0128\ x}$	$y = -2.523\ x + 1653$	Lw≤125
1.5≤DS≤2	$y = 74325\ e^{0.0102\ x}$	$y = -2.523\ x + 1653$	Lw≤100
2≤DS≤2.5	$y = 150682\ e^{0.0068\ x}$	$y = -2.511\ x + 1653$	Lw≤75
2.5≤DS≤3	$y = 280113\ e^{0.0077\ x}$	$y = -2.482\ x + 1652$	Lw≤50

Table 7: Oversaturated Period Based on the Length of RCA, DS and Sw on Observation Period 240 Seconds and Cycle Time 240 Seconds

Length of RCA	over-saturated period (seconds)			
meter	1≤DS≤1.5	1.5≤DS≤2	2≤DS≤2.5	2.5≤DS≤3
10	960	1,440	1920	1920
25	960	1,680	2160	2160
50	1,200	1,920	2640	2640
75	1,440	2,400	3120	3120
100	1,920	3,120	-	-
125	2,880	-	-	-

7. CONCLUDING REMARKS

A signal-control strategy for road closure area on two way two lanes roads which is treated as an isolated intersection during severe over saturation was developed using ratio of vehicle's cumulative departure to cumulative arrival (R) value as a switch over point parameter could be applied on a two phase oversaturated signalized traffic control strategy.
With the same arrival and saturation flow data, the switching method introduced in this study has a better performance results comparing with the Discrete Minimal Delay Model and the Maximum Throughput Model. The application of a ratio of vehicle's cumulative departure to cumulative arrival (R) value of 0.95, has improved the performance comparing with the two previous methods.
The switching method could be applied to signalized traffic control strategy on oversaturated two way two lane road closure areas by inputting the length of road closure area and the average journey speed in the road closure area.
The results of simulation to the various lengths of road closure area and the average journey speed in the road closure area are that minimum total delay is achieved when the detection period is more than 240 seconds and the optimal cycle time is 240 seconds
The length of Road Closure Area (Lw) could be accommodated by a signalized traffic control on two way two lane RCA at oversaturated period is limited and depend on the value of the total Degree of Saturation (DS) of the two approach. The approaching model of total delay and length of RCA relationship is an exponentials equation, while for the total average throughput and length of RCA relationship is a linier equation.

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